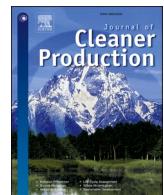




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Predicting the impact of the COVID-19 pandemic on globalization

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ABSTRACT

The COVID-19 pandemic has significantly influenced the global economy, international travel, global supply chains, and how people interact, and subsequently affect globalization in coming years. In order to understand the impact of COVID-19 on globalization and provide potential guidance to policymakers, the present study predicted the globalization level of the world average and 14 specific countries in scenarios with and without COVID-19 based on a new Composite Indicator method which contains 15 indicators. Our results revealed that the world average globalization level is expected to decrease from 2017 to 2025 under the scenario without COVID-19 by -5.99%, while the decrease of globalization under the COVID-19 scenario is predicted to reach -4.76% in 2025. This finding implies that the impact of COVID-19 on globalization will not be as severe as expected in 2025. Nevertheless, the downward trend of globalization without COVID-19 is due to the decline of the Environmental indicators, whereas the decline under the COVID-19 scenario is attributed to Economic aspects (almost -50%). The impact of COVID-19 on globalization varies across individual countries. Among the countries investigated, COVID-19 had a positive impact on the globalization of Japan, Australia, the United States, the Russian Federation, Brazil, India and Togo. In contrast, the globalization in the United Kingdom, Switzerland, Qatar, Egypt, China and Gabon are expected to decrease. The variation of impact induced by COVID-19 on those countries is attributed to the weighting of economic, environmental and political aspects of globalization is different across these countries. Our results can help governments take suitable measures to balance economic, environmental and political policies, which may better support their decision-making.

1. Introduction

Since the unprecedented breakout of the COVID-2019 pandemic at the end of 2019, it has swept the world and brought disaster to all countries. By July 29, 2022, the cases had reached 568,373,127. National governments were forced to curb the spread of the virus, namely through strict social distancing measures, quarantines, and lockdowns (Thu et al., 2020). How we live, work, and interact with each other has been affected (Cervera-Martínez et al., 2021). The COVID-19 pandemic has caused large-scale impacts on society and the environment, as governments have shifted priorities and diverted funding in response. (Qadeer et al., 2022). Urban governance capacity is believed to be a key factor in pandemic control and can improve a city's resilience against pandemics. (Yang et al., 2021; Tepe, 2023). A strict border control policy had been made to avoid imported COVID-19 cases jeopardizing

domestic containment efforts (Zhu et al., 2021). International travel, considered the primary vector for spreading the virus in a highly globalized world, faces unprecedented crises (Shin et al., 2022). At the same time, short-run economic impacts of the inbound tourism industry (Pham et al., 2021). According to World Travel and Tourism Council estimates for 2020, international travel arrivals could fall by 75% compared with previous years (World Travel and Tourism Council). The COVID-19 pandemic has remarkably influenced global higher education, especially due to travel restrictions and campus closures. As a result, international student mobility has dropped, and many students have canceled their study plans abroad (Altbach, 2020; Mok et al., 2021). Due to the pandemic's impact, people's movement has been restricted, which has also caused unprecedented economic and financial disruptions. As such, various supply chains have been affected by government strategies (Ivanov). Currently, the economic shock arising from

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this pandemic is still uncertain (Ibn-Mohammed et al., 2021). While with rapid vaccination rollouts, the recovery is full of information, as World Economic Situation and Prospects (WESP) in mid-2021 believe, following a sharp contraction of 3.6 percent in 2020, the global economy is projected to expand by 5.4 percent in 2021. At the same time, COVID-19 threatens to impede progress toward prosperous, environment-friendly, and sustainable global development in multiple ways.

Globalization is defined as openness to the world, which leads to an increasing connectedness and interrelatedness; simultaneously, it means the willingness and awareness of states, cities, and people to participate in global interconnectedness (Figge and Martens, 2014; Caselli, 2008). Restrictive measures taken by countries in response to COVID-19 will influence global economic, social, and political impact in many ways. Thus, COVID-19 will profoundly affect the development of globalization. To quantify the effect of COVID-19 on globalization, Globalization Evaluation Indexes, which are usually Composite Indicators (CIs), will be used.

CIs have been widely used in evaluating the level of globalization. They can match the multidimensional features of globalization and make it easy for the public to benchmark countries' performance (Caselli and Marco, 2008). Many CIs have been developed to evaluate globalization with a wide range of applications, such as the A. T. Kearney-/Foreign Policy Globalization Index (ATK/FP), CSGR Globalization Index (CSGR), The KOF Index of Globalization (KOF), Maastricht Globalization Index (MGI). Those four CIs have been used for many years. However, they have not given sufficient attention to the environmental field. Research showed that environmental changes are essential in affecting the progress of globalization (Frank, 1997). Economic and social globalization promotes carbon emissions while increasing political globalization can reduce environmental pollution (Akif et al., 2018). A recent evaluation of CI has included three environmental indicators to emphasize that the environment is an essential dimension of globalization, an advantage over the other frameworks. In this index, parameters are selected based on the previous frameworks for evaluation, with equal emphasis on the environmental dimension (Jin et al., 2021). In this index, the theoretical framework, data selection, imputation of missing data, multivariate analysis, normalization, weighting, and aggregation processes have strictly followed the Handbook on Constructing Composite Indicators (OECD) guideline. Robustness and sensitivity analysis select the most suitable methods for each process (Jin et al., 2021). Compared to previous studies, this framework is a more comprehensive, standardized, and robust globalization evaluation system verified by the theoretical guidelines.

Previous studies on globalization are almost based on statistical data which has happened, but few of them focus on predicting the trend of globalization with the prediction model. There have been a lot of studies on the prediction of each indicator trend with mature predictive models. Statistical forecasting is the art and science of forecasting from historical data, with or without knowing in advance what equation should use. Time series, Statistical Regression, and Artificial intelligence (AI) models are the widely used forecasting approaches in practice. Time series models have been used in forecasting global financial cycles, telecommunications, and ICT (Meade and Islam, 2015; Raheem, 2020). AI models were used to predict high crime-risk transportation areas and air pollution (Masood and Ahmad, 2021; Kouziokas, 2017). As globalization includes multiple indicators in various fields, statistical forecasting can be applied to predict the trend of each indicator separately, and all the predicted trends can support the prediction of globalization as a whole.

However, all the statistics-based forecasting methods mentioned above assume nothing unexpected has happened. The impact of the COVID-19 outbreak will change the dynamics of globalization. In case of unforeseen interruptions like the COVID-19 outbreak, judgmental forecasting is a powerful method to estimate the trend of each indicator. Judgmental forecasting aims at incorporating experts' knowledge into a

Table 1
Framework of the globalization composite indicator.

Dimensions	NO.	Indicators	Unit
Economic	1	Trade	Per GDP, %
	2	Foreign direct investment (FDI)	Per GDP, %
	3	Net income from abroad	Per GDP, %
Social & Culture	4	International telephone traffic	Mins per capita
	5	International Internet bandwidth	Mbit/s per capita
	6	Cultural goods	Per goods value, %
	7	International migrant stock	Per capita, %
	8	International tourism	Per capita, %
	9	International student populations	Per student in the country, %
Political	10	Memberships in international organizations	Absolute number
	11	Contributions to U.N. peacekeeping missions	Per GDP, %
	12	Embassies	Absolute number
Environmental	13	Biocapacity deficit/reserve	gha per capita
	14	Ratification of Multilateral Environmental Agreements	Absolute value
	15	Ozone-depleting substances (ODS) Consumption	Tones

predicting context (Liu et al., 2021). Today, judgment is an indispensable component of forecasting, and much research attention has been directed at understanding and improving its use. Human judgment can be demonstrated to significantly benefit forecasting accuracy (Lawrence et al., 2006). Song et al. combined the use of both judgmental forecasting and scenario writing. They defend that scenarios benefit from incorporating different relevant variables' values under uncertainty (Song et al., 2008). Scenarios offer an attractive alternative to the false precision promised by point estimate forecasts. We can write a plan for influenced indicators rather than calculate it and believe that this is softer; the qualitative character of scenarios is more in keeping with the messy future encountered in real-world forecasting—especially of crisis management, on which data are few and uncertainty is rife (Pearson and Clair, 1998; Schnaars and Ziamou, 2010).

Globalization prediction is vital, especially in COVID-19; it supports government decisions. The current COVID-19 crisis is characterized by a high degree of uncertainty. Given that the response to COVID-19 has focused on restricting human movement, the extent to which these measures have affected globalisation's different dimensions (Economic, Social & Culture, Political and Environmental) is varied. So, there is a need to predict how globalization will evolve, the trend with and without COVID-19, and the impact extent to different countries. The comparative results can help the government take precise and more targeted measures in advance of the most serious fields and indicators. Long-term policy recommendations are needed to address pandemics, and their interrelated crises and foster sustained growth (Gatto et al., 2022).

This paper aims to forecast the impact of COVID-19 on globalization in the coming five years by covering Economic, Social & Cultural, Political and Environmental indicators. The impact of COVID-19 in the selected 14 countries is evaluated to observe the different effects among countries. In this paper, Section 2 (the methodological framework) describes the two-step molding strategy, Section 3 presents some forecasting results, and Section 4 discusses and implements relative topics.

2. Methods

The framework adopted in this study is the Globalization Composite Indicator built previously by Jin et al. (2021), as this framework is developed strictly according to the Handbook on Constructing Composite Indicators (OECD) guideline, and it has also included environmental aspects of globalization. The general structure is shown in Table 1. The data selection, imputation of missing data, multivariate

Table 2

Seven alternative forecasting methods for baseline.

Type	No.	Method	Abb.	Formula
Time series	1	Simple average	SA	$X_{n+1} = \frac{\sum_i^n X_i}{n}$
	2	Weighted average	WA	$X_{n+1} = \sum_i^n X_i \bullet W_i, \sum_i^n W_i = 1$
	3	Moving average	MA	$X_{n+1} = \frac{\sum_{i=0}^{t-1} X_{n-i}}{t}$
	4	Weighted moving average	WMA	$X_{n+1} = \frac{\sum_{i=0}^{t-1} X_{n-i} \bullet W_{n-i}}{t}, \sum_{i=0}^{t-1} W_{n-i} = 1$
	5	Second exponential smoothing	SES	$S_n^{(1)} = aX_n + (1-a)S_{n-1}^{(1)}$ $S_{n+1}^{(2)} = S_n^{(1)} + (1-a)S_{n-1}^{(2)}$ $X_{n+T} = a_n + b_n \bullet T$ $a_n = 2S_n^{(1)} - S_n^2$ $b_n = \frac{a}{1-a} (S_n^{(1)} - S_n^{(2)})$
Statistical Regression	6	Liner regression	LR	$E(Y_i X_i = x_i) = \alpha + \beta x_i$
	7	Polynomial regression	PR	$Y = a_n x^n + a_{n-1} x^{n-1} + \dots + a_1 x + a_0$

analysis, normalization, weighting, and aggregation processes strictly follow the Handbook on Constructing Composite Indicators (OECD) guideline introduced by Jin et al. Robustness and sensitivity analysis are used to select the most suitable methods for each process (Jin et al., 2021).

To quantitatively forecast the influence of COVID-19 on globalization, the methods are structured in two stages. In Stage I, the best forecasting practices of each indicator are identified, and the globalization trend without COVID-19 is predicted as the basis value. In Stage II, the scenarios with COVID-19 influences are predicted at different levels to obtain the impact of globalization.

2.1. Stage I

2.1.1. Select alternate prediction models

Time series, Statistical Regression, and Artificial intelligence (AI) models are considered in this study to identify the optimal prediction method for each indicator.

Time series is a random variable set of observations ordered in time. The simple average (SA), Moving average, and Simple exponential smoothing are the most basic frequently used time series models. The simple average assumes that the best predictor of what will happen tomorrow is the average of everything that has happened up until now

(Nau, 2014). SA puts equal weights on the past years, which means the older years are as significant as the newer years in the future. Intuitively, the newer one should be more relevant than the older one for predicting what will happen next. Weighted average (WA) has been put forward, assigning higher weights to the newer years. It would make more sense to decrease the consequences on the older years gradually. Moving average gives another point of view, which takes an average of what has happened in some recent past year, while the former years will not be considered when predicting. Weighted moving average, just as WA, gave the highest weight to the newest past year. Simple exponential smoothing (SES) changed the ways are assigned based on WA. SES weights the past data in exponentially decreasingly is the most widely used time series model in business applications.

Statistical regression is the art and science of fitting lines to data patterns. A linear regression model allows us to find the relationship between the predictor variable (x) and the response or results variable (y). Linear regression allows the researcher to predict outcomes based on the relationship between X and Y in an equation (Prion and Haerling, 2020). Polynomial regression optimizes the linear model with higher dimensions, occurring for second and third-order multiple polynomial models (Gaffke and Heiligers, 1996).

AI models have been extensively used in many areas, such as engineering, economics, and psychology. This approach does not need

Table 3

Three scenarios for the influenced indicators.

Dimensions	Indicators	Scenario	2020	2021	2022	2023	2024	2025	Ref.
Economic	Trade	mild	-5%	0%	5%	3%	3%	3%	1
		medium	-15%	-5%	0%	1%	1%	1%	
		severe	-20%	-10%	-5%	0%	0%	0%	
	Foreign direct investment (FDI)	mild	-20%	-10%	0%	3%	3%	3%	2
		medium	-30%	-20%	-10%	0%	1%	1%	
		severe	-40%	-30%	-20%	-10%	-5%	0%	
Social& Culture	International telephone traffic	mild	20%	10%	5%	0%	-5%	-5%	3
		medium	30%	20%	8%	5%	1%	1%	
		severe	40%	30%	10%	5%	3%	3%	
	International Internet bandwidth	mild	30%	10%	0%	-5%	-5%	-5%	
		medium	40%	30%	15%	5%	0%	0%	
		severe	50%	30%	20%	10%	5%	0%	
	International tourism	mild	-50%	-30%	-10%	0%	3%	3%	4
		medium	-70%	-50%	-20%	-5%	0%	1%	
		severe	-90%	-70%	-30%	-10%	-5%	0%	
	International student populations	mild	-10%	-5%	0%	3%	3%	3%	5
		medium	-20%	-10%	-5%	0%	1%	1%	
		severe	-30%	-15%	-10%	-5%	0%	0%	
Environmental	Biocapacity deficit/reserve	mild	5%	0%	-5%	0%	-3%	-3%	6
		medium	10%	5%	0%	-1%	-1%	-1%	
		severe	15%	10%	5%	0%	0%	0%	

Note: 1. https://www.wto.org/english/res_e/statis_e/merch_trade_stat_e.htm. 2. Global foreign direct investment falls 49% in first half of 2020 | UNCTAD.3. <https://new.qq.com/rain/a/20200427A000AE00> 4. <https://www.unwto.org/impact-assessment-of-the-covid-19-outbreak-on-international-tourism>.5. <https://wenr.wes.org/2020/11/the-pandemic-drives-unprecedented-decline-in-international-students> 6. CALCULATING EARTH OVERTSHOOT DAY 2020: ESTIMATES POINT TO AUGUST 22ND.



Fig. 1. The countries selected in the study.

mathematical relationships between the system's variables or physical parameters. It can construct the relationships between the inputs and the outputs through the training-testing and validation process; However, there should be a lot of data to support the training-testing and validation processes (Pallathadka et al., 2021). Due to the limited data, AI models have not been chosen in this research.

Based on the analyses of each of the above models, we selected seven alternative prediction models (Table 2).

2.1.2. Determine the prediction model for each indicator

Globalization index consists of 15 indicators from four dimensions, the optimal forecasting methods of different dimensions are different, even more, are different for each indicator in the same dimension. Thus, seven methods are tested for each indicator. Global average data from 2004 to 2013 was put into seven strategies accordingly; predicted 2014 to 2017 are compared to the actual value by measuring the MAPE value. Mean absolute percentage error has been widely used as a performance measure in forecasting. One of the primary reasons for its popularity is that it is easy to interpret and understand (Lam et al., 2001). The formula is:

$$MAPE = \frac{100\%}{n} \sum_{i=1}^n \left| \frac{y'_i - y_i}{y_i} \right|$$

Where, n is the total number of data, y_i is the real value of data i, y'_i is the predicted value of data i. The formula calculates the MAPE value of 7

methods; the minor MAPE value method is considered the optical method to forecast the data from 2018 to 2025. Visual methods are chosen for 13 indicators with the above processes.

The other two indicators are specially handled. International migrant stock (Indicator 7) data are identical for every five years, so the data for 2017–2020 are the same as 2016; data for 2021 is considered as the average of 2016, 2011, and 2006. The data for 2022–2025 are the same as 2021. The embassy number (Indicator 12) is invariant during 2004–2016; for 2017–2025, we assume the value does not change.

2.1.3. Forecasting global level trend without COVID-19

After each indicator's forecast value, 2018–2025, is calculated, Equal Weights of indicators and Linear additive Aggregation processes will be taken following the index framework. The globalization score is obtained to predict the global level trend without COVID-19.

2.2. The strategy of the SII

In the second Stage (SII), a scenario-based judgmental forecasting method is adopted, and indicators potentially affected by the COVID-19 pandemic are identified. Three scenarios (mild, medium, and severe) for 2020–2025 of each influenced indicator are determined (Table 3).

International tourism and international student populations will absolutes seriously impacted. International telephone traffic and International Internet bandwidth will rise due to daily work and life needs. Trade and Foreign direct investment (FDI) will decrease because of the

Table 4
Basic information of the selected countries.

NO.	Country Name	Region/Union	Globalization Rank of 2016	Total cases	Total cases/1 M pop	National surface area (sq. km)	Global ranking of per capita GDP/2015 year
1	Luxembourg	OECD, EU	1	77,189	120,926	2590	4
2	Switzerland	OECD	3	823,074	94,266	41,290.39	5
3	United Kingdom	OECD, EU	4	7,400,739	108,327	243,610	30
4	Australia	OECD, APEC	19	85,648	3312	7,741,220	19
5	Qatar	MENA	22	235,386	83,833	11,490	13
6	United States	OECD, APEC	28	42,866,805	128,591	9,831,510	12
7	Russian Federation	E. Europe & C. Asia, APEC	32	7,274,928	49,825	17,098,250	101
8	Gabon	Africa	49	27,643	12,075	267,670	108
9	Japan	OECD, APEC	53	1,673,144	13,278	377,974	33
10	Brazil	LAC	87	21,230,325	99,026	8,515,770	100
11	India	East & South Asia	88	33,448,163	23,952	3,287,259	197
12	China	East & South Asia, APEC	90	95,689	66	9,600,012.9	105
13	Togo	Africa	117	24,519	2880	56,790	233
14	Egypt, Arab Rep.	MENA	124	296,276	2831	1,001,450	167

Table 5
The MAPE value of 7 predicting methods for each indicator.

No.	Indicators	CA	WCA	MA	WMA	SES	LR	PR
1	Trade	1.92	2.60	4.42	4.36	0.73	3.86	0.81
2	Foreign direct investment (FDI)	34.08	26.76	14.51	12.62	8.22	11.58	11.81
3	Net income from abroad	8.14	7.00	10.50	11.09	12.46	20.40	27.51
4	International telephone traffic	14.58	10.04	3.25	2.32	1.59	1.31	15.58
5	International Internet bandwidth	42.52	33.81	20.15	15.39	8.94	12.59	18.39
6	Cultural goods	19.17	15.77	7.72	9.88	16.22	7.12	5.88
7	International migrant stock	—	—	—	—	—	—	—
8	International tourism	10.05	5.34	2.74	3.06	3.69	11.08	18.45
9	International student populations	15.98	12.40	10.10	10.08	10.10	9.11	9.61
10	Memberships in international organizations	2.77	2.12	1.29	1.10	1.21	0.94	0.82
11	Contributions to U.N. peacekeeping missions	3.17	2.09	1.08	0.84	0.80	4.71	0.89
12	Embassies	—	—	—	—	—	—	—
13	Biocapacity deficit/reserve	4.77	4.20	3.77	3.10	1.63	1.22	9.80
14	Ratification of Multilateral Environmental Agreements	9.34	8.26	6.74	5.84	3.90	7.69	2.69
15	Ozone-depleting substances (ODS) Consumption	14.99	14.05	12.74	11.69	11.45	10.87	17.32

depressed market and the restriction of economic activity (Long and Ren, 2022). For the political indicators that do not seem to be affected very much, Biocapacity deficit/reserve is the only indicator that may be influenced (Cheval et al., 2020).

Seven indicators are affected by the COVID-19 pandemic, and each indicator has three scenarios. 2187 (3^7) scenarios are investigated, and the variation range of globalization trends is presented.

Those seven affected indicators in 2018 and 2019 use the same data as the precited value without COVID-19. The value of the other eight not influenced indicators in 2018–2025 adopt the same data as predicted in the SI. After obtaining yearly data for each indicator, the subsequent globalization evaluation processes (Weighting and Aggregation) are the same as those applied in the SI. By comparing the influenced globalization value and background value, the COVID-19 affection on globalization will be assessed.

2.3. Selection of typical countries

The impact of COVID-19 on globalization will undoubtedly be different in different countries because of the degree of globalization and the severity of the COVID-19 pandemic (Fig. 1, Table 4). We consider the following factors when selecting specific countries for more careful consideration.

Several criterions had been considered when selecting the objects:

1. Total cases and Total cases/1M pop are key indicators to evaluate the seriousness of COVID-19 infection. This paper covers the maximum interval range as much as possible to ensure that the selected samples are representative.

2. The initial level of globalization is different; this is based on the assumption that the impact of COVID-19 will vary depending on the level of globalization.
3. Locations; different continents may have different traffic control factors.
4. National territorial area and degree of economic development are considered, at the same time, covering different international cooperation organizations: OECD, MENA, APEC, LCA, Africa and East & South Asia.

Last updated: September 19, 2021, 09:11 GMT from <https://www.worldometers.info/coronavirus/#news>. <https://data.worldbank.org.cn/>

The global average value is calculated following the SI and SII to evaluate the global trend without COVID-19. Then, the selected countries' globalization trends under the COVID-19 scenarios were calculated following the same methods. Subsequently, the impact of COVID-19 on the globalization of the 14 selected countries is assessed by comparing the change between baseline (without COVID-19), and 2187 (3^7) impacted scenarios. The 2187 (3^7) impacted scenarios presented in the result pictures (Figs. 4 and 6) by a color probability distribution.

3. Results

3.1. Determining the most reliable predicting method for each indicator

As the indicators belong to different fields and vary in magnitudes and trends, the most accurate prediction method may differ among indicators. In the present study, the most reliable methods are selected among the seven methods based on the MAPE value.

As shown in Table 5, the green-marked MAPE values are the smallest

Table 6

The annual change rate of every indicator.

Dimensions	Indicator	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Economic	1	2.93	1.96	0.99	0.02	-0.95	-1.92	-2.89	-3.86	-4.83	-5.80	-6.77	-7.74	-8.71	-9.69
	2	-2.03	-3.74	-5.45	-7.16	-8.87	-10.58	-12.29	-14.00	-15.71	-17.42	-19.12	-20.83	-22.54	-24.25
	3	3.61	2.79	2.73	1.98	1.26	0.72	0.75	0.82	1.14	1.79	1.30	1.53	1.61	1.54
Social & Culture	4	1.60	3.78	5.97	8.15	10.33	12.52	14.70	16.89	19.07	21.25	23.44	25.62	27.81	29.99
	5	-1.19	-2.10	-3.01	-3.92	-4.83	-5.74	-6.65	-7.56	-8.47	-9.38	-10.29	-11.20	-12.11	-13.02
	6	-12.40	-17.25	-22.45	-27.99	-33.88	-40.11	-46.68	-53.59	-60.85	-68.45	-76.40	-84.69	-93.32	-102.30
	7	0.00	0.00	0.00	0.00	9.17	9.17	9.17	9.17	9.17	9.17	8.22	8.22	8.22	8.22
	8	1.17	0.81	0.66	0.88	0.78	0.77	0.81	0.79	0.79	0.80	0.79	0.79	0.80	0.79
	9	-9.63	-7.31	-4.99	-2.67	-0.35	1.98	4.30	6.62	8.94	11.26	13.58	15.91	18.23	20.55
Political	10	0.48	1.12	1.79	2.49	3.22	3.98	4.77	5.59	6.45	7.33	8.24	9.19	10.16	11.17
	11	0.17	0.32	0.46	0.61	0.75	0.90	1.04	1.19	1.33	1.48	1.62	1.77	1.91	2.06
	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Environmental	13	-0.18	0.62	1.42	2.22	3.02	3.82	4.62	5.42	6.22	7.02	7.82	8.62	9.42	10.22
	14	-6.69	-10.53	-14.77	-19.41	-24.44	-29.86	-35.68	-41.89	-48.50	-55.50	-62.90	-70.69	-78.88	-87.46
	15	10.31	8.46	6.61	4.75	2.90	1.05	-0.80	-2.65	-4.51	-6.36	-8.21	-10.06	-11.91	-13.76

Note: 1.Trade, 2.Foreign direct investment (FDI), 3.Net income from abroad, 4.International telephone traffic
 5.International Internet bandwidth, 6.Cultural goods, 7.International migrant stock, 8.International tourism,
 9.International student populations, 10.Memberships in international organizations, 11.Contributions to U.N.
 peacekeeping missions, 12.Embassies, 13.Biocapacity deficit/reserve, 14.Ratification of Multilateral
 Environmental Agreements, 15.Ozone-depleting substances (ODS) Consumption

among the seven proposed predicting methods, and the corresponding methods are the most accurate for each indicator. The predicting method was found to vary across indicators, even for the indicators in the same dimension. Statistical regression methods (LR and PR) seem superior to time series methods (SA, WA, MA, WMA, and SES), which fit seven indicators. SES and LR accurately predicted four indicators. PR is the best option for three indicators. At the same time, SA and WMA did not find it suitable to predict any indicator.

Regarding prediction accuracy, the indicators in the political field are relatively stable (Table 6). Social & cultural fields have an extensive range of more unpredictable variations. Therefore, the accuracy of the seven methods is relatively low. International Internet bandwidth and International Student Populations can be predicted with SES and LR, respectively, with MAPE values of 8.94 and 9.11. Ozone-depleting substances (ODS) Consumption seems to be very difficult to predict; the results obtained by the seven forecasting methods do not match the actual data very well; Linear regression (LR) received relatively accurate

forecasting results (MAPE value of 10.87).

International migrant stock and Embassies are indicators that require exceptional forecasting due to the lack of annual data. Global migrant stock, which uses the same value for five years, data from 2017 to 2020 use the data of 2016. Data for 2021 is the average of 2016, 2011, and 2006. 2022–2025 uses the data of 2021. Similarly, the data for 2026 is the average of 2021, 2016, and 2011. 2027–2030 uses the data of 2026. Embassies, whose value is stable during 2004–2016, assume that they do not change until 2030.

Hitherto, the methods for indicators are determined. Subsequently, the value predicted with each indicator's most reliable predicting method is applied in the globalization framework developed previously (Jin et al., 2021), and the globalization trends during 2018–2030 are presented in the next section.

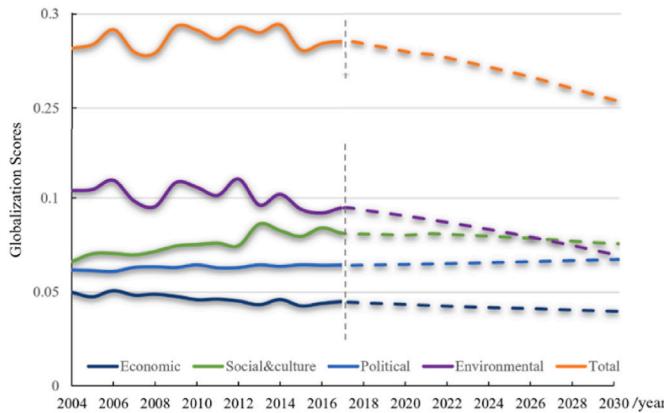


Fig. 2. The overall world average globalization trend without COVID-19 (orange), plotted together with the globalization trend in the four dimensions. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

3.2. How would globalization evolve without COVID-19?

3.2.1. The overall trend without COVID-19

The world average globalization trend without a COVID-19 break is shown in Fig. 2. According to our model, the world average's globalization level will decrease by 10.95% from 2017 to 2030, in which the environmental dimension contributed significantly to the overall decrease (Contribution rate 78.56%). Ratification of the Multilateral Environmental Agreement (Indicator 14) and Decrease of Ozone-depleting substances (ODS) Consumption indicator (Indicator 15) dominated the decrease in environmental dimensions. It is predicted that more countries will quit environmental protection agreements. Moreover, it is expected that the decrease in ODS discharge will slow down and potentially exacerbate ozone layer damage.

The economic dimension also shows a minor downward trend, with a 10.82% of decrease from 2017 to 2030, as it is predicted that trade (Indicator 1) and Foreign direct investment (FDI, Indicator 2) will continuously decrease in the coming years, especially the Foreign direct investment will decrease significantly from 0.0077 in the year 2017 to 0.0059 in the year 2030. The trade is expected to increase initially from

2017 to 2020, but it will follow a decreasing trend from 2020 to 2030, with a score of 0.0231 in 2020 to 0.0202 in 2030. Regarding the Social & culture dimension, the scores keep relatively stable with a slightly slow downward trend. Nevertheless, the indicators in this dimension would follow different trends. In particular, it is predicted that International telephone traffic (Indicator 4) will increase dramatically over the years, with a change rate of 1.6% in 2017 to 29.99% in 2022, implying that virtual communication will play an important part in global communication. In addition, the number of International students (Indicator 9) is expected to decrease initially from 2017 to 2021, and it will increase from 2022 and forward, with a strong growth trend change rate of 20.55% in 2030. In contrast, the Share of culture goods value among all goods value (Indicator 6) showed a magnificent decrease from 2017, and that would keep deteriorating over the years with a predicted change rate of -102.3% in 2030. The political dimension shows a slight increase in the coming years, mainly attributed to the increase in the memberships in international organizations, which means countries are predicted to participate in more international organizations to get extensive global relations and involvement.

3.2.2. Globalization trends across countries without COVID-19?

Although it is predicted that the globalization level of the global average will decline, the trend varies across countries. Among the fourteen representative countries studied in this work, six countries (Luxembourg, Switzerland, India, China, Togo, and Egypt) show a downtrend during the following years (Fig. 3a). Although the trend is similar for these countries, the reasons for the decline in globalization differ. Luxembourg shows an obvious downtrend but will still rank as the most globalized country of all. The score of Environmental indicators keeps decreasing is the main reason for the downtrend in Luxembourg and Egypt. Both countries showed a downward trend in indicators 14 and 15. The decline in globalization for Switzerland is due to the recession in the economic field, in particular, indicator 1. The indicators in the Social & Culture field (Indicator 6) dominated the decrease of globalization in India, and the case for Togo can be attributed equally between economic and environmental indicators (Indicators 1 and 15). The downturn reason for China is different from other countries. It is a Political downturn caused by reduced Membership in international organizations (Indicator 10). Fig. 3b presents the countries with a steady globalization status, which includes Australia, Qatar, the Russian

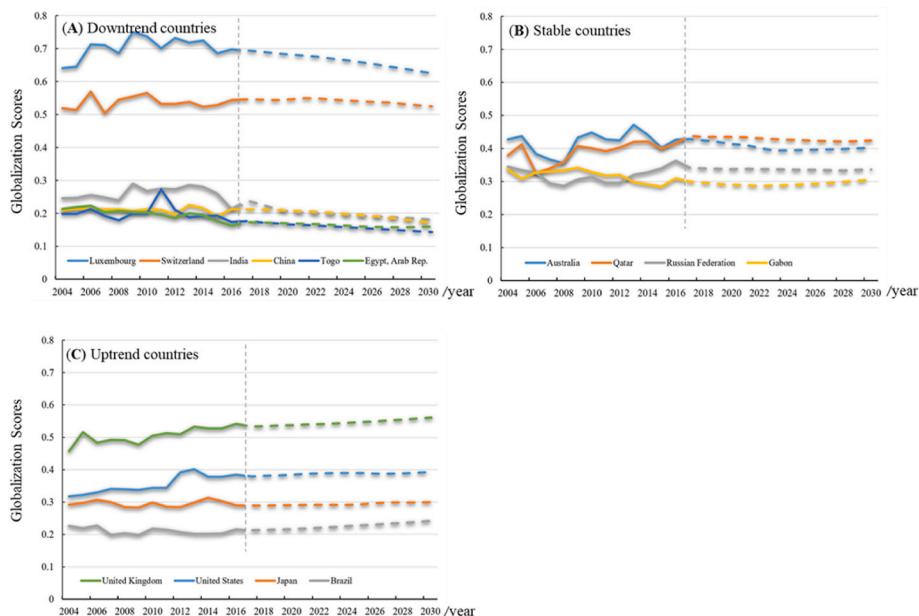


Fig. 3. The globalization trends of different countries without COVID-19.

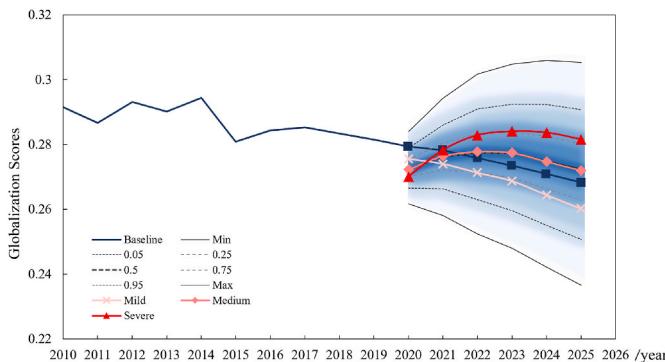


Fig. 4. The globalization trends under the impact of different COVID-19 scenarios.

Federation, and Gabon. United Kingdom, United States, Japan, and Brazil show an uptrend in the future without COVID-19 (Fig. 3c). The increase in the Social & Culture dimension (Indicators 6 and 9) promoted the United Kingdom's globalization, while environmental indicators drove the growth of the United States, Japan and Brazil (SI).

3.3. COVID-19 has larger possibilities for improving globalization

Globalization would range significantly under different COVID-19 scenarios, according to our prediction. The model showed that the globalization level was affected immediately by COVID-19 from 2020 under the mild, medium, and severe scenarios. The reason could be due to the immediate impact on global mobility of people by the COVID-19 lockdown; indicator 8 (International tourism) and indicator 9 (International student populations) dropped 70.06% and 21.9% from the year 2019–2020. International tourism and international student are plummeting due to different measurements of COVID-19 across countries. International Economic and FDI would also decrease for several reasons, such as border control measures and hesitation about economic trends. On the contrary, virtual global communication, such as international

telephone and surfing on the Internet, flourish to meet work and life needs. Information and communications technology (ICT) is critical to people's communication (Pan et al., 2022). That is a reason why there is a possibility that globalization would be better compared to the non-COVID-19 scenario in 2020.

Globalization will be retrieved to pre-affected levels by the end of 2022 under the medium and severe scenarios, subsequently surpass the non-COVID-19 scenario and reach the highest level by 2023. However, the model predicted that globalization would keep decreasing under mild scenarios (Fig. 4). Such contradicting results can be attributed to the recovery of environmental indicators compensated for the decrease in economic, social & culture dimensions under the medium and severe COVID-19 scenarios. While under the mild scenarios, the increase in environmental improvement is lower than the impact on other indicators.

Looking into a different dimension of indicators, the Economic field will severely affect (almost -50%) until 2025, and the influence will persist. The global business shock destroyed sustainable development (Song et al., 2022). With the mounting financial burden faced by all countries, including some developing countries, additional support is unlikely to be forthcoming in the near future (Barbier and Burgess, 2020). Developing countries must find innovative policy mechanisms to achieve sustainability and development aims cost-effectively. COVID-19 would cause an instant impact on the Social & Culture dimension, but there are larger possibilities that this impact could be lifted and even improve the level of globalization after 2022 (Fig. 5). In terms of the indicators in the Environmental dimension, the impact of COVID-19 is predicted to be positive in most cases for the reasons that Biocapacity increased. This indicator means the capacity of ecosystems to regenerate what people demand from those surfaces. With COVID-19, people's movement is restricted, pollutants produced by traffic are reduced, and the negative impact of human activities on the environment is reduced. Hence, the Biocapacity increased, which also means domestic environmental resources can meet the development needs in that area.

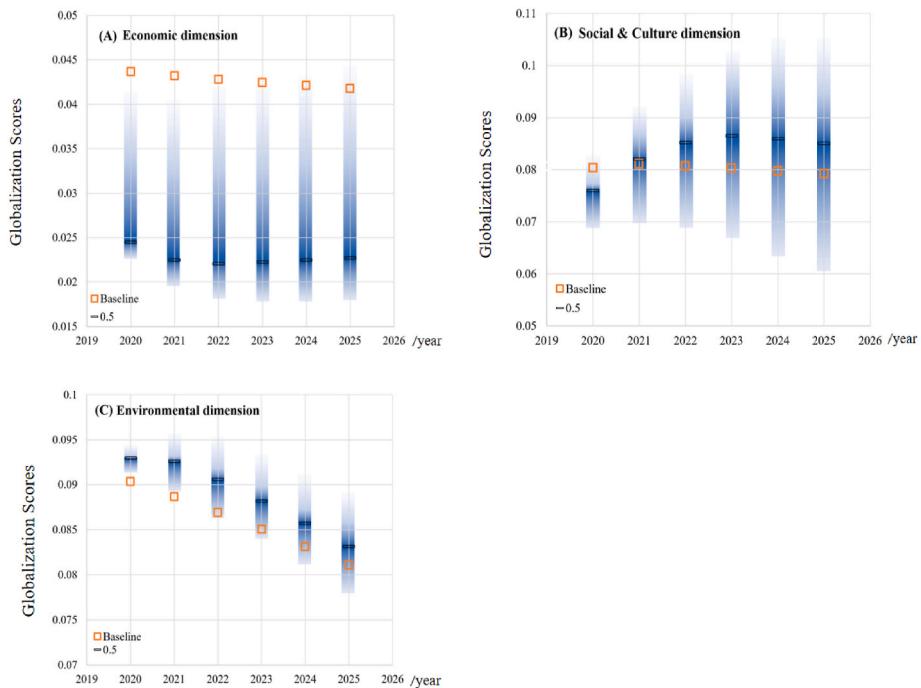


Fig. 5. The globalization trends of different dimensions with COVID-19 effect

Note: The Baseline means the situation without COVID-19, and the -0.5 situation means the median value under COVID-19 affection).

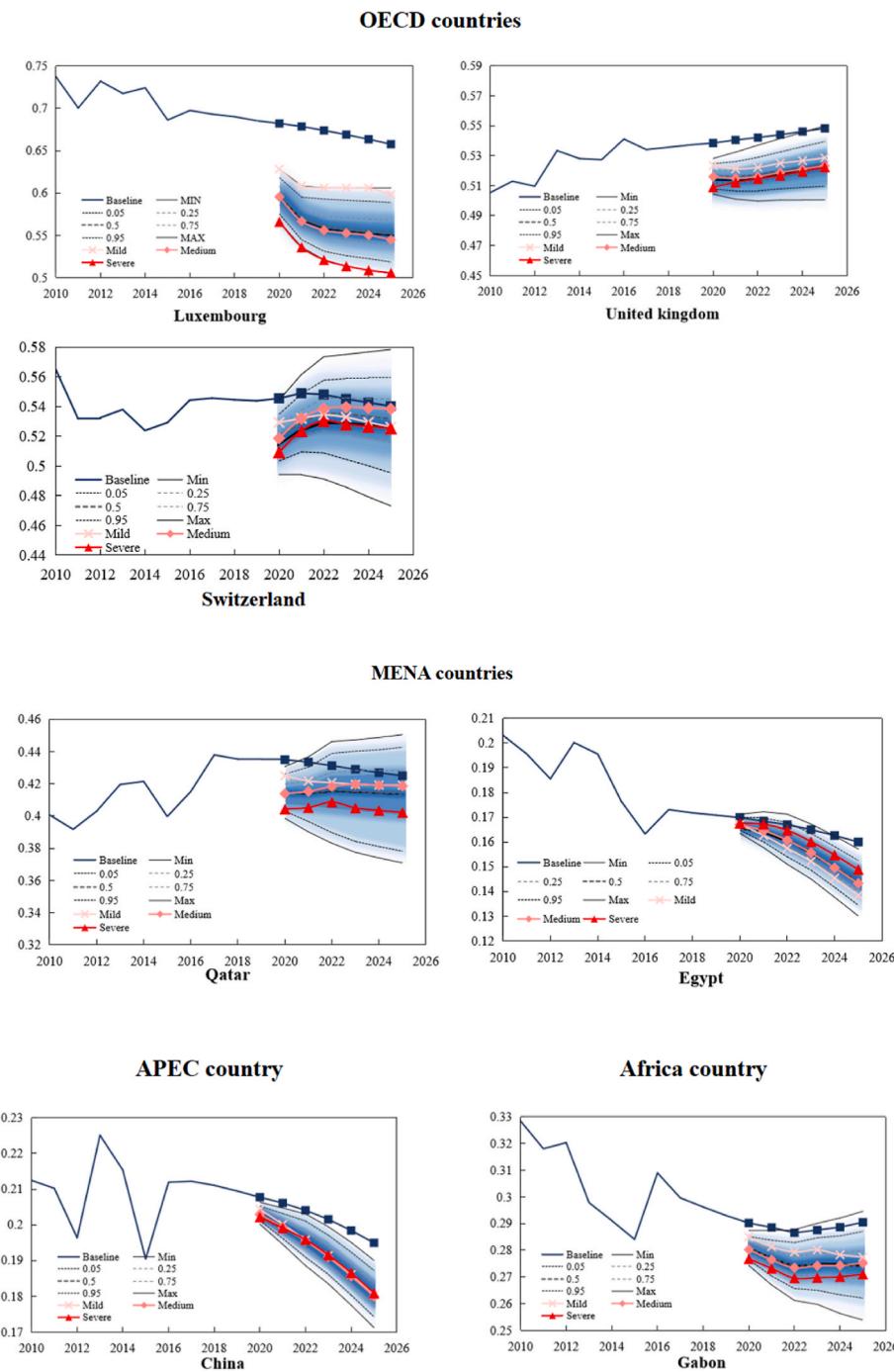


Fig. 6. The globalization trend of different countries negatively affected by COVID-19.

3.4. The impact of COVID-19 on globalization varies across countries

The impact of COVID-19 on globalization varies across countries. Our results demonstrated that the globalization level of seven countries would be immediately impacted by COVID-19 and negatively impacted by COVID-19 in the coming four years (Fig. 6). Among the seven countries, the globalization of Luxembourg, China, the United Kingdom, and Gabon are predicted to have a chance higher than 95% to be negatively impacted compared to the non-COVID scenario. Egypt is closely followed with more than 75% possibility of a decline in globalization compared to the non-COVID scenario. Switzerland and Qatar are predicted to have a more than 50% possibility but less than 75% possibility of facing a recession of globalization compared to the non-COVID

scenario. Among the seven globalization recession countries, the globalization of Luxembourg, China and Egypt is expected to continue to decrease over the next four years, while Switzerland has a large chance of recovery after 2022. The rest of the countries among the seven would face a drop in 2020 and keep a relatively steady status on globalization in the next four years under the COVID-19 scenario.

The chance that COVID-19 would positively affect the globalization of Australia, the United States, India, the Russian Federation and Brazil is larger than 75% (Fig. 7). While the impact of COVID-19 on Japan and Togo's globalization progress is uncertain as the chance of improving or decreasing globalization compared to the non-COVID-19 scenarios is equal (Fig. 7).

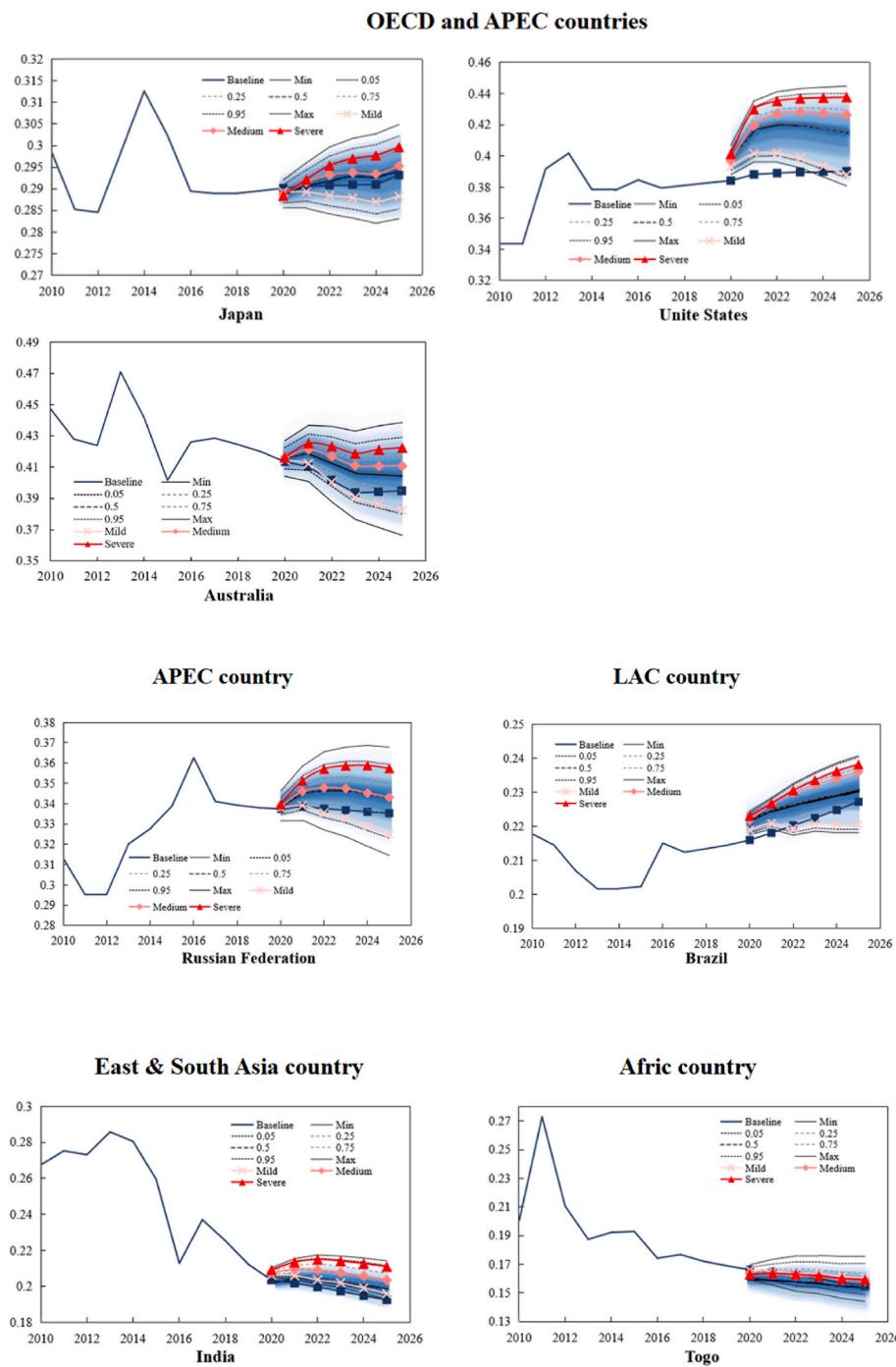


Fig. 7. The globalization trend of different countries positively influenced by COVID-19.

4. Discussions

COVID-19 has prevailed since the end of 2019, and it has impacted the economy, the social and culture, and many other aspects of the world. The present study predicted the trend of overall globalization from 2020 to 2025 with and without COVID-19 based on the globalization model proposed previously. The impact of COVID-19 on economic indicators, Social & Culture indicators, and environmental indicators is considered in the present study. Without COVID-19, the world average globalization level will decrease from 2017 to 2030 (-10.95%). Among the fourteen representative countries studied in this work, four countries showed an uptrend, four remained stable, and six showed a downtrend. The main reason is the decline of indicators in the

Environmental field, accompanied by declines in indicators in the economic, social & cultural fields. As the globalization evaluation always lags several years due to a lack of critical data, the present study provided a possibility to evaluate the potential impact of COVID-19 under different scenarios quantitatively. Furthermore, the prediction can help governmental authorities to better plan their strategies toward managing the impact of COVID-19 and reduce the potential impact on daily lives.

Our predicted results showed that the burden caused by COVID-19 on economic aspects is inevitably occurring worldwide. The disorders of global production networks and global supply chains generate massive unemployment (Shin, 2021). The drops in international trade, foreign direct investment, and net income from abroad are persistent

(Zhou et al., 2022) and could cause de-globalization in the post-COVID-19 decade due to the increased inequalities, protectionism, and weak binding of multilateral agreement (Ciravegna and Michailova, 2022). Meanwhile, COVID-19 also caused profound impacts and changes in the globalization of social & cultural aspects. The quarantine and travel restrictions have significantly reduced international travel and tourism. Food security issues result from disruptions in the global supply chain caused by border closures implemented to combat COVID-19 (Santeramo and Kang, 2022). Moreover, the international student population has dropped temporarily due to the COVID-19 measures. It is apparent how COVID-19 directly reduced physical movement and communication in various ways. Furthermore, these changes can pose a catastrophic impact on the economies that rely on tourism and education. Although physical communication has been limited across countries, digital communication is expected to be promoted (Schilirò, 2020). Communication via telephone and the Internet can help ease the psychological anxiety caused by COVID-19 (Yan et al., 2021). Studies showed that the prevalence of virtual communication is expected to persist even as COVID-19 measures are eased in the future (Schilirò, 2020). On the other hand, digital payments, especially mobile money, may support the business continuity of Micro and Small Enterprises (Bai et al., 2021).

Our result revealed that COVID-19 would positively impact the global environment, which agrees with many recent studies. The restriction imposed by the government, including travel restrictions, lockdowns, and quarantine requirements, could reduce the impact of human activities on the environment. For instance, it was found that PM_{2.5}, PM₁₀, NO₂, and CO levels reduced in most regions globally, and SO₂ and O₃ levels increased or did not show significant changes. Carbon emissions were reduced primarily due to travel restrictions and less usage of utilities, although emissions from certain ships did not change significantly to maintain the supply of essentials. Surface, coastal, and groundwater quality improved globally during the COVID-19 lockdown, except for a few reservoirs and coastal areas (Yang et al., 2022). By extension, at-risk ecosystems have been given the improved environmental quality. Some scholars have concluded that COVID-19 benefits the sustainable development of the global environment (Abubakar et al., 2021).

In line with other studies, our result revealed that the pandemic had caused an unprecedented burden on globalization through various ways, and it is undoubtfully that globalization would face recession over the next few years. Nevertheless, its impact is heterogeneously distributed across countries (Schilirò, 2020; Shrestha et al., 2020; Hameiri, 2021; Sforza and Marina, 2020). Compared to the predicted impact of COVID-19 with the great influenza of 1918–1920 on globalization, the predicted trend in this study is in line with the historical findings that the pandemic could interrupt globalization, but the actual impact on globalization would vary across countries (Siklos, 2022). The reason for such difference is that different indicators dominate the globalization of different countries. The main drivers for the increase in globalization in particular countries can be attributed to the fact that the environmental recovery and the flood of digital communication surpass the recession in economic and social & cultural aspects among these countries. Our results support the evaluation of the impact of COVID-19 on globalization on a country-by-country basis. Furthermore, our result revealed that the impact of COVID-19 on globalization has not been as severe as expected, and although it has declined, it can recover in many scenarios in the coming years. The Economic field will affect severely (almost –50%) by the COVID-19 eruption, but the Social & culture and Environmental fields will contribute positively to the overall picture. Local government should consider its own advantages and roles in the global value chain and network to minimize the impact of COVID-19.

5. Conclusion

The present study investigates the globalization trend with and

without COVID-19, emphasizing the impact of COVID-19 on economic, Social & Culture, and environmental indicators in fourteen countries. Our results demonstrated that globalization is declining under the scenario without COVID-19, with 10.95% from 2017 to 2030. Among the fourteen representative countries studied in this work, four countries showed an uptrend, four remained stable, and six showed a downtrend. The main reason is the decline of indicators in the Environmental field, accompanied by the decline of indicators in the Economic and Social & culture fields.

Our results showed that the impact of COVID-19 on globalization is not as severe as expected. The Economic field will affect severely (almost –50%) by COVID-19, but the Social & culture and Environmental fields will be promoted. The impact of COVID-19 on the degree of globalization varies from country to country. Among the countries investigated, COVID-19 positively impacts the globalization of Japan, Australia, the United States, the Russian Federation, Brazil, India and Togo. In contrast, the globalization in the United Kingdom, Switzerland, Qatar, Egypt, China and Gabon are expected to decrease. The variation of impact induced by COVID-19 on those countries is attributed to the weighting of economic, environmental and political aspects of globalization is different across these countries.

As the globalization evaluation always lags several years due to the lack of critical data, the present study provided a possibility to evaluate the potential impact of COVID-19 under different scenarios quantitatively. Furthermore, the prediction can help governmental authorities to better plan their strategies toward COVID-19 and reduce the potential impact on daily lives.

CRediT authorship contribution statement

Yi Zhang: Data collection, Writing – original draft. **Fangfang Sun:** Data collection, Methodology, Investigation. **Zhiqiu Huang:** Advising, Methodology, Revision. **Lan Song:** Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration. **Shufang Jin:** Formal analysis, Visualization, Writing – original draft. **Long Chen:** Formal analysis, Writing – original draft, Revision.

Declaration of competing interest

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

Data availability

Data will be made available on request.

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