Re-examining the nexuses of communicable diseases, environmental performance, and dynamics of sustainable Development in OECD countries

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Received: 4 December 2021 / Accepted: 18 April 2022 / Published online: 30 April 2022
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Abstract
We investigate the determinants of communicable diseases (CDs) and nexus of financial development, economic development, and renewable energy consumption to address the issues of ecological footprint level, the impacts of communicable diseases (CDs), and economic growth of the OECD countries throughout 2000-2019. The results from FMOLS and DOLS reveal that the levels of financial development, energy consumption, and trade volume significantly contribute to overcoming the death toll occurring due to CDs. As regards the growth function, the level of trade in the economy is significantly associated with economic growth. The findings reveal that the improvements and developments in the financial sectors and trading activities cause a reduction in the infection cases represented by COVID-19. In contrast, economic growth does have a negative but insignificant impact upon COVID-19. We conclude that sound financial development combined with economic and environmental regulations could be strategically helpful to cope with CDs.

Keywords Renewable energy · CO₂ emissions · Sustainable development goals · Financial development · Millennium Development Goals (MDGs)

Introduction
The Sustainable Development Goals (SDGs) were put forward as an aftermath of Millennium Development Goals (MDGs) that were designed to reduce communicable diseases like malaria etc., and child mortality rates to target improved maternal health; to combat HIV/AIDS; to ensure gender equality and women empowerment; to achieve poverty reduction; and to attain higher levels of education for all, thereby achieving sustainable development including environmental sustainability through global partnerships (United Nation 2017). Afterward, the SDGs stated seventeen
The regional economic, financial, and trade integration among the OECD economies promote the bilateral economic, financial, and trade-related sectors, for instance, health, education, research and development, and technology transfer, leading to sustainability. The regional integration also needs to respond to the CDs by effectively coordinating significant policies’ frameworks to secure the individuals from the adverse economic, financial, and health issues, especially during the COVID-19 like pandemics. The COVID-19 has impacted every aspect of individuals’ well-being across the globe including the OECD countries. OECD organizations initiated different policies’ frameworks to refocus, redesign, realign, and reconnect with the member countries to achieve “triple win” aims during the COVID-19 pandemic. The aims are to support sustainability, financial inclusion, job opportunities, and to strengthen the mental and physical health of the people (OECD 2022).

There are empirical shreds of evidence that highlight the strong and complex relationships among communicable diseases, economic, social, and financial variables (Ceddia et al. 2013; Goenka and Liu 2020). Other studies find significant relationships among the economic, environmental, human development, and financial variables (Khan et al. 2021; Feghali et al. 2021; Demirguc-Kunt et al. 2017, Khan et al. 2017; Khan et al. 2021h; Sun et al. 2021; Goenka and Liu 2020). The studies cited above open the new debate on how the innovations in the use of financial instruments, services, and technology increase the level of financial development and ultimately may have impacts on developments relating to human health. The global integrated dynamic social, economic, and financial systems are also causing the higher rate of communicable diseases, but the impacts of such diseases are more harmful to the developing economies where the health system is not well equipped and individuals are less careful about their health as compared to their wealthier counterparts. We find a sheer lack of empirical studies investigating the impacts of financial development, environmental performance, and sustainable development on communicable diseases (CDs) for the economic regional group countries of OECD. So, it seems significant to bring into focus the diverse economic, financial, environmental, and health issues considering the latest of its kind – the COVID-19 scenario. Therefore, the main objective of our study is to reinvestigate the determinants of communicable diseases by bridging and modeling the abovementioned multidisciplinary concepts under the broader umbrellas of MDGs and SDGs in the context of OECD economies and adds to the contemporary research strands as follows.

First, we explore the causality between financial development and CDs. Second, our study examines the impacts of environmental performance on the level of infectious diseases. Third, we reinvestigate the association of sustainable development of OECD countries with CDs incorporating also the data of contemporary COVID-19 pandemic. Fourth, the

(17) embedded goals to replace the MDGs, targeted to be achieved by 2030. Khan et al. (2021a, b, c) asserts that the financial services provided by the intermediaries, banks, etc., are essential for economic development and innovation for which financial education should be focused. Yu and Khan (2021) and Khan et al. (2021d) also emphasize financial inclusion for individuals and small firms’ access to essential financial services. Similarly, the overall goal of sustainable development (SD) is the long-term stability of the economy and environment, only achievable through a mere acknowledgment and integration of social, environmental, and economic dimensions to be achievable via a financial system (Emas 2015).

According to Ceddia et al. (2013), the epidemics reflect the dynamics of complex ecological-economic systems, and their expansion gives birth to the disease emergence. It has been empirically established that the emergence and spread of contagious diseases are caused by the interaction of both economic and ecological factors, while the disease ecology openly recognizes how the socio-economic system and natural environment combine to form a complex and adaptive system (Philipson 2000; Khan et al. 2021e; Pearce and Merletti 2006; Ceddia et al. 2013; Yu and Khan 2022; Goenka and Liu 2020).

Due to the advent of the modern healthcare regime, the burden of contagious diseases has been much reduced and gradually becoming insignificant, as is also evident from the steady decline in infectious diseases mortality (IDM) and overall incidence (Sun et al. 2021; Yang et al. 2017; Khan et al. 2021f; Wu et al. 2017). However, the outbreak of several epidemics of contagious diseases, such as the Middle East respiratory syndrome (MERS), highly pathogenic avian influenza (H5N1), severe acute respiratory syndromes (SARS), human immunodeficiency virus (HIV) (Castelli and Sulis 2017), and lastly the coronavirus breakout (Wu et al. 2020), has so far produced severe health security threats and economic impacts. Coronavirus has been a new contagious disease with relatively higher transmissibility rates, and it has spread worldwide very swiftly since January 2020. The World Health Organization (WHO 2021) Coronavirus Dashboard reports that as of 19 November 2021, there have been 255,324,963 confirmed cases of COVID-19, including 5,127,696 deaths, while over a total of 7,371 million vaccine doses had been administered to combat the pandemic. A significant decline in the volume of trade has been recorded throughout 2020–2021 owing to the COVID-19 pandemic, and the globe is experiencing a new financial crisis (Phan and Narayan 2020) and adverse spillovers related to the natural economic systems. It is posited that all such contagious diseases have played an essential role in the economy, transportation safety, and health policy over the globe (Bloom et al. 2020; Khan et al. 2021g; Wenham et al. 2020; Wu et al. 2021).
present study adopts the level of domestic borrowing as proxy variables for financial development to estimate their impacts on communicable diseases during the study period. The objective is to investigate the impact of the level of domestic borrowing extended in the economy to meet the basic needs of human beings as well as the business operations under the different schemes of the government upon the CDs.

**Literature review**

**Communicable diseases**

The pandemic of COVID-19 has become an unprecedented crisis in recorded humanitarian history, severely affecting global business dynamics. The outbreak of pandemics in the past caused much vulnerability; however, COVID-19 has impacted human life and business activities extraordinarily. In this context, the prevention and rehabilitation strategies now require the concerned quarters, including medical professionals, researchers, pharmacists, policy-makers, and security consultants, to vigilantly conceptualize their goals, action plans, and roadmaps to overcome the novel sustainability challenges during the emerging- and post-COVID-19 situation. Therefore, this research study aims at exploring the nexus among the specific aspects of economic viability and sustainability perspectives in the context of the prevalent CDs in respect of the OECD countries.

Among the various types of disasters categorized by the World Health Organization (WHO), the outbreaks of joint diseases, epidemics, and the global pandemic of COVID-19 have proven to be the most destructive to human beings and the business world and national economies. During the outbreak of joint diseases and global pandemics, there was a full or partial shutdown of the manufacturing sector all over the affected territorial boundaries through a connected network over the geographic area or along with the trading partners’ network.

As far as the microlevel operations are concerned, most of the affected industrial sectors experience the workers’ absenteeism; many of them are either affected themselves or attending the affected ones among their family members. Resultantly, there is a significant fall in the output levels, and the sustainability of the economy is disturbed (Yu and Khan 2022). Historically, the world has experienced such challenges many times due to the great pandemics, which exerted devastating long-term effects upon industrial operations, social dynamics, and regional economies (Ivanov 2020).

Of these notable ripple effects, around 20 to 50 million people died from the Spanish Influenza outbreak during 1918–1919. Similarly, the Ebola virus has also exerted unmatched impacts upon all dimensions of human life. Likewise, the significant epidemics of communicable diseases such as malaria, plague, cholera, AIDS, MERS, and SARS have adversely affected society and the national economy, along with accumulated losses amounting to billions of US dollars (Farooq et al. 2021). Similarly, when we talk about environmental degradation, many environmental pollution and wastages are being caused every year (Habib et al. 2019), which is also growing at an alarming rate. Due to certain factors, the problem has worsened much in recent years regarding the frequency and severity of pandemics.

The above empirics highlight that the CDs impact every aspect of human lives including the threat of their survival. The frequency and severity of the CDs’ pandemics have been increasing at a larger scale as compared to their earlier visions. The reasons may be the much higher degree of global integration in terms of global trade and mobility of the tourists across the globe to seek business, economic, health, and other opportunities. In the modern world, every country has significant specific and common goals, to achieve the goals, formulating the economic, monetary, and fiscal policies to sustain the growth. The growing importance of regional integration supports the member countries to achieve the common goals but is accompanied by the higher risks of the spread of CDs. So, it seems imperative to explore the factors that may cause to impact the spread of CDs for the sample of OECD countries in the COVID-19 scenario.

**Financial development**

Promoting sustainable growth and addressing climate change are two critical challenges countries face worldwide. This is undoubtedly the case for OECD countries. In the context of 2030 SDGs, financial credit expansion serves as a vehicle for implementing sustainable development strategies and therefore is viewed as a priority among the seventeen objectives of SDGs. Researchers and policymakers have tried to identify each determinant or victim of carbon emission in the wake of rising carbon emissions worldwide. Various research studies (Khan et al. 2021i) agree that financial development can simultaneously foster economic growth and reduce environmental pollution.

Asumadu-Sarkodie and Owusu (2016) find that a vital role is attributed to energy utilization and financial development in controlling environmental degradation in Sri Lanka. Khan et al. (2017) examine the matter of energy utilization regarding thirty-four economies and report a causal relationship among urbanization, the use of renewable and nonrenewable energy sources, trade openness, financial development, and greenhouse gases. The causality test results discovered the existence of unidirectional causality between greenhouse gases and economic development in Europe, Africa, and America and nonrenewable energy and greenhouse gases in Africa and America. It was also reported that growth in the financial sector...
compounds the environmental damages in Europe, whereas the usage of nonrenewable energy sources causes ecological degradation.

However, financial development decreases the environmental damages in America, Africa, and Asia, promoting RESC in Europe. In another study by Khan et al. (2021b, c, j), financial development was found positively associated with the RESC and COEM. Shahzad et al. (2017) also investigated the relationship between COEM, RESC, TRL, and FD in Pakistan through the VECM technique. They reported the prevalence of the feedback hypothesis between the RESC and GDP growth. However, in the case of 34 developed countries, Khan et al. (2019) also empirically tested the nexus between RESC, FD, and overall energy utilization.

Liu et al. (2021) has done an extensive study on the impact of financial development on economic growth and environmental performance. They employ the supply–demand model, 2SLS, and dynamic GMM regression techniques to study the impacts of financial development on the economic growth of economies on the one belt-one route (OBOR) throughout 2007–2019 and report that the number of bank branches, debit, and credit cards positively impact the economic growth of sampled economies. The demand and supply factors of financial development play a vital role in the growth of the sampled economies. The carbon-based emissions, energy, and industry appear to positively impact economic growth, whereas agriculture negatively impacts the growth of the sampled economies. They conclude that financial development causes carbon emissions and economic growth to increase. Further, they find that FDI and energy consumption caused increased growth and carbon emissions in the sampled economies along the OBOR. The financial systems can be pretty well developed for their size, but financial development still needs an improvement.

Khan (2011) points out three benefits of financial development contributing to the economy’s financial stability. Firstly, the small businesses lending helps the banks mitigate against the risk, thereby reducing the volatility and relative size of any single potential or present borrower in the lending portfolio and reducing the “interconnectedness risks of overall portfolio.” Secondly, increasing the number of relatively small savers through financial development reduces the banks’ dependence upon “noncore financing” and bankruptcy risk during crises because the deposit base is strengthened. Thirdly, widespread financial development helps translate the monetary policy goals to the bottom, thereby leading to financial stability. Finally, financial development helps access many services, including those available through basic infrastructure such as freely accessible medical facilities through health cards, income support program cards, and other banking facilities through the ATMs, which have recently been introduced in emerging countries like Pakistan. So, even though the impact of financial development upon the general welfare of the inhabitants as measured by the human development index (HDI) and financial stability has already been reported in many studies, namely Soyemi et al. (2020) and Feghali et al. (2021), respectively, there have been pressing recommendations studies cited above to investigate further the role of financial development in the uplift of the general well-being of the masses.

Access to significant financial products plays a vital role to support individuals, small and medium businesses, and other corporate sectors. The credit facility gains more importance during the CD pandemic when the economy is locked down by limiting the mobility of the people. The economic and social lives of the common people get harsh to sustain as there is a higher likelihood of the failure of the business and loss of the jobs. In such critical situations, the government support programs are redesigned by the monetary, fiscal, and economic policies to protect the businesses and people by focusing on the health, economic, and social aspects. So, based on the above points, we expect that financial development may impact the CDs’ latest version in the form of COVID-19 in the sampled OECD economies. In this study, we hypothesize that financial development in the form of credit access is more likely to enhance the stakeholders’ access to various necessary services and sources of savings and payments, their economic well-being also reported by Demirguc-Kunt et al. (2017), and thereby improve their ability to combat the CDs.

**Energy consumption**

As per the data compiled by IEA (2018), approximately 80% of the energy consumption for the regional commercial requirements is based on fossil fuel combustion, causing greenhouse gas emissions to rise and resulting in critical climatic changes (Dong et al. 2020). Some states have implemented policies to encourage more green production methods to tackle the issue of carbon-based emissions and control fossil fuels consumption (OECD 2020). Therefore, it is essential to explore and quantify the nexus between energy consumption, financial development, and carbon-based emissions in the context of OECD.

Hussain et al.’s (2021) study critically investigate the nexus of financial inclusion and environmental performance along with other control variables such as energy consumption, corruption, economic growth, and infrastructure for the OECD economies from 2004 to 2017. They apply the augmented mean group and common correlated effects mean group techniques to deal with the heterogeneity issue in the panel data for OECD economies. They find that financial inclusion positively impacts the environmental degradation in OECD economies, so there is a need to reconsider the role of financial inclusion, as an increase in financial inclusions...
facilitates the industry to access finance and causes an increase in energy consumption and an increase in energy consumption increases the production and positively impacts the economic growth of the OECD economies.

Islam at el. (2021) study the impacts of trade openness, urbanization, energy, economic growth, technological innovation, and capital formation on the environmental degradation in the context of Bangladesh’s economy throughout from 1972 to 2017. They apply the dynamic ARDL approach and report that trade openness, urbanization, energy consumption, and economic growth play a vital role in Bangladesh’s economic growth and degrading the environment. They conclude that before the establishment of factories and industries, modern technologies should be well-equipped to mitigate the possible negative impacts on the environment, and the same proposition was also.

Qader et al. (2021) find that shifting economic activities from the urban to rural due to the development of industrial sectors has increased the negative impacts on Bahrain’s economy, climate, and environment. They suggest that there is a severe need to switch from conventional sources of energy to renewables to mitigate the global warming effects on the economy of Bahrain. The poor air quality causes health issues and needs more investment in the health sec. Therefore, the economies such as Bahrain need to maintain carbon neutrality.

Based on the critical literature review, we conclude that demand for energy consumption has been increasing with the increase in economic activities. But during the CDs, when the economic activities are limited, energy consumption in the business and corporate sectors may be reduced whereas an increase may occur in the domestic usage. So, we expect that energy consumption may have a different consumption pattern during the CDs in the sampled OECD country panel.

**Economic growth**

Economic growth in boosting performance in various sectors, including health, is well established. Disease control programs can be carried out effectively with a high level of economic growth and adequate funding sources. During the COVID-19, there has been strong evidence that the developed countries have been very much able to ensure maximum vaccination of their population in the early phases, compared to the developing countries where the vaccination program is still in its infancy. So, the relationship between the GDP growth and control of CDs appears to be an established empirical fact. So, the rate of spread of CDs can significantly be reduced, and the GDP growth can also contribute to this phenomenon.

Sun et al. (2021) report that fluctuations in the quarterly GDP negatively affect the annual infectious diseases mortality (IDM) and that the mortality of contagious diseases varies countercyclically with the business cycle in China. The rate of IDM appears to increase with the deteriorating economic scenario. The study offers policy implications for controlling contagious diseases by adopting effective strategies to mitigate the adverse effects of economic fluctuations on IDM, ensuring sustainable economic growth and increasing state expenditure to prevent the contagious diseases’ impact.

Goenka and Liu (2020) employ cross-country analysis to estimate the linkages of infectious diseases and income growth. They find that high-income and developed economies with higher education levels have better control of infectious diseases than the middle and lower-income (poor) economies. There is a need to invest in health infrastructure to prevent infectious diseases. Sun et al. (2020) investigate the impacts of infectious diseases on China’s economic growth by applying the vector autoregressive model. They find that economic growth is negatively associated with infectious diseases. The poor economic conditions cause to increase the infectious diseases.

We expect that during the CDs period, the lockdown of the economies limited the economic activities and may reduce in GDP the contribution of the different economic sectors that have higher chances to spread the CDs. So, during the CDs in the form of COVID-19, the contribution of the economic activities in GDP may fall when the governments of the OECD economies restrict the economic activities by imposing the economic lockdown.

**Trade**

Trade has always been the primary driving force of economic change, human health, and social sustainability. By trading relations, the trading countries were able to acquire safety equipment and vaccination dozes timely to combat the pandemic of COVID-19. Ismahene (2021) has reported bidirectional causality between infectious diseases, trade openness, and economic growth. Ismahene (2021) makes an intensive study of eighty-eight economies to estimate the nexus among infectious diseases, trade, and economic growth throughout 1996–2018. They apply the FMOLS, DOL, and VECM techniques to investigate the association between trade, infectious diseases, and economic growth. They design a panel of 44 developed and 44 developing economies and find that infectious diseases have a more destructive role on the economy of the developing countries as compared to that of developed ones. In contrast, infectious diseases have a higher magnitude of negative impacts on the trade for the developed economies than developing ones.

Ceddia et al. (2013) conducted an extensive survey on the relationship between economic growth and infectious diseases. They find that economic growth causes environmental
degradation, and eventually an increase in environmental degradation causes infectious diseases to increase. The study also highlights the direct relationship between global mutual trade and infectious diseases. Third, they find the lack of human adaptive behavior to respond to infectious diseases in a complex system within ecological and economic-social dimensions.

According to Sain et al. (2016), the development economists recommend providing essential financial services on a massive scale accessible by all, thereby ensuring an all-inclusive financial system. According to Farooq et al. (2021), by enhancing the quality and quantity of core financial services such as savings mobilization, availability of credit, risk management, and mitigation regime, insurance can pave the way for sustainable production and growth, especially for relatively small and medium-sized enterprises.

We posit that since during the CDs, the governments of OECD economies imposed the economic lockdown and closed the cross-border movement to prevent the further spread of CDs, all these measures adversely impact the international trade among the OECD countries and also with the rest of the world.

Theoretical framework and hypothesis development

In the detailed discussion above, we formulate the theoretical framework and hypotheses. Figure 1 explains the significant determinants of CD. Figure 1 also portrays the direction of hypotheses formulated for empirical testing in this environmental study. Accordingly, the following research hypotheses are formulated for empirical testing under the methodological framework of the study to achieve our study objectives:

H1: The level of national income growth is associated with the prevalence of CDs.
H2: The level of financial development as measured by the access to credit borrowings and disbursements is associated with the prevalence of CDs.
H3: The level of fossil fuels consumption is associated with the prevalence of CDs.
H4: The level of carbon emission damages is associated with the prevalence of CDs.
H5: The level of trading activities is associated with the prevalence of CDs.
H6: The level of energy consumption is associated with the prevalence of CDs.

Methodology and data

Variable definitions and data sources

The present study investigates the determinants of the level of prevalence of CDs in the OECD economies for the period covering from 2000 to 2019. Table 1 contains a brief account regarding the abbreviations and definitions of variables and the sources of data utilized. Data for the empirical task is obtained from the World Development Indicators. The dependent variable of deaths caused by malnutrition, prenatal and maternal diseases, communicable diseases, etc. is represented by COVID-19 and measured in terms of the percentage of the total deaths for the sampled period.

Table 2 presents the proxy variables of the study. The level of CO2-based emissions and fossil fuel-based energy usage are used to measure the environmental degradation level. The level of CO2-based emissions
is measured as the log of metric tons per capita. Fossil fuel-based energy usage is represented by FFC and is measured as the % of total energy consumption during the period sampled.

The economy’s performance is measured in terms of the annual percentage of GDP growth. At the same time, the total energy usage is represented by ENG and measured in terms of kgs. of the oil equivalent per capita. The volume of trade is represented by TRA and measured in terms of the percentage of GDP. Lastly, the level of financial development is represented by the private sector, and domestic borrowing level is represented by FDC measured in terms of a percentage of GDP (Liu et al. 2021).

### Econometric model

We empirically analyze the economic data to test the proposed hypotheses based on the following empirical model to investigate the determinants of infectious diseases:

\[
\text{COVID}_{ji} = \beta_0 + \beta_1 \text{COEM}_{ji} + \beta_2 \text{FFC}_{ji} + \beta_3 \text{ENG}_{ji} + \beta_4 \text{FDC}_{ji} + \beta_5 \text{TRA}_{ji} + \beta_6 \text{GDP}_{ji} + \epsilon_{i,j}
\]

In Eq. 1, the term:

- \(\beta_0\) presents the constant (intercept) of the model that shows the OECD countries’ specific characteristics.
- \(\beta_{1-6}\) presents the long-term coefficients of regressors.
- \(\text{COVID}_{ji}\) presents the communicable diseases in country \(j\) at the time \(i\).

\(\text{COEM}_{ji}\) and \(\text{FFC}_{ji}\) present the carbon emission and fossil fuel consumption proxy variables for environmental performance in country \(j\) at the time \(i\).

\(\text{FDC}_{ji}\) represent the level of private sector/domestic borrowing proxy variables for financial development in country \(j\) at the time \(i\).

\(\text{TRA}_{ji}, \text{GDP}_{ji}, \text{ENG}_{ji}\) present the trade, GDP growth, and energy usage proxy variables for sustainable development in country \(j\) at the time \(i\).

\(\epsilon_{i,j}\) presents the residuals at the time \(i\) for country \(j\).

There are different econometric techniques to estimate Eq. 1 including traditional panel techniques including pooled OLS, fixed and random effect, and other panel cointegration regressions. The traditional panel techniques yield biased estimates in the presence of cross dependency, serial correlation, and heterogeneity. The panel cointegration approaches focus on the long-run relationships by applying the nonparametric approach FMOLS and parametric approach DOLS and are appropriate for the finite panel sample studies (Mitra and Abedin 2021).

Before applying any econometric technique, it is better to test its suitability. Therefore, we run the different diagnostic tests to check the suitability of the proposed economic model. First, we test the cross-dependency of our study variables by applying the first-generation test. The studies of Mitra and Abedin (2021) check the cross-dependency among the OCED countries by applying the test. So we also prefer to apply the test to check the
cross-dependency of study variables. This test checks the cross dependency for the OECD countries by assuming that panel has the same estimates for AR(1) and allows for countries and years’ effects. Our study has short panel data, and we expect that the variations across the OECD countries are higher than the variations across the years. The non-stationarity at level (0) leads us to unbiased estimates. The stationarity at level (1) suggests going for further diagnostic tests.

Second, after checking the stationarity of series variables at level (1), we apply the cointegration tests of Pedroni and Kao to estimate the long-run and short-run association among the variables. The study of Hussain et al. (2021) on the OECD countries apply the Pedroni (1999) and Kao (2002) tests to estimate long-run relationships among the variables. So, we also prefer to apply these tests to check the long and short-run relationships among the study variables. Both Pedroni (1999) and Kao (2002) cointegration test the advanced version of the Engle-Granger test. These tests are appropriate to incorporate the heterogeneity of the panel data by capturing the short-run and long-run dynamics. Pedroni’s (1999) tests check the cointegration for the panel variables by allowing the heterogeneity, whereas Kao’s (2002) test checks the specified cross-section intercepts and homogeneous coefficients for the panel studies.

Cross-panel dependency test and the Pedroni (1999) and Kao (2002) tests suggest the suitability of FMOLS and DOLS. DOLS captures the endogeneity issue by including the regressors’ leads and lags. At the same time, FMOLS performs the nonparametric approach in the presence of serial correlation. The first contribution was made by Phillips and Hansen (1990) to the development of FMOLS during the estimation of optimal cointegration regression. We employ Pedroni’s (2001) FMOLS version to correct the endogeneity bias and serial correlation. It is considered appropriate for analyzing panel data that has heterogeneous cointegration (Hamit-Haggar 2012). Pedroni (2001) FMOLS is widely used to establish a long-term relationship (Gozgor et al. 2020; Janpo-lat et al. 2021).

The panel FMOLS estimator works better to estimate Eq. 1 using the following model:

\[
\hat{\rho}^*_{NT} - \hat{\rho}_0 = \left( \sum_{i=1}^{N} L_{21}^2 \sum_{t=1}^{T} (X_{it} - \bar{X}_{it}) \right)^2 \sum_{i=1}^{N} L_{11}^2 L_{22}^2 \left( \sum_{i=1}^{T} (X_{it} - \bar{X}_{it}) \mu^*_t - T\hat{\gamma}_t \right)
\]

where \(\mu^*_t = \mu_t - \frac{\bar{T}}{T_{22}} \Delta \mu_t, \hat{\gamma}_t = \hat{\gamma}_{21} \hat{\Omega}_{22}^{-1} \hat{\beta}_t, \) and \(\hat{\Omega}_{22} = \hat{\Omega}_{22}^0 \), and \(\hat{\omega}_t\) is the lower triangulation of \(\hat{\Omega}_t\).

### Results and discussion

In this study, we attempt to explore the effects of environmental performance, financial development, and sustainable development as the determinants of infectious diseases like COVID-19. The extant literature is silent about the direct economic, financial, and environmental impacts on communicable diseases. So, to the authors’ best knowledge, it is the first study that captures the influences of environmental performance, financial development, and sustainable development upon communicable diseases.

We estimate mean, median, highest, and lowest values, kurtosis, and J-Bera statistics of the variables to check the distribution of the data series as presented in Table 3. As shown in Table 3, financial development is measured by the percentage of domestic credit to the private sector. The results show that the average value of FDC is 4.1647, with a maximum value of 4.5772. We measured environment performance using the proxies of CO2-based emissions and fossil fuel energy consumption, whose average values are 2.1365 and 4.1647. The minimum values of CO2-based emissions and fossil fuel energy consumption are 1.3036 and 2.4208. The mean, minimum, and maximum values of CO2-based emissions are more significant than the values reported by Khan et al. (2020) using the SAARC countries data. We use trade proxies as % of GDP, COVID-19, energy use, and GDP growth rate for sustainable development, whose average values are 4.6066, 1.7598, 3.2089, and 0.9778. The significance values of Jarque Bera statistics reject the null hypothesis that the data series is standard.

We report the correlation coefficients in Table 4, which are all significant at a 1% significance level. The CO2 emissions have a negative association with FD and energy per capita. COVID-19 shows a positive relationship with FD and fossil fuel energy consumption, but it positively correlates with the other variables. Trade shows a positive relationship with FFC but a positive link with the GDP growth rate for the OECD countries.

Further, the small correlation coefficients reveal that there is no multicollinearity issue in the sampled data. The study results further reveal that financial development as represented by FDC is negatively associated with the GDP, TRA, and ENG. This finding contradicts the study findings by previous studies, who reported a direct association between financial inclusion and both COEM and ENG levels in the context of OECD member nations. It may imply that the policy-makers must make financial development
more compatible with environmental policies considering the critical nexus of financial inclusion, COEM, ENG, and GDP in the policy-making regime. Another policy implication suggested is to expand the climate finance to facilitate the economically disadvantaged masses; micro, small, and medium enterprises (MSMEs); and sole proprietorship business units to help them cope with the increasing levels of COEM. Secondly, since the above-noted factors were also supposed to be associated with the access of OECD citizens to the appropriate and timely healthcare services amid the CD shocks, these citizens might have eventually been affected by the loss of income, thus, financial command over healthcare. Resultantly, the lockdowns in the economy and shutdowns in industries caused a loss in their regular pay and payments for healthcare treatments. Thirdly, while the personal earnings and savings appear to be the first line of defense during the shocks of CDs, the OECD residents may well employ credit financing and resort to borrowings offered by improved levels of financial development, as reported by Anser et al. (2021). In the context of the above discussion, among other SDGs, the importance of appropriate public and private investments is highly recommended for transition to a green economy with high levels of environmental sustainability as well as general public health, as was also suggested by Sachs et al. (2019) and Le et al. (2020). Figures 2, 3, and 4 represent the scatter graphs of COVID-19 with GDP, trade, and fossil fuel consumption. The trend lines show the negative relationship between the two variables measured along both axes.

Since the last three decades, it has been a burning question whether the unit root test is essential in applied studies of macroeconomic variables or not. So, as a precautionary measure, we test the stationary by applying the test for our study. Our study covers the sample period of twenty years from 2000 to 2019 and for thirty-seven member countries of OECD. It assumes that each country in the panel has the same estimates for AR(1), but it allows for country and

Table 3  Descriptive statistics

|       | COEM  | COVID-19 | FDC  | FFC  | ENU  | TRA  | GDP   |
|-------|-------|----------|------|------|------|------|-------|
| Mean  | 2.1365| 1.7598   | 4.4261| 4.1647| 3.2089| 4.6066| 0.9778|
| Median| 2.1494| 1.7700   | 4.5024| 4.3042| 3.2420| 4.5700| 1.2011|
| Maximum| 3.2513| 2.6285   | 5.7365| 4.5772| 3.7207| 6.0146| 3.2643|
| Minimum| 1.3036| 0.6981   | 2.6298| 2.4208| 2.4438| 2.3369| −0.7624|
| Std. dev | 0.3411| 0.3503   | 0.4845| 0.4429| 0.2239| 0.4532| 1.0092|
| Kurtosis| 3.5073| 3.3981   | 2.9097| 7.2970| 3.8576| 4.1432| 5.3321|
| J-Q Bera Prop | 20.330| 28.102   | 14.346| 772.41| 50.318| 38.087| 322.71|
| Prop | 0.000 | 0.000    | 0.0007| 0.0000| 0.0000| 0.0000| 0.0000|
| Observation | 520   | 520      | 520   | 520   | 520   | 520   | 520   |

Table 4  Correlation matrix

| Variables | COEM  | COVID-19 | FDC  | FFC  | ENG  | TRA  | GDP   |
|-----------|-------|----------|------|------|------|------|-------|
| COEM      | 1     | 0.1191   | 0.4047| 1    | 0.4047| 1    | 1     |
| COVID-19  | 0.1191| 1        |      | -0.0461| 0.4047| 1    | 1     |
| FDC       | 0.4047| 1        | -0.1362| 1    | 0.4047| 1    | 1     |
| FFC       | 0.1311| 0.4047   | 1    |      | -0.1362| 1    | 1     |
| ENG       | -0.0461| 0.4047  | -0.1362| 1    | 0.4047| 1    | 1     |
| TRA       | 0.0595| -0.1362  | -0.3046| 0.0235| 0.0329| 1    | 1     |
| GDP       | 0.3382| -0.1362  | -0.3046| 0.0235| 0.0329| 1    | 1     |

Fig. 2  Relationship between GDP and COVID-19
time effects. So, this study has a small panel data set, and we expect the variations in cross-sectional data of countries to be higher than the variations in the time covered. The test results given in Table 5 show that our data has a stationary issue at level, but it is significant at I (1). So, our data is stationary at I (1).

As the test proposed by indicates that our data series are nonstationary at level, we apply Pedroni (1999) and Kao (2002) cointegration tests to check the long-run association among the variables. Both tests are the extending version of Engle and Granger (1987) based on residuals. These tests incorporate the heterogeneity in the panel studies to capture the short-run and long-run dynamics. Pedroni (1999) suggested seven tests to check the cointegration among the panel variables by allowing heterogeneity.

In contrast, Kao (2002) specified cross-section intercepts and homogenous coefficients for the panel regressors in the first stage. Table 6 presents the cointegration tests of Pedroni (1999) and Kao (2002). The Pedroni (1999) statistics for the within dimensions like Rho, PP, and ADF are significant. It shows that the study variables are cointegrated within the dimensions. Similarly, the PP test for the dimensions (group attributes) is also significant. Conclusively, we reject the

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**Table 5** Panel unit root test

| Variable | At level Statistic | P value | At first difference Statistic | P value | Order of integration |
|----------|--------------------|---------|-------------------------------|---------|---------------------|
| COEM     | 5.2821 0.9899      | −9.6711***0.0000 | I(1) |
| COVID-19 | −1.6196 0.0893*   | −11.0636***0.0000 | I(1) |
| ENG      | 4.9057 0.9785      | −9.10484***0.0000 | I(1) |
| GDP      | 6.1332 0.9982      | −4.9098***0.0000  | I(1) |
| FFC      | −0.2308 0.4087     | −11.9778***0.0000 | I(1) |
| FDC      | 3.0369 0.9988      | −7.4188***0.0000  | I(1) |
| TRA      | −0.2308 0.4087     | −11.9778***0.0000 | I(1) |

***, **, and * indicate 1%, 5%, and 10% level of significance

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**Table 6** Co-integration test

Common AR coefficient (within-dimensions)

| Attribute   | Statistic | Probability |
|-------------|-----------|-------------|
| The v-statistics | 1.21312   | 0.1323      |
| The rho-statistics | −1.24123   | 0.0253**   |
| The PP-statistic | −4.46263   | 0.0000***  |
| The ADF-statistics | −4.2572    | 0.0000***  |

| Weighted statistic | Probability |
|--------------------|-------------|
| Panel v-statistics | −1.7246    | 0.8911      |
| Panel rho-statistics | −1.2579   | 0.01987**  |
| Panel PP-statistic | −4.87961   | 0.0001***  |
| Panel ADF-statistics | −1.1078     | 0.1245      |

Individual AR coefficient (between-dimension)

| Group attribute | Statistic | Probability |
|-----------------|-----------|-------------|
| The rho-Statistic | −1.3126   | 0.1223      |
| The PP-Statistic | −4.3490   | 0.0002***   |
| The ADF-Statistic | −0.8215   | 0.3410      |

Kao

| Attribute | Statistic | Probability |
|-----------|-----------|-------------|
| ADF       | −3.9280   | 0.0000***   |

***, **, and * indicate 1%, 5%, and 10% level of significance
null hypothesis is that there is no cointegration among the study variables. We also apply Kao’s (2002) cointegration test to check the robustness of our study variables. The ADF statistics are significant, and as such, our study variables are considered cointegrated.

The stationary and cointegration tests suggest that OLS leads to the spurious estimates for our model. So, the cointegration regressions of fully modified least square (FMOLS) and dynamic ordinary least square (DOLS) methods are appropriate for this study analysis. DOLS estimator covers the endogeneity problems by adding lags and leads of the independent variables. In contrast, FMOLS performs the same as DOLS but follows the nonparametric approach in the presence of serial correlation. Kao and Chiang (2000) argued that DOLS is a superior form of analysis than the FMOLS estimator as it better reduces biases. We perform both tests to check the robustness of our results. Communicable diseases are more likely to spread quickly with close interactions in communities due to economic, social, commercial, and financial activities without SOPs. So, we assume that better environmental performance, financial development, and sustainable development cause communicable diseases to decrease in OECD member countries.

Table 7 below presents the results of the model. The results of the FMOLS estimator exhibit that the proxies of environmental performance (EP) like COEM and FFC, and that of financial development FDC, appear as significant factors with the hypothesized signs or directions. The results reveal that both EP variables appear to negatively affect the dependent variable of communicable diseases (COVID-19). The variable of sustainable development (SD), namely TRA, negatively affects the dependent variable while the variables of ENG and GDP stand as insignificant.

Our findings are similar to those reported by Anser et al. (2021). The variables for the environmental performance COEM and FFC with coefficients of 0.0039 and 0.2133 negatively impact communicable diseases like COVID-19 and the earlier variants of CDs. It can be postulated that a one percent increase in environmental performance by reducing carbon emissions and fossil fuels causes a decrease in the cases of communicable diseases by 0.39% and 21.33%, respectively. The results imply that increased environmental degradation by the more combustion of fossil fuel and carbon emission increase the number of infected cases. In other words, better environmental performance boosts people’s immunity and reduces the spread of communicable diseases, as was also reported by Anser et al. (2021). The average value of the carbon-based emissions of the OECD countries is 2.1365 tons per capita during the sampled period; that is, half of the world average “4 tons per capita.”

Further, the economies of France, Iceland, New Zealand, and Norway are among the top ten economies with the lowest consumption of fossil fuels. We can safely conclude that better environmental performance boosts the people’s immunity in the OECD countries and reduces the spread of communicable diseases. The financial development proxy FDC appears to negatively impact communicable diseases with the coefficients of 0.1291. It means that 1% increases in financial development cause to decrease the communicable diseases by 12.9% and. It implies that the credit facility strengthens the healthcare structure and eventually reduces communicable diseases. The results suggest that an increase in the credit facility, particularly for the health sector, better logistics, and supply management (Govindan et al. 2020), reduce the possibility of coronavirus-based diseases (Anser et al. 2021). Theoretically speaking, access to financial resources and savings stimulates economic prosperity and leads to a better standard of living that ultimately results in longevity.

The proxy of sustainable development TRA negatively impacts communicable diseases with a coefficient of 0.06997. It means that a 1% increase in trade volume causes to decrease the communicable diseases by 0.6997%. It implies that the OECD countries’ trade balance sheet contains essential medical and nonmedical items. These economies need to strengthen the healthcare structure and supply chain during communicable diseases to reduce the pandemic effects. The elimination of poverty strengthens the advancement against communicable diseases, with other development strategies closely interlinked with the CDs (Raviglione and Maher 2017).

Table 7 The panel fully modified least squares and DOLS

| Variable | Coefficient | t statistic | Probability | Variable | Coefficient | t statistic | Probability |
|----------|-------------|------------|-------------|----------|-------------|------------|-------------|
| COEM     | -0.0421     | -0.0310    | 0.2012      | COEM     | -0.19180   | -0.3645    | 0.1694      |
| FDC      | -0.1291     | -4.2915    | 0.009*      | FDC      | -0.29326   | -2.23123   | 0.0206**    |
| FFC      | -0.3140     | -2.8924    | 0.0601*     | FFC      | -0.3512    | -2.56321   | 0.0131**    |
| ENG      | 0.07927     | 0.5749     | 0.4513      | ENG      | -0.1867    | -0.55801   | 0.5710      |
| TRA      | -0.07109    | 1.7180     | 0.0831*     | TRA      | -0.0910    | 1.4120     | 0.0123**    |
| GDP      | -0.011      | -1.2410    | 0.1570      | GDP      | -0.0311    | -1.6961    | 0.1472      |

***, **, and * indicate 1%, 5%, and 10% level of significance
The other implied meaning is that the financial and commercial activities in the economy carried out by following the SOPs lower the infection cases, particularly in OECD countries. COVID-19 is reported to contract and curtail the trade interconnections among the economies (Vidya and Prabheesh 2020). The commercial activities increase the COVID-19 new cases in the cross-sectional study of seventeen world economies (Anser et al. 2021). In contrast, consumption and GDP are found insignificant; energy and as such are also corroborated by our findings that also don’t reveal any significant influences of energy consumption and GDP on the spread of viral diseases.

Our results remain unchanged in DOLS, showing the results’ stability and supporting our relevant hypotheses that FIN, environmental performance, and sustainable development negatively impact the infection cases of communicable diseases represented by COVID-19. So, based on our study results, we can safely conclude that increases in the financial development, environmental quality, and trade activity have a significant role in mitigating and curtailing the viral effects of CDs during the period under consideration for the sampled OECD countries.

Conclusion and policy implications

This study takes rather intensive considerations to examine the determinants of communicable diseases in the context of the OECD member countries. We use the environmental performance, financial development, and sustainable development factors to estimate their impact on morbidity levels on communicable diseases. The selection of the OECD member countries was made due to their regional and global diversity, including South and North America, Asia-Pacific, and Europe. Further, these countries will have more sustainable development, financial development, and environmental performance to reduce infectious diseases. Our study results lead us to conclude that OECD member countries with higher levels of carbon-based emissions and fossil fuel consumption invest in healthcare structure and related items and extend bank credit to strengthen their healthcare structure and reduce infectious diseases. We may infer that during the last 2 years, the COVID-19 pandemic forced the member countries to implement a lockdown in their economy, invest more in their healthcare structure, and trade in medicines and medical equipment to fight against the pandemic.

Further, this lockdown due to the higher spreading of viral diseases limited their economic activities significantly, and thus consumption of fossil fuels, and thereby carbon-based emissions, have declined. The individuals switched to online modes of financial dealings, such as using point of sale options and making online payments and receipts through banks apps instead of ATMs. The firms also avail minor credit from the banks for non-health industries. Though the extant literature provides insightful findings on the importance of controlling pollution and environmental damages for targeting the SDGs, more research is required on how financial development and SDGs could be aligned with the environmental policies and the regulation of energy usage.

For each of the economies, there stands a dire need to minimize the susceptibility of various sectors to unforeseen natural events and global market volatility. In addition to the above, our study proposes the following policy implications for the OECD member countries. First, there must be ensured long-term strategic planning to improve and sustain the environment by gradually adopting renewable energy sources and reducing carbon emissions. The member countries should search and embrace new alternatives like hydro-based and solar energy to curtail the greenhouse gases majorly emitted from fossil fuel energy consumption. In this way, they would control the speedy spread of viral diseases in the community with weak immunity and reduce the negative impacts upon environmental performance. So, there is a need to have an intensive implementation of policy to reduce the environmental degradation elements, for instance, carbon emission and high dependency on fossil fuels. As carbon emission negatively impacts human health and weak immunity, people are at higher risk of being infected during viral pandemics. Second, the states should take serious measures to bring most individuals under financial networks, have their bank accounts, and introduce different incentive programs to encourage them to carry out daily transactions through mobile banking, and/or banking channels for their businesses. By doing so, the individuals would reduce the personal visits to the banks and ATM cabins and thereby cause the infection rates of the communicable diseases to reduce. Further, OECD member countries should also introduce financial support and incentives for encouraging public–private partnerships in the health sector to control and reduce communicable diseases. Similarly, the authorities should introduce effective policies to increase the credit for the private sector for health and its related infrastructure provisions. Third, OECD countries should broaden the scope of trade agreements to facilitate the cross-border trade for general and especially medical, surgical, and other related products and services to mitigate the effects of communicable diseases.

Fourth, sedative methods and other relief policies could be geared at mitigating the effects of pandemic-based externalities. Hence, from the perspective of policy formulation, there is a need to develop shields against global pandemics, which is essential in particular, given the massive negative spillovers arising from COVID-19.

Fifth, the governments should implement policies in the form of coverage and social safety nets, reaching susceptible
segments of the population, especially those being under-served, reinforcing the research capabilities and intense monitoring in the light of the existing global policy framework. These could help strengthen and sustain the economic development towards controlling the negative spillovers of communicable diseases in the OECD countries.

Sixth, there is an urgent need to financially support and boost the cooperation among the OECD countries to cope the environmental degradation. They should initiate comprehensive climate and environmental policies to achieve the SDGs and eventually reduce the chances of the severity of CDs by encouraging a clean and healthy environment. Seventh, there should be appropriate private–public partnership programs to cope with different current and potential challenges including to achieve the green economy status and to reduce the chances of CDs pandemics, for instance, COVID-19.

Limitations and future agenda

This study considers the OECD member countries with integrated policy for their economic cooperation. These economies have economic and financial structures distinct from the rest of the world. So, the present study might not apply to other cooperative economic regions. Further research may be conducted to examine the determinants of communicable diseases by taking a broader sample from a diversified set of countries to generalize the results. Other social, economic, environmental, and financial development variables may be considered to estimate their impacts upon communicable diseases, such as infection rates across gender, social class, poverty, and other microlevel financial factors such as frequency of money transfers through mobile accounts, cellular phones, etc.

This study uses certain variables as proxies for environmental performance, financial development, and sustainable growth. Future research may be conducted to estimate the impacts of these variables by constructing an index as a single proxy variable that may capture the effects better than two or more proxy variables. Secondly, given the emergence of a change from factor-driven to more technological innovation-driven financial development as posited by Xin-gang and Wei (2020) and Xin-gang et al. (2021), future research may also consider the impact of the role of technological innovation upon the financial development and sustainable growth. Another suggestion is to use more robust econometric techniques of the autoregressive distributed lag model (ADRL) and the dynamic SYS-GMM for empirical analysis. Since another limitation of the current study is the nonavailability of comprehensive data for years later than 2019, future studies may well be conducted on the dynamics of the same topic considering updated and complete panels of data sets covering the most relevant variables of interest.

Author contribution ZY, MUQ, and MHA: conceptualization, methodology software. MHA, LR, SARK: data collection, writing-original draft preparation. MUQ, MHA, MT, MSA, and ZY: visualization, Investigation. ZY, MUQ, MT, MSA, and LR: software, validation. MUQ, ZY, and LR: writing – reviewing and editing.

Funding This research is supported by the Beijing Key Laboratory of Urban Spatial Information Engineering (NO. 20210218).

Data availability The datasets used and results analyzed during the current study are available on reasonable request.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors no competing interests.

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