Prevention of COVID-19 pandemic through technological innovation: ensuring global innovative capability, absorptive capacity, and adaptive healthcare competency

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Received: 28 October 2020 / Revised: 24 April 2022 / Accepted: 21 August 2022 / Published online: 3 September 2022
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Abstract
The study examines the role of technology transfer in preventing communicable diseases, including COVID-19, in a heterogeneous panel of selected 65 countries. The study employed robust least square regression and innovation accounting matrixes to get robust inferences. The results found that overall technological innovation, including innovative capability, absorptive capacity, and healthcare competency, helps reduce infectious diseases, including the COVID-19 pandemic. Patent applications, scientific and technical journal articles, trade openness, hospital beds, and physicians are the main factors supporting the reduction of infectious diseases, including the COVID-19 pandemic. Due to inadequate research and development, healthcare infrastructure expenditures have caused many communicable diseases. The increasing number of mobile phone subscribers and healthcare expenditures cannot minimize the coronavirus pandemic globally. The impulse response function shows an increasing number of patent applications, mobile penetration, and hospital beds that will likely decrease infectious diseases, including COVID-19. In contrast, insufficient resource spending would likely increase death rates from contagious diseases over a time horizon. It is high time to digitalize healthcare policies to control coronavirus worldwide.

Keywords Communicable diseases · COVID-19 pandemic · Healthcare expenditures · Robust least square regression · Technological innovation

Introduction
Coronavirus disease 2019 (COVID-19) has reached a worldwide total of over 171 million infected cases (total cases, i.e., 171,938,586), resulting in the death of over 3,500,000 persons (total deaths, i.e., 3,575,782). The US economy endured a greater number of registered and fatal cases than the rest of the globe, which exceeded 34,136,738 infected cases and 610,436 fatalities. India, Brazil, and France all increased their infection rates in lockstep with the US economy, at 28,307,832; 16,625,572; and 5,677,172, respectively. Asia and Europe are most susceptible, with 51,491,875 and 46,661,409 coronavirus-infected cases, respectively, followed by North America, with 28,307,832; 16,625,572; and 5,677,172, respectively. Asia and Europe are most susceptible, with 51,491,875 and 46,661,409 coronavirus-infected cases, respectively, followed by North America, with 28,307,832; 16,625,572; and 5,677,172, respectively. Asia and Europe are most susceptible, with 51,491,875 and 46,661,409 coronavirus-infected cases, respectively, followed by North America, with 28,307,832; 16,625,572; and 5,677,172, respectively. Asia and Europe are most susceptible, with 51,491,875 and 46,661,409 coronavirus-infected cases, respectively, followed by North America, with 28,307,832; 16,625,572; and 5,677,172, respectively. Asia and Europe are most susceptible, with 51,491,875 and 46,661,409 coronavirus-infected cases, respectively, followed by North America, with 28,307,832; 16,625,572; and 5,677,172, respectively. Asia and Europe are most susceptible, with 51,491,875 and 46,661,409 coronavirus-infected cases, respectively, followed by North America, with 28,307,832; 16,625,572; and 5,677,172, respectively. Asia and Europe are most susceptible, with 51,491,875 and 46,661,409 coronavirus-infected cases, respectively, followed by North America, with 28,307,832; 16,625,572; and 5,677,172, respectively. Asia and Europe are most susceptible, with 51,491,875 and 46,661,409 coronavirus-infected cases, respectively, followed by North America, with 28,307,832; 16,625,572; and 5,677,172, respectively. Asia and Europe are most susceptible, with 51,491,875 and 46,661,409 coronavirus-infected cases, respectively, followed by North America, with 28,307,832; 16,625,572; and 5,677,172, respectively. Asia and Europe are most susceptible, with 51,491,875 and 46,661,409 coronavirus-infected cases, respectively, followed by North America, with 28,307,832; 16,625,572; and 5,677,172, respectively. Asia and Europe are most susceptible, with 51,491,875 and 46,661,409 coronavirus-infected cases, respectively, followed by North America, with 28,307,832; 16,625,572; and 5,677,172, respectively. Asia and Europe are most susceptible, with 51,491,875 and 46,661,409 coronavirus-infected cases, respectively, followed by North America, with 28,307,832; 16,625,572; and 5,677,172, respectively. Asia and Europe are most susceptible, with 51,491,875 and 46,661,409 coronavirus-infected cases, respectively, followed by North America, with 28,307,832; 16,625,572; and 5,677,172, respectively.
to flourish in the globalization period. Artificial intelligence has a wide range of applications in navigation, robotics, and medical diagnostics, all of which are critical for digitalization. Natural user interfaces, virtual reality, augmented reality, analytics and visualization, blockchain, and robots all fall under the category of data sciences, resulting in enviable big data analytics (Krasadakis, 2017). The most recent UNIDO call for proposals (2020) focuses on presenting creative ideas and technology development to mitigate the danger of a COVID-19 pandemic and emphasizes the critical need to advance healthcare technological innovation to combat the COVID-19 epidemic. The World Bank (2021) released the most recent aggregated statistics on research and development expenditures, scientific and technical journal publications, and resident patent applications for various world regions. North America spends the most on R&D, accounting for 2.694 percent of GDP, followed by East Asia and the Pacific at 2.402 percent and the Eurozone at 2.150 percent. Additionally, the East Asia and Pacific region has overtaken North America, the Eurozone, and South Asia in journal papers published in scientific and technical journals. Finally, the total number of resident patent applications is 1,820,380 in the East Asia and Pacific region, 289,444 in North America, and 79,781 in the Euro area.

Earlier studies on technological factors and the COVID-19 epidemic have discussed the following factors: public health leadership and political will (Guest et al., 2020), governance reforms (Janssen and van der Voort, 2020), 3D printing (Choong et al., 2020), virtual intensive care unit (Dhala et al. 2020), green innovation, and food supply chain management (Rowan and Galanakis, 2020). Additionally, several additional characteristics have been shown in previous investigations, which are summarized in Table 1.

This research departs from previous academic work on the subject in three significant ways. First, prior research has concentrated on two aspects of technical factors: ‘innovative capability’ and ‘absorptive capacity’ (see, Castellacci and Natera 2013; Najafi-Tavani et al. 2018; Aboelmaged and Hashem 2019). While ‘healthcare competence’ elements have been included in this research, they provide extra novel ideas for addressing major healthcare concerns. Second, previous research analyzed coronavirus pandemics primarily using COVID-19 infection rates and death tolls as proxy variables (see Ahmad et al. 2020, Qiu et al. 2020, Anzai et al. 2020). The present research compared specific values (ranging from 1 to 5) for the coronavirus pandemic to the country’s devoted efforts to manage coronavirus via healthcare spending. Finally, our research used intertemporal forecasting to determine the critical technology variables required to handle the COVID-19 pandemic across a time horizon.

This research explores the influence of innovative capacity, absorptive capacity, and healthcare competence in reducing fatalities from infectious illnesses, including the COVID-19 pandemic, across a broad panel of nations. The following are the more precise objectives:

1. To examine the influence of R&D expenditures, scientific and technical journal publications, and patent applications on the decline of infectious illnesses across nations, including COVID-19.
2. To investigate the role of mobile phone subscribers and trade openness in generating widespread awareness and providing healthcare trading goods to help control deaths caused by communicable diseases such as COVID-19, and
3. To assess the impact of healthcare expenditures and hospital infrastructures on reducing the significant number of infected cases on a large scale.

These aims need a high-level empirical activity to accomplish the stated purpose of solid conclusions.

### Materials and methods

The research considered a variety of parameters about three main areas of technological advancement. First, factors affecting innovative capability include R&D expenditures as a percentage of GDP (denoted by RDE), the total number of scientific and technical journal articles (denoted by STJ), and the total number of resident patent applications (denoted by PAP). Second, variables affecting absorptive capacity include trade openness (denoted by TOP) as a percentage of GDP and the total number of mobile phone customers (denoted by MOB). Finally, there are adaptive competency factors, which include healthcare expenditures per capita (denoted by HEXP) in US dollars, hospital beds per 1,000 people (denoted by HOSP), and the number of doctors per 1,000 persons (denoted by PHYS). Both ‘causes of mortality due to communicable illnesses’ (abbreviated CD) and ‘COVID-19’ data were used as response variables in separate equations. On the other hand, the remaining variables act as a collection of regressors. Multiple values for the COVID-19 variable indicate the possibility of coronavirus illness spreading throughout the general population across nations. The value 1 assigns to nations with very low healthcare expenditures and economies that lack the resources necessary to offer better health care to their citizens, which ranges between US$25 and US$1000 per capita. Value 2 refers to nations that spend between US$1001 and US$2500 on health care. Value 3 is assigned to nations with healthcare expenditures between US$2501 and US$5000, value 4 is assigned to countries with healthcare spending between US$5001 and US$7500, and value 5 is assigned to countries with healthcare expenditures of more than US$7500. The goal is that nations with low per capita healthcare spending
Table 1 Literature on COVID-19 pandemic and technological innovation

| Authors                      | Technological factors                          | COVID-19 and other factors                                      | Results                                                                 |
|------------------------------|------------------------------------------------|----------------------------------------------------------------|-------------------------------------------------------------------------|
| Abi Younes et al. (2020)     | R&D expenditures, patent applications, and ICTs| COVID-19 vaccine, testing kits, and health expenditures          | Much money has been spent on technology and health care to contain the COVID-19 epidemic |
| Santos Rutschman (2020)      | Intellectual property rights, R&D spending, and patent applications | Healthcare expenditures and COVID-19 vaccine                      | Global R&D cooperation is critical for developing and distributing a coronavirus vaccine |
| Deb et al. (2020)            | Patents, R&D spending,                           | COVID-19 testing laboratories and healthcare costs               | The policy should ensure that a single source conducts diagnostic testing to decrease contaminated instances |
| Velásquez (2020)             | R&D healthcare spending, healthcare technologies| Pharmaceutical products and health governance system            | It is critical to alter how healthcare policies for therapeutic drugs are structured to allow more investment in research and development that improves people’s lives |
| Whitelaw et al. (2020)       | Digital health technology, mobile technology    | COVID-19 cases and mortality rates                                | Digital health technology can assist with contact tracking, testing kits, clinical management, and quarantine processes |
| Torous et al. (2020)         | Telehealth, digital health technologies         | Healthcare investment                                            | Digital technology may aid in the reduction of mental health difficulties, which are on the rise, particularly during COVID-19 |
| Oliver et al. (2020)         | Mobile phone technology                         | Healthcare issues and public health actions                      | Mobile phone technology may be efficiently used to disseminate information about the COVID-19 pandemic’s susceptibility and to deliver a message to the public about the need to prevent infectious illness |
| Lamprou (2020)               | Emerging technologies, additive manufacturing technologies | COVID-19 cases                                                    | Emerging and additive manufacturing technologies reduce COVID-19 cases by enabling the development of efficient drug delivery systems and medical devices, which are enhanced further by the use of 3D printing and microelectromechanical systems (MEMS) for early case detection and remedial measures |
| Shaw et al. (2020)           | Emerging technologies                           | Healthcare treatment and governance mechanism                   | During COVID-19, the government’s substantial control, governance, inventive capacity, and transparency restricted the influence on reducing mental healthcare issues |
| Dubov and Shoptaw (2020)     | Mobile technology                               | Contact tracing                                                   | Mobile technology enables the identification and sharing of new susceptible coronavirus cases, disseminating information about the danger of infection, and maintaining standard operating procedures for social distancing |
would suffer most from communicable illnesses. In comparison, nations with a significant healthcare expenditure are less likely to be impacted and, in the event of a rapid reaction to the epidemic, to become impotent. Between 2010 and 2019, the research gathered panel data on 65 diverse nations from the World Bank's (2021) database. The nations were chosen based on their R&D expenditures on strengthening healthcare infrastructure, including massive expenditures to mitigate the COVID-19 pandemic’s occurrence. Additionally, technological penetration and scientific and technical journal articles weigh heavily on the decision to sample these nations. The chosen nations invested heavily in combating infectious illness, notably the COVID-19 pandemic, which is critical for developing global healthcare infrastructure. Table 2 presents a list of sample countries used in the study.

The research benefits from current academic work on the mentioned topic, which enables empirical modeling exercises to measure COVID-19 susceptibility across nations, such as Javaid et al. (2020), Anser et al. (2020), Wang et al. (2020), and Kumar et al. (2020). These studies mainly focused on technical innovation and healthcare costs to contain the COVID-19 pandemic in various economic situations. Based on these data, the research employed the following two equations to examine the influence of technological innovation and healthcare growth in containing the COVID-19 pandemic in a sample of 65 nations, namely, where CD shows communicable diseases, RDE shows research and development expenditures, STJ shows scientific and technical journals, PAP shows patent applications, TOP shows trade openness, MOB shows mobile subscribers, HEXP shows healthcare expenditures, HOSP shows hospital beds, PHYS shows the number of physicians, and COVID19 shows coronavirus disease.

Equations (1) and (2) demonstrate that technological advancements and increased healthcare competency likely reduce communicable illnesses, especially COVID-19. The research included five measures of technical innovation to capture two wider dimensions of creativity: inventive capability and absorptive capacity. The healthcare competence included in the equations described the spillover effect of healthcare technology, which was quantified in three ways: healthcare expenditures, hospital beds, and total physician population. The research predicted that worldwide control of infectious illnesses, including COVID-19, will be achieved by healthcare infrastructure and technology breakthroughs.

The following research hypotheses have been developed to assess economic policies that have controlled mainly communicable diseases, including COVID-19, across countries:

**H1** The likelihood that innovative capability has largely controlled communicable diseases, including COVID-19, across countries.

### Model I: technological innovations, healthcare infrastructure, and communicable diseases

\[
\begin{align*}
\ln(CD)_{65, 2010-2019} &= \beta_0 + \beta_1 \ln(RDE)_{65, 2010-2019} + \beta_2 \ln(STJ)_{65, 2010-2019} + \beta_3 \ln(PAP)_{65, 2010-2019} + \beta_4 \ln(TOP)_{65, 2010-2019} + \beta_5 \ln(MOB)_{65, 2010-2019} + \beta_6 \ln(HEXP)_{65, 2010-2019} + \beta_7 \ln(HOSP)_{65, 2010-2019} \\
\frac{\partial \ln(CD)}{\partial \ln(RDE)} &< 0, \frac{\partial \ln(CD)}{\partial \ln(STJ)} < 0, \frac{\partial \ln(CD)}{\partial \ln(PAP)} < 0, \frac{\partial \ln(CD)}{\partial \ln(TOP)} < 0, \frac{\partial \ln(CD)}{\partial \ln(MOB)} < 0, \frac{\partial \ln(CD)}{\partial \ln(HEXP)} < 0, \frac{\partial \ln(CD)}{\partial \ln(HOSP)} < 0.
\end{align*}
\]

### Model II: technological innovations, healthcare infrastructure, and COVID-19 pandemic

\[
\begin{align*}
\ln(COVID19)_{65} &= \beta_0 + \beta_1 \ln(RDE)_{65, 2010-2019} + \beta_2 \ln(STJ)_{65, 2010-2019} + \beta_3 \ln(PAP)_{65, 2010-2019} + \beta_4 \ln(TOP)_{65, 2010-2019} + \beta_5 \ln(MOB)_{65, 2010-2019} + \beta_6 \ln(HEXP)_{65, 2010-2019} + \beta_7 \ln(HOSP)_{65, 2010-2019} \\
\frac{\partial \ln(COVID19)}{\partial \ln(RDE)} &< 0, \frac{\partial \ln(COVID19)}{\partial \ln(STJ)} < 0, \frac{\partial \ln(COVID19)}{\partial \ln(PAP)} < 0, \frac{\partial \ln(COVID19)}{\partial \ln(TOP)} < 0, \frac{\partial \ln(COVID19)}{\partial \ln(MOB)} < 0, \frac{\partial \ln(COVID19)}{\partial \ln(HEXP)} < 0, \frac{\partial \ln(COVID19)}{\partial \ln(HOSP)} < 0.
\end{align*}
\]
The projected positive correlation between absorptive capacity measures and reducing COVID-19 instances in a panel of chosen nations; and.

The growth of healthcare infrastructure would be critical in containing COVID-19 cases across countries.

These hypotheses would be tested using the panel's robust least square regression estimator, impulse response function, and variance decomposition analysis. The first approach used a panel robust least square MM estimator to determine the resilient coefficient values that constrain any outliers from exogenous and endogenous factors. Following that, the impulse response function evaluated the effect of external influences on the dependent variable with a one standard error shock. The last measure, variance decomposition analysis, may be used to determine the variance of the variables across time.

Results and discussion

The variables' descriptive statistics are shown in Table 3. The mortality rate due to infectious illnesses ranges from around 1.2 percent to 39.1 percent, with a mean of 7.632 percent. The average cost of research and development, the total number of scientific and technical journal publications, and the total number of patent applications are 1.181 percent of GDP, 28,744.100, and 22,969.110, respectively. Trade openness has a minimum value of 22.486 percent of GDP and a maximum value of 408.363 percent and 1.65e + 09, respectively, with a mean value of 100.514 percent and 57,083,657. The average cost of health care per capita is US$2052.229, the total number of hospital beds per 1000 people is around 4.414, and the total number of doctors per 1000 persons is approximately 3.254. COVID-19 statistics are derived from per capita healthcare expenditures that, on average, fall into the second group, with per capita healthcare expenditures ranging between US$ 1001 and US$2500. Countries such as the USA and the UK invest a disproportionate amount of their national healthcare budgets in healthcare reforms and R&D initiatives to limit coronavirus. The nations' efforts will enable them to cut infection and mortality rates, while the increased investment in research and development will enable the production of coronavirus vaccines for global distribution.

The correlation matrix in Table 4 demonstrates that innovative capability, absorptive capacity, and healthcare competence all connect adversely with communicable illnesses. This implies that research and development expenditures, scientific and technical journal articles, patent applications, trade openness, healthcare expenditures, hospital beds, and doctors contribute significantly to reducing communicable disease-related deaths. On the other hand, R&D expenditures are positively connected with the publication of scientific and technical journal articles, the filing of patent applications, and the spending on health care. The pandemic of COVID-19 increases the number of doctors working in hospitals, healthcare expenses, and R&D spending across nations.

Table 2 List of sample countries. Source: World Bank (2021)

| Sample of countries: 65 | Number of observations: 650 |
|------------------------|-----------------------------|
| Argentina, Armenia, Australia, Austria, Belarus, Belgium, Brazil, Bulgaria, Canada, China, Colombia, Croatia, Cuba, Cyprus, Czech Republic, Ecuador, Egypt, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Kazakhstan, Korea, Kyrgyz Republic, Latvia, Lithuania, Luxembourg, Malaysia, Malta, Mexico, Moldova, New Zealand, North Macedonia, Norway, Oman, Pakistan, Panama, Peru, Poland, Portugal, Romania, Russia, Saudi Arabia, Serbia, Singapore, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Tajikistan, Tunisia, Turkey, Ukraine, UAE, UK, USA, Uruguay, Uzbekistan |

Table 3 Descriptive statistics

| Variables | CD | RDE | STJ | PAP | TOP | MOB | HEXP | HOSP | PHYS | COVID19 |
|-----------|----|-----|-----|-----|-----|-----|------|------|------|--------|
| Mean      | 7.632 | 1.181 | 28,744.100 | 22,969.110 | 100.514 | 57,083,657 | 2052.229 | 4.414 | 3.254 | 2 |
| Maximum   | 39.100 | 4.553 | 528,263.300 | 1,393,815 | 408.362 | 1.65E+09 | 10,014.710 | 11.500 | 8.399 | 5 |
| Minimum   | 1.200 | 0.055 | 33.830 | 2 | 22.486 | 341,077 | 26.568 | 0.500 | 0.790 | 1 |
| Std. Dev  | 6.363 | 0.952 | 74,021.560 | 125,507.200 | 67.374 | 1.69E+08 | 2317.931 | 2.308 | 1.400 | 1.231 |
| Skewness  | 2.256 | 1.090 | 4.754 | 8.318 | 2.115 | 6.824 | 1.569 | 0.740 | 0.932 | 1.020 |
| Kurtosis  | 9.357 | 3.623 | 26.420 | 79.462 | 8.615 | 54.545 | 4.880 | 3.338 | 4.196 | 2.835 |

CD shows communicable diseases, RDE shows research and development expenditures, STJ shows scientific and technical journals, PAP shows patent applications, TOP shows trade openness, MOB shows mobile subscribers, HEXP shows healthcare expenditures, HOSP shows hospital beds, PHYS shows the number of physicians, and COVID19 shows coronavirus disease
The panel robust least square regression estimates for Eq. (1) in Table 5 demonstrate that when the number of scientific and technical journal articles, patent applications, hospital beds, and doctors increases, the causes of mortality due to communicable illnesses decrease. The share of falling infectious diseases is due to an increase in the percentage increase in the number of hospitals per bed per 1000 people (−0.361, p<0.000). This is followed by an increase in the percentage increase in the number of hospitals per bed and physicians per 1000 people, with elasticity estimates of −0.299, p<0.000 and −0.268, p<0.000, respectively. The proportion of patent applications to reduce mortality from communicable illnesses is around −0.092 percentage points. In comparison, R&D spending, mobile penetration, and hospital spending cannot be used to reduce infectious disease-related deaths across nations.

The following policy conclusions have been drawn from the regression estimates, which have been linked to prior research for robust inferences:

1. The free flow of logistics for delivering healthcare protective equipment is necessary to combat infectious illnesses across nations (see Liu et al. 2020; Anesi et al. 2020; Subramanian 2020).
2. The ICT infrastructure can assist in the dissemination of healthcare messaging and contact tracking, hence increasing public knowledge of the disease (see, Ekong et al. 2020; Budd et al. 2020; Wouters et al. 2020).
3. The enormous need to increase healthcare expenditures in terms of expanding healthcare infrastructure and healthcare instruments in order to reduce the global incidence of communicable diseases (see McGinnis and Suffoletto 2020; Wilkason et al. 2020; Bloom et al. 2022); and
4. Healthcare technological innovation is highly desirable to slow the spread of infectious diseases (see, Mamyrbekova et al. 2020; Lytras et al. 2020; Li et al. 2020).

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4. Healthcare technological innovation is highly desirable to slow the spread of infectious diseases (see, Mamyrbekova et al. 2020; Lytras et al. 2020; Li et al. 2020).

The panel robust least square regression for Eq. (2) is shown in Table 6. The findings indicate that increased scientific and technical journal articles contributed significantly to a growing body of information regarding the COVID-19 pandemic, which saw coronavirus spread among the masses. The elasticity estimates supported
the less elastic link between the two variables, i.e., a 1% increase in scientific and technical journal articles results in a −0.136 percent drop in the COVID-19 epidemic. As a result, it may help disseminate awareness about avoiding coronavirus worldwide (Ting et al., 2020; Riva et al., 2020). Additionally, there is an indirect association between trade openness and the COVID-19 pandemic, meaning that a 1% rise in trade liberalization policies results in a −0.059 percent drop in the COVID-19 pandemic. During the COVID-19 pandemic, trade liberalization rules favored the free movement of healthcare logistics commerce, supplying protective equipment and surgical supplies to frontline doctors and paramedical employees to avoid infection by the coronavirus (Sharma et al., 2020; Gillson and Muramatsu, 2020). The rising number of hospital beds and doctors contributes to reducing the COVID-19 pandemic, i.e., a 1% increase in the number of hospital beds and physicians results in a −0.086% and −0.051% reduction in COVID-19, respectively. Thus, there is an urgent need to expand research and development spending on healthcare infrastructure, particularly critical care beds and ventilators, which are judged ideal for assigning newly recorded coronavirus cases (Emanuel et al., 2020).

The research used various distinct elements with greater weight in terms of their influence; hence, it incorporates several weighting coefficient components. The principal component analysis (PCA) of inventive capability, absorptive capacity, and adaptive competence components generate weighted coefficients for more concrete findings in Table 7.

Table 6 Panel robust least square regression estimates for Eq. (2)

| Variable | Coefficient | Std. Error | z-Statistic |
|----------|-------------|------------|-------------|
| Constant | −2.141      | 0.287      | −7.443      |
| ln(RDE)  | 0.100       | 0.022      | 4.490       |
| ln(STJ)  | −0.136      | 0.014      | −9.214      |
| ln(PAP)  | 0.058       | 0.008      | 6.541       |
| ln(TOP)  | −0.059      | 0.020      | −2.917      |
| ln(MOB)  | 0.035       | 0.016      | 2.149       |
| ln(HEXP) | 0.478       | 0.012      | 37.869      |
| ln(HOSP) | −0.086      | 0.021      | −4.050      |
| ln(PHYS) | −0.051      | 0.026      | −1.913      |

Robust statistics

- $R^2$: 0.674
- Adjusted $R^2$: 0.670
- $Rw^2$: 0.893
- Adjusted $Rw^2$: 0.893
- AIC: 762.930
- SIC: 805.280
- $Rn^2$: 4616.596
- Prob($Rn^2$): 0.000

Table 7 Principal components analysis (PCA)

| Weighted Factors | Variables | Eigenvalues | Eigenvectors (loadings) |
|-----------------|----------|-------------|-------------------------|
|                 |          | PC 1        | PC 2        | PC 3        |
| Innovative capability | RDE     | 1.996       | 0.393       | 0.910       | 0.130       |
|                  | STJ     | 0.830       | 0.664       | −0.183      | −0.724      |
|                  | PAP     | 0.172       | 0.635       | −0.371      | 0.676       |
| Absorptive capacity | TOP    | 1.236       | −0.707      | 0.707       |             |
|                  | MOB     | 0.763       | 0.707       | 0.707       |             |
| Adaptive competency | HEXP    | 1.419       | 0.451       | 0.764       | 0.459       |
|                   | HOSP    | 1.007       | 0.539       | −0.644      | 0.541       |
|                   | PHYS    | 0.572       | 0.710       | 0.003       | −0.703      |

RDE shows research and development expenditures, STJ shows scientific and technical journals, PAP shows patent applications, TOP shows trade openness, MOB shows mobile subscribers, HEXP shows healthcare expenditures, HOSP shows hospital beds, and PHYS shows the number of physicians.
of communicable disease transmission. Bloom et al. (2018) stated that access to a universal healthcare system should be limited to combating communicable illnesses while alleviating the financial hardships of those who cannot get high-quality medical treatment. Kostova et al. (2017) emphasized the need to establish global health security initiatives that contribute to preventing and controlling non-communicable illnesses. The healthcare monitoring system facilitates reduced exposure to infectious illnesses.

The findings of another regression apparatus indicate that the weighted coefficient factor of absorptive ability contributes to reducing COVID-19 instances across nations. At the same time, innovative capability and adaptive competency factors will be ineffective in reducing the incidence of the COVID-19 pandemic due to insufficient R&D spending on improving healthcare infrastructure, a lack of public and private healthcare investment programs, and an insufficient number of hospitals and physicians, as well as an insufficient amount of healthcare spending. These variables contribute to the emergence of pandemic recession in a sample of chosen nations. To limit COVID-19 instances, the logistics trade supply chain and mobile penetration are aided. According to Gereffi (2020), the global healthcare supply chain is affected mostly during the COVID-19 pandemic, resulting in a lack of personal protective equipment. International cooperation is critical to ensuring an indestructible healthcare supply chain that aids in the recovery from the pandemic recession. Mahmood et al. (2020) stressed the need to use digital technology to bolster the public health system. The internet provides the primary source of information for sustaining

| Table 8 | Robust least square regression for weighted coefficient factors |
|----------------|-----------------|-----------------|----------------|
| Variables       | ln(CD)           | ln(COVID19)     |               |
|                 | Coefficient     | Prob. value     | Coefficient   | Prob. value |
| Constant        | 1.782           | 0.000           | 0.695         | 0.000       |
| Innovative Capability | −0.039       | 0.108           | 0.820         | 0.000       |
| Absorptive capacity     | 0.036           | 0.229           | −0.140        | 0.000       |
| Adaptive competency     | −0.297           | 0.000           | 0.037         | 0.004       |

| Statistical tests |
|-------------------|
| $R^2$              | 0.239           |
| Adjusted $R^2$     | 0.236           |
| $R_w^2$            | 0.312           |
| $R_n^2$            | 226.577         |
| Prob.($R_n^2$)     | 0.000           |

| Tables 9 | Panel impulse response function and variance decomposition analysis for Eq. (1) |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Period          | CD          | RDE          | STJ           | PAP           | TOP           | MOB           | HEXP           | HOSP           | PHYS           |
| February 2021   | 0.539       | 0.002       | 0.012         | −0.0001      | 0.001         | −0.001       | −0.005         | −0.021         | 0.012           |
| March 2021      | 0.531       | 0.012       | 0.007         | −0.004       | 0.010         | −0.007       | −0.009         | −0.025         | 0.038           |
| April 2021      | 0.521       | 0.024       | 0.011         | −0.009       | 0.021         | −0.011       | −0.014         | −0.027         | 0.074           |
| May 2021        | 0.510       | 0.035       | 0.011         | −0.014       | 0.034         | −0.014       | −0.019         | −0.030         | 0.117           |
| June 2021       | 0.498       | 0.047       | 0.013         | −0.019       | 0.048         | −0.017       | −0.024         | −0.033         | 0.165           |
| July 2021       | 0.486       | 0.059       | 0.014         | −0.024       | 0.062         | −0.021       | −0.028         | −0.036         | 0.216           |
| August 2021     | 0.473       | 0.071       | 0.015         | −0.029       | 0.077         | −0.024       | −0.033         | −0.039         | 0.271           |
| September 2021  | 0.460       | 0.083       | 0.016         | −0.034       | 0.092         | −0.028       | −0.038         | −0.043         | 0.328           |
| October 2021    | 0.446       | 0.096       | 0.017         | −0.040       | 0.108         | −0.032       | −0.043         | −0.047         | 0.387           |

| February 2021   | 99.854      | 0.001       | 0.026         | 4.57E−06      | 0.00005      | 0.0006       | 0.005          | 0.084          | 0.026           |
| March 2021      | 99.596      | 0.019       | 0.024         | 0.002        | 0.013        | 0.002        | 0.015          | 0.130          | 0.190           |
| April 2021      | 98.987      | 0.066       | 0.029         | 0.009        | 0.053        | 0.016        | 0.030          | 0.166          | 0.640           |
| May 2021        | 97.891      | 0.144       | 0.033         | 0.021        | 0.128        | 0.029        | 0.051          | 0.200          | 1.501           |
| June 2021       | 96.199      | 0.252       | 0.037         | 0.039        | 0.244        | 0.043        | 0.077          | 0.233          | 2.873           |
| July 2021       | 93.845      | 0.391       | 0.042         | 0.062        | 0.404        | 0.059        | 0.107          | 0.266          | 4.820           |
| August 2021     | 90.806      | 0.558       | 0.047         | 0.091        | 0.608        | 0.077        | 0.141          | 0.299          | 7.368           |
| September 2021  | 87.101      | 0.752       | 0.051         | 0.125        | 0.855        | 0.097        | 0.179          | 0.332          | 10.503          |
| October 2021    | 82.792      | 0.968       | 0.055         | 0.164        | 1.138        | 0.119        | 0.219          | 0.364          | 14.176          |

CD shows communicable diseases, RDE shows research and development expenditures, STJ shows scientific and technical journals, PAP shows patent applications, TOP shows trade openness, MOB shows mobile subscribers, HEXP shows healthcare expenditures, HOSP shows hospital beds, and PHYS shows the number of physicians
the gap between health delivery and its monitoring system. COVID-19 instances may be minimized by a rapid information-sharing system that assists in identifying vulnerable cases and assisting in the management of public health situations. As seen in Table 9, growing patent applications, mobile phone penetration, healthcare spending, and hospital beds will almost certainly reduce infectious illnesses. On the other side, the lack of R&D spending, scientific journal publications, commerce, and physician numbers will likely result in a rise in communicable illnesses during the following year. According to the VDA research, increasing the number of doctors would dramatically decrease communicable disease fatalities, followed by increased trade openness and R&D spending. Over a time, the least impacted will be scholarly journal publications on infectious illnesses.

The COVID-19 pandemic will be contained by raising the total number of patent applications, trade openness, mobile phone penetration, hospital beds, and doctors, as shown in Table 10. In comparison, owing to limited R&D funding, scientific journal papers, and healthcare costs, the COVID-19 pandemic is predicted to worsen during the next decade. Thus, the VDA projections indicate that healthcare spending will be critical in containing coronavirus illnesses, followed by trade openness and research and development expenditures.

### Conclusion

This research aims to examine the influence of technology innovation in containing infectious illnesses, namely the COVID-19 pandemic, in a panel of 65 nations from 2010 to 2019. Technological innovation is classified into three broad categories, each with its sub-category, namely innovative capability (which has three sub-categories), absorptive capacity (which has two sub-categories), and healthcare competency (having three sub-factors). The innovative capabilities were shown by R&D spending, scientific and technical journal publications, and patent filings. Trade openness and mobile phone prevalence are associated with absorptive capacity, whereas healthcare expenditures, hospital beds, and doctors are associated with an economy’s healthcare capability. The findings demonstrate that insufficient R&D and healthcare spending are incapable of reducing the mortality toll from infectious illnesses, including the COVID-19 pandemic. In comparison, many scientific and technological journal articles, patent applications, hospital beds, and doctors advocated for the worldwide management of the coronavirus pandemic. Three-dimensional printing technologies, telemedicine, integrated point-of-care biosensor systems, Internet of

### Table 10  Panel impulse response function and variance decomposition analysis for Eq. (2)

| Response of COVID19 | RDE | STJ | PAP | TOP | MOB | HEXP | HOSP | PHYS |
|---------------------|-----|-----|-----|-----|-----|------|------|------|
| February 2021       | 0.132 | 0.004 | 0.004 | 0.001 | −0.018 | −0.0009 | 0.018 | −0.004 | 0.003 |
| March 2021          | 0.133 | 0.005 | 0.0008 | 1.94E − 05 | −0.018 | −0.001 | 0.016 | −0.002 | 0.002 |
| April 2021          | 0.121 | 0.007 | 0.002 | −0.0009 | −0.019 | −0.002 | 0.020 | −0.003 | 0.002 |
| May 2021            | 0.112 | 0.009 | 0.001 | −0.002 | −0.018 | −0.002 | 0.022 | −0.003 | 0.002 |
| June 2021           | 0.103 | 0.011 | 0.002 | −0.003 | −0.018 | −0.003 | 0.024 | −0.003 | 0.001 |
| July 2021           | 0.095 | 0.012 | 0.002 | −0.004 | −0.017 | −0.004 | 0.026 | −0.004 | 0.0004 |
| August 2021         | 0.087 | 0.014 | 0.002 | −0.005 | −0.017 | −0.005 | 0.028 | −0.004 | −0.0004 |
| September 2021      | 0.080 | 0.015 | 0.002 | −0.006 | −0.016 | −0.006 | 0.029 | −0.004 | −0.001 |
| October 2021        | 0.074 | 0.016 | 0.002 | −0.007 | −0.016 | −0.007 | 0.031 | −0.005 | −0.002 |

**Variance decomposition of COVID19**

| February 2021       | 98.616 | 0.038 | 0.037 | 0.003 | 0.604 | 0.001 | 0.652 | 0.030 | 0.015 |
| March 2021          | 98.058 | 0.067 | 0.028 | 0.002 | 0.919 | 0.006 | 0.863 | 0.032 | 0.020 |
| April 2021          | 97.424 | 0.121 | 0.032 | 0.003 | 1.173 | 0.011 | 1.170 | 0.039 | 0.024 |
| May 2021            | 96.827 | 0.192 | 0.031 | 0.007 | 1.357 | 0.018 | 1.494 | 0.046 | 0.024 |
| June 2021           | 96.196 | 0.281 | 0.032 | 0.015 | 1.507 | 0.027 | 1.859 | 0.055 | 0.023 |
| July 2021           | 95.524 | 0.388 | 0.033 | 0.028 | 1.635 | 0.041 | 2.262 | 0.064 | 0.021 |
| August 2021         | 94.799 | 0.513 | 0.034 | 0.047 | 1.747 | 0.059 | 2.702 | 0.075 | 0.019 |
| September 2021      | 94.018 | 0.655 | 0.035 | 0.072 | 1.849 | 0.084 | 3.178 | 0.085 | 0.019 |
| October 2021        | 93.178 | 0.814 | 0.036 | 0.103 | 1.942 | 0.116 | 3.690 | 0.097 | 0.021 |

RDE shows research and development expenditures, STJ shows scientific and technical journals, PAP shows patent applications, TOP shows trade openness, MOB shows mobile subscribers, HEXP shows healthcare expenditures, HOSP shows hospital beds, PHYS shows the number of physicians, and COVID19 shows coronavirus disease.
Things ecosystems, infrared systems, and thermal scanners are just a few examples of hardware and technology that may assist in containing the COVID-19 pandemic. The findings above suggest the following possible recommendations to government officials and healthcare practitioners for developing long-term sustained healthcare policies to control infectious diseases, including COVID-19:

1. To ensure a free flow of healthcare logistics supply during the COVID-19 pandemic and to provide protective equipment, testing kits, surgical instruments, therapeutic medicines, ventilators, and other safety instruments to effectively controlled.

2. To invest much more in research and development of vaccines, hospital infrastructure, physician and para-medical personnel, and other surgical operations. Then, contaminated instances may be drastically decreased on a large scale.

3. To foster industry–academia collaborations and publish high-quality scientific and technological journal articles and patent applications to enable governments to acquire preventative and remediation plans for the COVID-19 pandemic.

4. To digitalize the healthcare sector and make healthcare facilities accessible to the general public via mobile phone penetration and other information and communication technologies in order to spread word of mouth about preventive measures against infectious diseases; and

5. The critical need to subsidize the healthcare sector by increasing healthcare bills on the national agenda while monitoring healthcare assessment reports to analyze the latest coronavirus pandemic trend for e-health.

These recommended policies would aid in formulating an effective healthcare policy that is resistant to infectious illnesses, such as the COVID-19 pandemic.

Acknowledgements Researchers Supporting Project number (RSP2022/87), King Saud University, Riyadh, Saudi Arabia.

Declarations

Conflict of interest The authors declare no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

References

Abi Younes G, Ayoubi C, Ballester O, Cristelli G, de Rassenfosse G, Foray D, Zhou L (2020) COVID-19: insights from innovation economists. Science and Public Policy 47(5):733–745
Aboelmaged M, Hashem G (2019) Absorptive capacity and green innovation adoption in SMEs: the mediating effects of sustainable organizational capabilities. J Clean Prod 220:853–863
Ahmad K, Erqui S, Shah N, Nazir U, Morrison AR, Choudhary G, Wu WC (2020) Association of poor housing conditions with COVID-19 incidence and mortality across US counties. PloS one 15(11):e0241327
Anesi GL, Lynch Y, Evans L (2020) A conceptual and adaptable approach to hospital preparedness for acute surge events due to emerging infectious diseases. Critical Care Explorations 2(4):e0110. https://doi.org/10.1097/CCE.0000000000000110
Bloom DE, Khoury A, Subbaraman R (2018) The promise and peril of universal health care. Science 361:6404. https://doi.org/10.1126/science.aat9644
Bloom DE, Kuhn M, Prettner K (2022) Modern infectious diseases: macroeconomic impacts and policy responses. J Econ Lit 60(1):85–131
Budd J, Miller BS, Manning EM, Lamos V, Zhuang M, Edelstein M, Short MJ (2020) Digital technologies in the public-health response to COVID-19. Nat Med 26:1183–1192
Castellacci F, Natera JM (2013) The dynamics of national innovation systems: a panel cointegration analysis of the coevolution between innovative capability and absorptive capacity. Res Policy 42(3):579–594
Choong YYC, Tan HW, Patel DC, Choong WTN, Chen CH, Low HY, Chua CK (2020) The global rise of 3D printing during the COVID-19 pandemic. Nat Rev Mater 5:637–639
Deb C, Moneer O, Nicholson Price W (2020) Covid-19, single-sourced diagnostic tests, and innovation policy. J Law Biosci. https://doi.org/10.1093/jlb/lsaa053
Dhala A, Sasangohar F, Kash B, Ahmadi N, Masud F (2020) Rapid implementation and innovative applications of a virtual intensive care unit during the COVID-19 pandemic: case study. J Med Internet Res 22(9):e20143
Dubov A, Shoptaw S (2020) The value and ethics of using technology to contain the COVID-19 epidemic. Am J Bioeth 20(7):W7–W11
Ekong I, Chukwu E, Chukwu M (2020) COVID-19 mobile positioning data contact tracing and patient privacy regulations: exploratory search of global response strategies and the use of digital tools in Nigeria. JMIR Mhealth Uhealth 8(4):e19139
Emanuel EJ, Persad G, Upshur R, Thome B, Parker M, Glickman A, Phillips JP (2020) Fair allocation of scarce medical resources in the time of Covid-19. N Engl J Med 382:2049–2055
Gereffi G (2020) What does the COVID-19 pandemic teach us about global value chains? the case of medical supplies. J Int Bus Policy 3(3):287–301
Gillson I, Muramatsu K (2020) Health services trade and the COVID-19 pandemic. Online available at: https://medium.com/innovation-machinery/8495
Gillson I, Muramatsu K (2020) Health services trade and the COVID-19 pandemic. Online available at: https://doi.org/10.1056/j.jinfomgt.2020.102180
Krasadakis G (2017) Technology innovation—trends and opportunities. In: Innovation in health informatics. Academic Press, pp. 3–38
Lamprou DA (2020) Emerging technologies for diagnostics and drug delivery in the fight against COVID-19 and other pandemics. Expert Rev Med Devices 17(10):1007–1012
Li C, Chen YJ, Huang YM (2020) Challenges and opportunities for China entering global research and development for emerging infectious diseases: a case study from Ebola experience. Infect Dis Poverty 9(1):1–10
Liu M, Cao J, Liang J, Chen M (2020) Basic concept of epidemiologistics. In: Epidemiologistics Modeling: A New Perspective on Operations Research. Springer, Singapore pp. 1–12
Lytras MD, Papadopoulou P, Sarirete A (2020) Smart Healthcare: emerging technologies, best practices, and sustainable policies. In: Innovation in health informatics. Academic Press, pp. 3–38
Mahmood S, Hasan K, Carras MC, Labrique A (2020) Global preparedness against COVID-19: we must leverage the power of digital health. JMIR Public Health Surveill 6(2):e18943
Mamyrbekova S, Nurgaliyeva Z, Saktapov A, Zholdasbekova A, Kudai-bergenova A (2020) Medicine of the future: digital technologies in healthcare. In: E3S Web of Conferences. EDP Sciences Vol. 159, p. 04036
McGinnis KA, Suffoletto MS (2020) The US Department of veterans affairs (VA) as a model for stronger public health infrastructure to combat HCV and other infectious diseases and reduce disparities. eClinicalMedicine 22:100391
Najafi-Tavani S, Najafi-Tavani Z, Naudé P, Oghazi P, Zeynaloo E (2018) How collaborative innovation networks affect new product performance: product innovation capability, process innovation capability, and absorptive capacity. Ind Manag Manage 73:193–205
Oliver N, Leibri B, Sterly H, Lambiote R, Deletaille S, De Nadai M, Colizza V (2020) Mobile phone data for informing public health actions across the COVID-19 pandemic life cycle. Sci Adv 6:23. https://doi.org/10.1126/sciadv.abc0764
Qiu Y, Chen X, Shi W (2020) Impacts of social and economic factors on the transmission of coronavirus disease 2019 (COVID-19) in China. J Population Econ 33(4):1127–1172
Riva G, Mantovani F, Wiederhold BK (2020) Positive technology and COVID-19. Cyberpsychol Behav Soc Netw 23(9):581–587. https://doi.org/10.1089/cyber.2020.29194.gri
Rowan NJ, Galanakis CM (2020) Unlocking challenges and opportunities presented by COVID-19 pandemic for cross-cutting disruption in agri-food and green deal innovations: Quo Vadis? Sci Total Environ 748:141362
Santos Rutschman A (2020) The COVID-19 vaccine race: intellectual property, collaboration (s), nationalism and misinformation. Online available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3656929# (accessed on 8th September, 2020)
Sharma A, Gupta P, Iha R (2020) COVID-19: impact on health supply chain and lessons to be learnt. J Health Manag 22(2):248–261
Shaw R, Kim YK, Hua J (2020) Governance, technology and citizen behavior in pandemic: lessons from COVID-19 in East Asia. Progess Disaster Sci 6:100090
Subramanian L (2020) Enabling health supply chains for improved well-being. In: Supply chain forum: an international journal. Taylor & Francis, pp. 1–8
Ting DSW, Carin L, Dzau V, Wong TY (2020) Digital technology and COVID-19. Nat Med 26(4):459–461
Torous J, Myrick KJ, Rauseo-Ricupero N, Firth J (2020) Digital mental health and COVID-19: using technology today to accelerate the curve on access and quality tomorrow. JMIR Mental Health 7(3):e18848
UNIDO (2020) Innovative ideas and technologies versus COVID-19 and beyond: a global call for developing countries. United Nations Industrial Development Organization, Vienna
Velásquez G (2020) Rethinking R&D for pharmaceutical products after the novel coronavirus COVID-19 shock. Online available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3640355 (accessed on 8th September, 2020)
Wang L, Li J, Xie N, Yao L, Cao Y, ... Song D (2020) Real-time estimation and prediction of mortality caused by COVID-19
with patient information based algorithm. Sci Total Environ 727:138394
Whitelaw S, Mamas MA, Topol E, Van Spall HG (2020) Applications of digital technology in COVID-19 pandemic planning and response. The Lancet Digital Health 2(8):e435–e440
Wilkason C, Lee C, Sauer LM, Nuzzo J, McClelland A (2020) Assessing and reducing risk to healthcare workers in outbreaks. Health Sec 18(3):205–211
World Bank (2021) World development indicators. World Bank, Washington DC
Worldometer (2021) COVID-19: Coronavirus pandemic. Online available at: https://www.worldometers.info/coronavirus/ (accessed on 2nd June, 2021)

Wouters OJ, McKee M, Luyten J (2020) Estimated research and development investment needed to bring a new medicine to market, 2009–2018. JAMA 323(9):844–853

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