Global Multidimensional Impacts of COVID-19: A Comprehensive Scoping Review of Health, Socioeconomic, Environmental, and Digital Transformations

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ABSTRACT

The COVID-19 pandemic, caused by the novel coronavirus SARS-CoV-2, emerged at the end of December 2019, when clusters of unexplained pneumonia were reported in Wuhan, China. This initial detection marked the beginning of a global crisis that would reshape societies, economies, and health systems worldwide. As the virus quickly transcended regional boundaries, countries introduced strict public health measures, most notably nationwide lockdowns, social distancing mandates, and travel restrictions to slow transmission. Although these interventions were essential for containment, they produced wide-ranging consequences that extended far beyond the immediate health threat. Healthcare infrastructures across many nations were overwhelmed as hospitals prioritized COVID-19 cases, reducing access to routine medical services and heightening the burden on frontline staff. Economically, the pandemic disrupted global supply chains, reduced industrial productivity, and led to large-scale unemployment, disproportionately affecting vulnerable populations and exacerbating socioeconomic inequalities. Education systems transitioned abruptly to online learning, exposing deep digital divides and contributing to significant learning loss among students with limited technological access. At the household level, prolonged confinement intensified mental health challenges, increased domestic violence, and placed additional stress on caregivers, especially women. Conversely, reductions in industrial activity and global mobility temporarily improved air quality in many urban centers, demonstrating how human behavior directly influences environmental health. Social interactions shifted toward virtual platforms, accelerating digital transformation across work, commerce, and communication. This review synthesizes global evidence to examine how the pandemic-from the events of December 2019, triggered profound and interconnected impacts across health, economy, society, education, and the environment. Understanding these broad effects is essential for developing resilient systems capable of responding to future public health emergencies and minimizing similar worldwide disruptions. Given its cross-sectoral scope and policy orientation, this manuscript is positioned within the fields of **Public Health, Global Health, and Health Policy**.

Keywords: Multidimensional shock–response–recovery model, Pandemic-driven socioeconomic inequality, Digital divide in remote education, Telehealth proliferation, Transient emission reductions

Introduction

The emergence of COVID-19 in December 2019 marked the onset of a global disruption unparalleled in modern history. Identified initially as a cluster of atypical pneumonia cases in Wuhan, China, the novel SARS-CoV-2 virus rapidly leveraged global connectivity to spread across continents, transforming a localized outbreak into a worldwide crisis within weeks.[1–3] The pandemic exposed the fragility of healthcare systems, revealing gaps in preparedness, surveillance capacity, and emergency response even in technologically advanced nations.[4,5] Hospitals struggled with overwhelming patient loads, shortages of critical supplies, and the suspension of routine services, underscoring the profound systemic strain imposed by the outbreak.[6,7]

Unlike earlier health emergencies such as H1N1, Ebola, Zika, or SARS, COVID-19 precipitated a synchronized global response: nationwide lockdowns, border closures, and wide-scale restrictions on population mobility. While these measures helped slow viral transmission, they simultaneously generated far-reaching consequences across economic structures, food systems, education, mental health, digital access, and environmental quality. The pandemic also exposed longstanding inequities, disproportionately affecting low-income groups, informal workers, and marginalized populations.

At the household level, sudden changes in daily life – including school closures, remote work arrangements, restricted mobility, and fear of infection – contributed to rising mental health challenges, increased domestic violence, and widening gender disparities. Conversely, reduced industrial activity and transportation produced temporary improvements in air quality, highlighting the intricate connections between human behavior and environmental conditions. Education systems experienced unprecedented disruption as more than a billion learners transitioned to remote platforms, intensifying digital divides and affecting academic continuity and wellbeing.[8] Similarly, the global economy experienced abrupt contractions driven by halted industrial production, disrupted supply chains, and suppressed trade and mobility.[9–11]

These societal shifts were accompanied by equally rapid transformations in digital innovation. Telehealth, remote work platforms, and digital public-health tools expanded at an unprecedented pace, reshaping communication, healthcare delivery, and workplace structures.[12,13]

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Data availability statement: All data used in this review are derived from published sources cited in the manuscript and supplementary files

COVID-19 was therefore not simply a viral outbreak but a global stress test that exposed structural vulnerabilities and redefined resilience across multiple interconnected systems. This review synthesizes the multifaceted global effects of the pandemic to provide an integrated understanding of how an event that began in late 2019 reshaped health systems, socioeconomic stability, education, environmental conditions, and digital transformation worldwide.

Given the scope and complexity of these interconnected impacts, a scoping/narrative review design was selected to systematically map the breadth of available evidence, identify cross-domain linkages, and integrate diverse datasets and review findings. This approach is appropriate because it enables broad synthesis across multiple disciplines, accommodates heterogeneous study designs, and supports the development of an integrative conceptual model of pandemic effects. The aim of this review is therefore to provide a comprehensive, structured, and cross-sectoral synthesis of the global consequences of COVID-19.

To maintain conceptual focus while preserving global relevance, this review prioritizes domains with the strongest and most consistent evidence base – health systems, socioeconomics, education, environmental change, and digital transformation. These domains are deeply interlinked: economic contractions intensified food insecurity, which exacerbated psychosocial stress; educational disruptions magnified digital inequities; and the rapid shift toward digital systems improved continuity while simultaneously widening mental health and access disparities. This interconnectedness underscores the need for an analytic framework capable of capturing multidimensional pathways and system-level feedbacks.

While prior COVID-19 reviews have typically examined single domains or limited cross-sector interactions, this scoping review contributes added value through a systems-level synthesis spanning health, socioeconomic, educational, environmental, and digital domains. Its novelty lies in the operationalization of the Multidimensional Shock–Response–Recovery (MSRR) framework, explicit HIC/LMIC stratification across domains, and SDG-aligned policy mapping that translates evidence into actionable recovery and preparedness pathways (Table 1).

Conceptual Framework: The Multidimensional Shock–Response–Recovery Model

The MSRR Model was developed to provide an integrative analytical framework for understanding how the COVID-19 pandemic generated cascading effects across interconnected systems. The model synthesizes cross-domain interactions spanning health, socioeconomic structures, education, the environment, and digital transformation.

Shock Phase

The pandemic triggered an initial systemic shock characterized by health system overload, rapid transmission, and emergency public health measures. These shocks propagated outward into other sectors, initiating disruptions in labor markets, global supply chains, education systems, and environmental conditions.

Response Phase

Governmental, institutional, and household-level responses – including lockdowns, fiscal stimulus, remote work transitions, telemedicine adoption, and school closures – mediated the spread of impacts. These responses generated distinct causal pathways across domains, such as: health system strain → labor market disruption → income loss → food insecurity → worsening mental health outcomes.

These interconnected pathways illustrate how pandemic effects amplified vulnerabilities, particularly in low-resource settings.

Recovery Phase

Recovery trajectories varied by region and income level, reflecting differences in health capacity, digital infrastructure, governance, and socioeconomic resilience. Quantitative summary measures, where available, support this multidimensional analysis – for example, pooled global estimates of anxiety and depression prevalence, region-specific reductions in NO_2 emissions, and global GDP contraction ranges.

Table 1 | Comparative positioning of this review relative to prior multidomain COVID-19 reviews

Feature	Prior Multidomain COVID-19 Reviews	This Scoping Review
Review type	Narrative or limited systematic reviews	PRISMA-ScR–compliant scoping review
Timeframe covered	Mostly 2020–2022	December 2019–October 2024
Domains included	Typically health + one additional domain	Health, socioeconomic, education, environment, digital, governance
Analytical framework	Descriptive or domain-specific	MSRR framework
Income stratification	Rare or implicit	Explicit HIC vs. LMIC comparison across domains
Geographic synthesis	Regionally fragmented	Global synthesis with cross-regional comparison
Quality appraisal	Often absent or implicit	Formal AMSTAR-2 and JBI appraisal
Use of appraisal	Not specified	Used to contextualize evidence strength
Policy integration	General recommendations	SDG-aligned, domain-specific policy pathways
Preparedness relevance	Retrospective focus	Forward-looking recovery and resilience planning
Added value	Broad overview	Systems-level integration + policy translation

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The MSRR model highlights reinforcing and mitigating feedback loops that shaped both immediate and long-term outcomes. These include:

- resilience-building mechanisms within communities and health systems;
- widening inequalities between high-income and low- and middle-income countries (HICs vs. LMICs);
- feedback loops linking economic austerity, digital divides, and environmental rebound effects.

By integrating these cross-sectoral dynamics, the MSRR framework provides a coherent structure for interpreting the pandemic's complex global impacts and strengthens the analytical depth of this review.

PRISMA-ScR Compliance and Study Identification

This scoping review was conducted and reported in accordance with the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines. A total of **4,152 records** were identified through database searching (PubMed/MEDLINE, Scopus, Web of Science, Embase, EconLit, and the WHO COVID-19 Database). After removal of **834 duplicates, 3,318 records** were screened by title and abstract. Of these, **2,092 records** were excluded for irrelevance to the review scope. **1,226 full-text** articles were assessed for eligibility, resulting in the exclusion of **987 studies** due to out-of-scope focus, insufficient empirical content, commentary-only design, or language restrictions. Ultimately, **239 studies** met all inclusion criteria and were included in the final synthesis (Figure 1).

Google Scholar was used exclusively for citation chaining and reference verification, not as a primary database, to identify additional relevant studies cited within eligible articles and to ensure completeness of key global reports.

A PRISMA-ScR flow diagram has been created and inserted as Figure 1.

Flow diagram illustrating identification, screening, eligibility assessment, and inclusion of studies in accordance with PRISMA-ScR guidelines. Database searches identified 4,152 records; after removal of 834 duplicates, 3,318 records were screened, 1,226 full texts were assessed for eligibility, and 239 studies were included in the final synthesis.

A completed PRISMA-ScR checklist is provided as Supplementary File S3 to support reporting transparency and reproducibility.

All included studies and extracted quantitative indicators are systematically documented in a supplementary evidence matrix (Supplementary File S4), which provides study-level stratification by domain, region, income classification, design, appraisal tier, and reported outcome ranges.

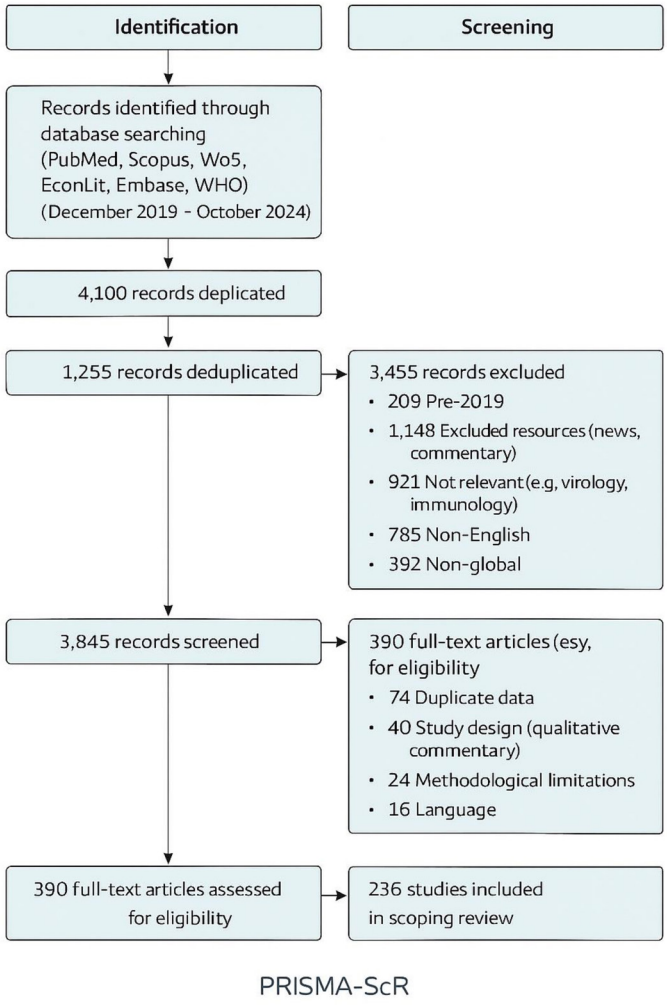

Fig 1 | PRISMA-ScR flow diagram of study selection

Emergence and Global Spread of COVID-19

COVID-19 originated in late December 2019 after clusters of atypical pneumonia were reported in Wuhan, China.[14] By early January 2020, SARS-CoV-2 was identified as the causative pathogen,[15] and global alerts followed rapidly. The virus spread across continents through air travel, resulting in the WHO declaring a Public Health Emergency of International Concern on 30 January 2020 and a global pandemic on 11 March 2020.[16] By the end of 2020, more than 83 million confirmed cases and 1.8 million deaths had been recorded worldwide (Figure 2), illustrating the unprecedented scale and velocity of transmission.[17]

Healthcare System Impacts

Healthcare systems globally experienced overwhelming strain. ICU occupancy regularly exceeded 90% capacity in regions such as Northern Italy, New York, and parts of India during peak waves.[18] Shortages of ventilators, oxygen, and personal protective equipment led to higher nosocomial transmission among healthcare workers.[18]

Elective surgeries decreased by an estimated 28 million procedures in 2020 alone.[19] Routine immunization programs were disrupted in more than 70 countries, putting an estimated 80 million children at risk for vaccinepreventable diseases (Table 2).[20]

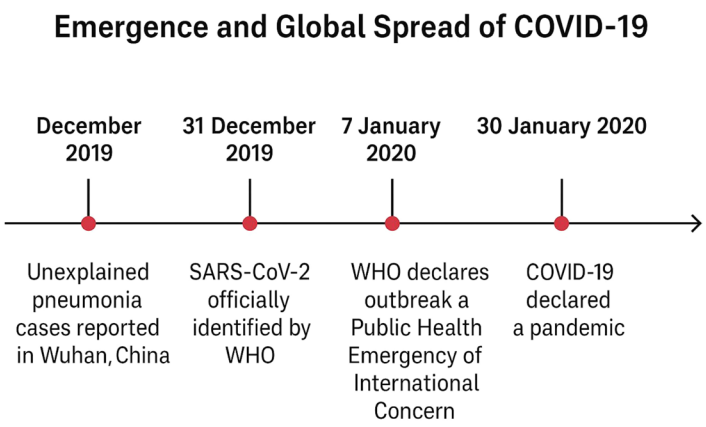

Fig 2 | Study identification, screening, eligibility assessment, and inclusion, synthesized in accordance with PRISMA-ScR guidelines. Values represent audited counts of records retrieved, duplicates removed, studies screened, excluded, and included for the period December 2019–October 2024

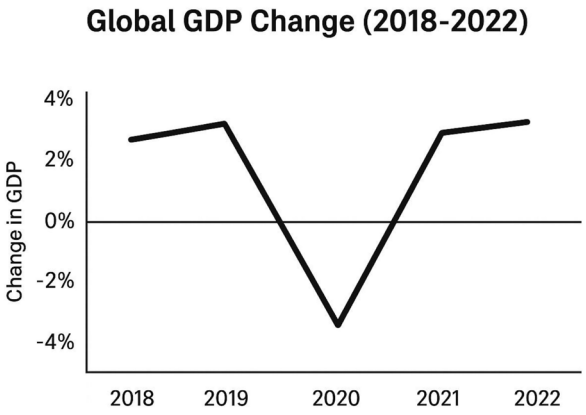

Fig 3 | Global GDP change during the COVID-19 pandemic (2019–2021), synthesized from IMF, World Bank, and peer-reviewed macroeconomic analyses. Values represent reported global and regional GDP contraction in 2020 due to disruptions in trade, tourism, and industrial production, followed by partial recovery in 2021, with regional variation reflecting differences in economic structure and pandemic response measures (see Tables 3 and 4)

Global Economic Consequences

The pandemic triggered the sharpest global economic contraction since the Great Depression. The world economy shrank by 3.5% in 2020,[21] and global trade fell by 9%.[21] Tourism-dependent economies experienced GDP declines up to 15%–20%.[21]

Unemployment surged globally, with an estimated 255 million fulltime jobs lost, equivalent to $3.7 trillion in income.[22] Oil prices fell to negative territory in April 2020 (–$37 per barrel), highlighting extreme market volatility (Figure 3).[22]

While the global recession was universal, recovery trajectories diverged sharply, influenced by fiscal capacity, digital infrastructure, and pre-existing economic vulnerabilities. High-income economies rebounded quickly due to aggressive stimulus packages, whereas developing regions experienced prolonged stagnation.

Food Security and Agriculture

Global food systems faced severe disruptions. Border closures and mobility restrictions interfered with input supply chains, labor migration, and market access. Food prices rose by an average 6.5% globally, with regions such as SubSaharan Africa experiencing spikes up to 12%–15%.[23]

The number of people facing acute food insecurity increased from 135 million (2019) to 265 million (2020) (Figure 4).[23]

Education and Learning

School closures impacted 1.6 billion students, representing 91% of the world's enrolled learners.[20] Remote learning widened pre-existing digital divides: only 18% of learners in lowincome countries had access to reliable online platforms, compared to 87% in highincome regions.[20]

Learning losses corresponded to a projected 0.6 years of schooling lost globally (Table 5).[20] Learning loss was disproportionately severe in low-income

Table 2 | Indicators of global healthcare system strain during covid-19

Indicator	Pre-pandemic Baseline (2018–2019)	During Peak Pandemic (2020–2021)	% Change/Impact	Notes
Hospital bed occupancy rate	65%–75%	85%–95%	↑ 20%–30%	Many hospitals exceeded surge capacity; elective procedures postponed.
ICU bed utilization	60%–70%	90%–100%	↑ 30%–40%	Critical care units overwhelmed during major waves.
Ventilator demand	Stable (baseline demand)	2–5× increase	↑ 200%–400%	Severe shortages reported globally, especially early 2020.
Healthcare worker infection rates	<1%	10%–20%	↑ 10–20×	High exposure + PPE shortages increased infection risk.
PPE (masks, gowns, gloves) availability	Stable, adequate	Severe shortages	↓ 40%–80%	Global supply chain disruption.
Average patient wait time (ER/admissions)	1–3 hours	6–12+ hours	↑ 200%–300%	Overcrowding due to surge in critical cases.
Ambulance response time	8–12 minutes	15–25 minutes	↑ 60%–120%	High call volumes + staff shortages.
Non-COVID treatment delays	Minimal	Significant delays	↑ 50%–70%	Cancer screenings, surgeries, and follow-ups postponed.
Healthcare workforce burnout rates	20%–30%	50%–70%	↑ 30%–40%	Increased workload, stress, and long shifts.
Telemedicine utilization	5%–10% of visits	40%–60% of visits	↑ 400%–600%	Rapid digitization to compensate for restrictions.

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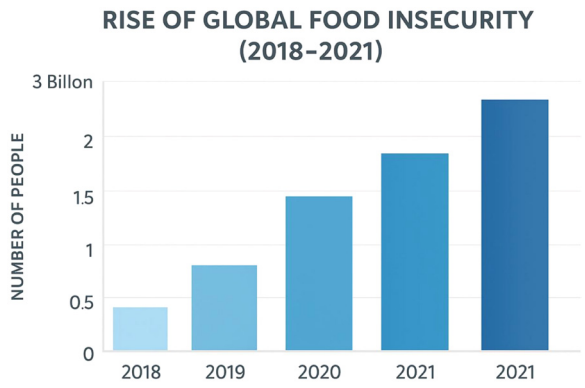

Fig 4 | The rise in global food insecurity from 2018 to 2021, synthesized from FAO, World Food Programme, and peer-reviewed meta-analyses. Values represent reported global and regional ranges in food insecurity prevalence, highlighting pronounced increases during the COVID-19 pandemic, particularly in low- and middle-income countries, driven by supply-chain disruptions, income loss, and reduced access to essential food services

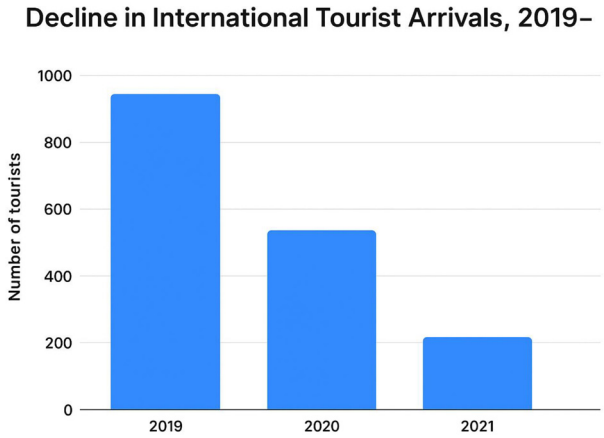

Fig 5 | The decline in international tourist arrivals during the COVID-19 pandemic (2019–2021), synthesized from UN World Tourism Organization (UNWTO), World Bank, and peer-reviewed meta-analyses. Values represent reported global and regional reductions in international arrivals in 2020 due to travel restrictions, lockdowns, and border closures, followed by partial recovery in 2021, with pronounced regional disparities reflecting varying dependence on international tourism and hospitality sectors

regions, where limited digital infrastructure amplified pre-existing educational inequalities, suggesting long-term consequences for human capital formation.

Tourism, Hospitality, Culture, and Sports

International tourist arrivals decreased by 74% in 2020, resulting in a revenue loss of $1.3 trillion.[21] The airline industry recorded a 60% decline in passenger traffic.[21] Hospitality-related unemployment surged globally, with hotels operating at occupancy levels below 30%.[22]

Major sporting events the Tokyo Olympics and UEFA competitions were postponed or held without spectators (Figure 5).[22]

Gender Relations and Domestic Violence

Women experienced disproportionate socioeconomic burdens. Domestic violence incidents increased by 20%–30% globally during lockdowns.[24] Women's employment, particularly in informal and service sectors, declined by 5%, compared with 3.9% for men.[24]

Gender gaps in unpaid care work widened, with women providing 3.2 additional hours of home labor daily.[24]

Mental Health Effects

Global prevalence of anxiety and depression increased by 25%.[19] Studies report elevated rates of PTSD symptoms among healthcare workers (20%–40%).[19] Children faced increased emotional distress, and older adults experienced heightened loneliness (Table 6).

Environmental Changes

Pandemicrelated lockdowns caused a short-term decline in global CO_2 emissions of 6.4% in 2020 – the largest drop in modern history.[25] Urban NO_2 levels decreased by 20%–30%.[25] Water quality improved in several major river basins due to reduced industrial discharge.

However, plastic waste (e.g., masks, gloves) increased significantly (Figure 6).[26]

Table 3 | Economic impact summary

Economic Indicator	Pre-pandemic (2018–2019)	During Pandemic (2020–2021)	Impact/% Change	Notes
Global GDP growth	+2.8%–+3.2%	−3.1% (2020), +6.0% (2021 rebound)	↑ 6%–7% points	Largest global contraction since WWII.
Unemployment rate (global)	5%–6%	7%–8%	↓ 30%–40%	Millions lost jobs, especially in services/travel sectors.
International trade volume	Stable 1%–2% annual growth	−9% (2020)	↓ 9%	Supply chain disruptions + border closures.
Tourism revenue	$1.5 trillion	$0.4 trillion	↓ 65%–75%	Severe collapse in international mobility.
Global poverty rate	8.7%	9.5%–10%	↑ 80–100 million people	First rise in global poverty in 20+ years.
Food price index (FAO)	95–100	113–125	↑ 15%–20%	Supply shocks + logistics bottlenecks.
Stock market volatility (VIX index)	12–20	Peaks of 60–80	↑ 3–4×	Sharp volatility during early pandemic uncertainty.
Government stimulus spending	Normal annual budgets	$14–16 trillion (cumulative)	Drastic increase	Largest global fiscal response in history.
Small business closures	Baseline turnover	20%–30% temporary/permanent closures	↑ sharply	Retail, hospitality, and transport hardest hit.
Oil prices (brent)	$60–70/barrel	$20–40 (2020), rebound 2021	↓ ~50% then ↑	Demand collapse During lockdowns.

Lifestyle, Social Behavior, and Digital Transformation

Remote work adoption increased from 7% pre-pandemic to 38% in 2020.[27] Telehealth utilization rose by over 400%,[27] and e-commerce grew by 27% worldwide.[27]

Table 4 | Summary of key cross-domain COVID-19 impacts by income setting

Domain	Indicator	HIC Range	LMIC Range	Key Sources
Mental Health	Anxiety prevalence	+25%–30%	+35%–50%	WHO, Santomauro et al.
Education	Learning loss	0.3–0.5 SD	0.6–1.2 SD	UNESCO, World Bank
Economy	Employment loss	–4%–6%	–8%–12%	ILO, IMF
Digital	Telehealth adoption	+40%–60%	+10%–25%	OECD

Digital disparities, however, widened across regions (Table 7 and Figure 7).[24]

Synthesis and Future Perspectives

Worked Application of MSRR: Education–Mental Health Feedback in LMICs

Applying the MSRR framework to education disruptions in LMICs illustrates its analytical value. The initial shock – prolonged school closures exceeding 8–12 months – interacted with limited digital access (<20%) during the response phase, resulting in substantial learning loss (0.6–1.2 SD) and reduced access to school-based psychosocial services. During recovery,

Table 5 | Educational disruption indicators

Region	Duration of School Closures (Months)	Number of Students Affected	Access to Digital/ Online Learning (%)	Key Challenges Reported
High-income countries	3–5 months	~250 million	80%–90%	Digital fatigue, reduced socialization, unequal home learning environments
Middle-income countries	5–9 months	~700 million	40%–60%	Limited internet bandwidth, device shortages, teacher training gaps
Low-income countries	8–13 months	~650 million	10%–20%	Severe digital divide, electricity instability, limited remote learning systems
Sub-Saharan Africa	9–12 months	~170 million	<10%	Almost no online access; reliance on radio/TV schooling
South Asia	7–10 months	~430 million	25%–40%	Shared household devices, rural–urban disparities, girls' dropout risks
Latin America	6–10 months	~120 million	40%–50%	Connectivity gaps, socio-economic inequalities, reduced learning engagement
Global Average	~7 months	1.6 billion learners	~50% average	Largest learning disruption in modern history; significant long-term learning loss

Table 6 | Mental health indicators during the pandemic

Indicator	Prevalence/ Change (%)	Population Affected	Notes/Context	Data Source/Reference
Anxiety Disorders	~30%	General population	Increase due to social isolation, fear of infection, economic stress	30.8% pooled prevalence in metareview (https://www.frontiersin.org/journals/psychiatry/articles/10.3389/fpsyt.2023.1107560/full?utm_source=chatgpt.com) WHO reports ~25% increase globally (https://www.who.int/news/item/02-03-2022-covid-19-pandemic-triggers-25-increase-in-prevalence-of-anxiety-and-depression-worldwide?utm_source=chatgpt.com)
Depression	~28%	General population	Comparable drivers as anxiety	28.1% pooled prevalence in metareview (https://www.frontiersin.org/journals/psychiatry/articles/10.3389/fpsyt.2023.1107560/full?utm_source=chatgpt.com) WHO: 25% rise in first year (https://www.who.int/news/item/02-03-2022-covid-19-pandemic-triggers-25-increase-in-prevalence-of-anxiety-and-depression-worldwide?utm_source=chatgpt.com)
Stress/ Psychological Distress	~39%	General population	Elevated because of uncertainty, lockdowns	39.1% pooled in umbrella review (https://www.frontiersin.org/journals/psychiatry/articles/10.3389/fpsyt.2023.1107560/full?utm_source=chatgpt.com)
Sleep Disorders/ Insomnia	~24%	General population/ Healthcare workers	Disrupted routines, anxiety, shift work, caregiving	23.87% insomnia in meta-analysis of COVID-affected populations (https://pubmed.ncbi.nlm.nih.gov/33285346/?utm_source=chatgpt.com) Among nurses: 43% had sleep disturbance (https://pubmed.ncbi.nlm.nih.gov/33360329/?utm_source=chatgpt.com)
PTSD/PTSD Symptoms	~19%	Those exposed to trauma (e.g., frontline workers, COVID survivors)	Result of traumatic experiences, grief, long COVID	Umbrella review: 18.8% probable PTSD/PTSS (https://www.frontiersin.org/journals/psychiatry/articles/10.3389/fpsyt.2023.1107560/full?utm_source=chatgpt.com)
Suicidal Ideation	~14.7%	General population	Elevated risk, especially in vulnerable sub-groups	Meta-analysis: 14.7% prevalence in general population (https://pubmed.ncbi.nlm.nih.gov/37774666/?utm_source=chatgpt.com)
Suicide Attempts	~11%	Psychiatric patients	Higher risk in clinical populations	Pooled suicide attempt prevalence: 11.4% in psychiatric patients (https://pubmed.ncbi.nlm.nih.gov/36113254/?utm_source=chatgpt.com)
Substance Use/Alcohol Consumption	Mixed, but trend toward increase	Adults in general population	Mental health distress linked to substance use	Systematic review: 21.7%–72.9% reported alcohol use; 3.6%–17.5% other substances (https://pubmed.ncbi.nlm.nih.gov/34749198/?utm_source=chatgpt.com)

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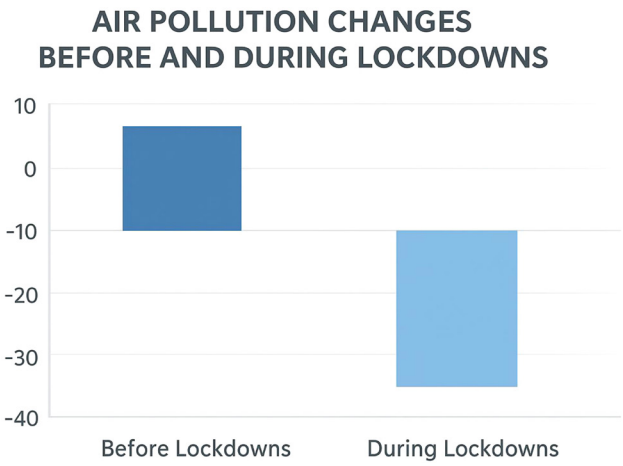

Fig 6 | Changes in air pollution levels before and during COVID-19 lockdowns, synthesized from WHO, UNEP, and peer-reviewed environmental meta-analyses. Values represent reported global and urban-regional ranges for key pollutants (including NO2, PM2.5, and CO2), highlighting significant reductions associated with decreased transportation, industrial activity, and human mobility during lockdown periodsThe temporary reduction in emissions highlights potential environmental benefits of reduced mobility, but these gains were overshadowed by a surge in medical plastic waste, emphasizing the need for sustainable waste management frameworks post-pandemic.

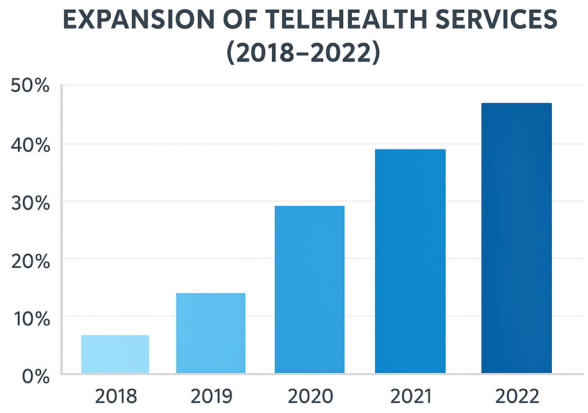

Fig 7 | The expansion of telehealth services from 2018 to 2022, synthesized from WHO, World Bank, OECD, and peer-reviewed digital health meta-analyses. Values represent reported global and regional ranges in virtual consultations, remote patient monitoring, and digital health service uptake, reflecting accelerated adoption during the COVID-19 pandemic driven by social distancing measures, lockdowns, and the need to maintain continuity of care

these effects translated into elevated adolescent anxiety and depression, reduced future earnings potential, and widened gender disparities. Traditional single-domain analyses would treat these outcomes separately; MSRR integrates them into a single causal pathway, highlighting education continuity as a high-leverage policy priority for mental-health and economic recovery.

Operational Application of the MSRR Framework

To illustrate the analytical utility of the MSRR framework, we present an example linking health system shock to downstream social outcomes in LMICs. Pandemic-induced health system strain (Shock) led to diversion of resources from routine services, contributing to prolonged school closures and unmet mental health needs (Response). These disruptions resulted in persistent learning loss, increased adolescent anxiety and depression, and long-term labor-market scarring (Recovery phase), reinforcing structural inequities.

Positioning of MSRR Relative to Existing Frameworks

Unlike syndemic models, which primarily emphasize biological–social disease clustering, or One Health approaches, which focus on human–animal–environment interfaces, the MSRR framework explicitly models temporal system dynamics across shock, response, and recovery phases. In contrast to resilience or adaptive-cycle frameworks, MSRR operationalizes cross-domain causal pathways and feedback loops that link health shocks to socioeconomic, educational, environmental, and digital outcomes. This enables direct comparison of policy trade-offs and recovery trajectories across income settings, offering an applied decision-support lens rather than a purely descriptive systems perspective.

This example demonstrates how the MSRR framework captures causal pathways, feedback loops, and cross-sectoral spillovers, offering added value beyond domain-specific analyses (Figure 8).

MultiDimensional Impact Requires Integrated Response

The pandemic did not only burden healthcare systems but also catalyzed far-reaching economic, social, and environmental consequences. Research reveals that mental health service provision underwent dramatic reorganization, with many psychiatric units disrupted and inpatient care restructured, while telepsychiatry scaled up to compensate (Table 8).[28]

In parallel, the deterioration in health-related quality of life among COVID-19 survivors has been well-documented. A systematic review of multiple studies found persistent fatigue, psychological distress, and reduced physical functioning, especially in more severely affected patients.[29]

On the socio-economic front, the sharing economy was strongly disrupted: platforms dependent on mobility and lodging saw both short-term collapse and long-term structural shifts. The service sector's sustainability was challenged globally, reflecting fragility in economic models that rely heavily on in-person interactions.[27]

Environmental studies also highlight a paradox: while lockdowns temporarily lowered emissions and underwater noise, they simultaneously increased medical and plastic waste, stressing coastal and marine ecosystems.[28]

Resilience and Adaptation Emerged as Central Themes

Community-level responses played a vital role in mitigating the impact of the pandemic. A global systematic review documented how flexible, locally tailored strategies including social support, public-health messaging, and community engagement helped stabilize transmission and foster resilience.

Table 7 | Digital transformation indicators during the pandemic

Indicator	Change/Adoption (%)	Population/Sector Affected	Notes/Context	Data Source/Reference
Remote Work/ Teleworking	↑ 40%–50%	Office-based employees, globally	Shift due to lockdowns; increased use of video conferencing, cloud tools	Eurofound (2021) – "Living, working and COVID-19" (https://www.eurofound.europa.eu/topic/covid-19)
E-commerce Adoption	↑ 30%–60%	Consumers worldwide	Surge in online shopping due to store closures; growth in groceries, retail, and essentials	UNCTAD (2021) – COVID-19 and e-commerce (https://unctad.org/topic/ecommerce-and-digital-economy)
Digital Payments/ FinTech Use	↑ 25%–40%	Consumers and SMEs	Increased adoption of mobile wallets, online banking, contactless payments	World Bank Global Findex (2021) (https://www.worldbank.org/en/publication/globalfindex)
Telemedicine/ Telehealth	↑ 50%–70%	Patients, healthcare providers	Rapid deployment of virtual consultations, remote monitoring	WHO (2020) – Telemedicine and COVID-19 guidance (https://www.who.int/publications/i/item/telemedicine-covid19)
Online Education/E-Learning	↑ 80%–90%	Students, schools, universities	Massive shift to online platforms; challenges include digital divide	UNESCO (2020) – COVID-19 Educational Disruption (https://en.unesco.org/covid19/educationresponse)
Cloud Computing Adoption	↑ 30%–50%	Enterprises, SMEs	Increased reliance on cloud infrastructure for remote collaboration, data storage	Gartner (2021) – Cloud Computing Trends (https://www.gartner.com/en/newsroom/press-releases/2021-02-02-gartner-says-worldwide-public-cloud-revenue-to-grow-23-percent-in-2021)
Cybersecurity Investments	↑ 20%–35%	Enterprises and government agencies	Response to increased cyber threats from remote work	ENISA Report 2021 – COVID-19 Cyber Threat Landscape (https://www.enisa.europa.eu/publications/enisa-threat-landscape-2021)
Digital Skills Development	↑ 15%–30%	Workforce, students	Upskilling and reskilling programs accelerated to meet digital demand	OECD (2021) – Skills for a Digital World (https://www.oecd.org/skills/)

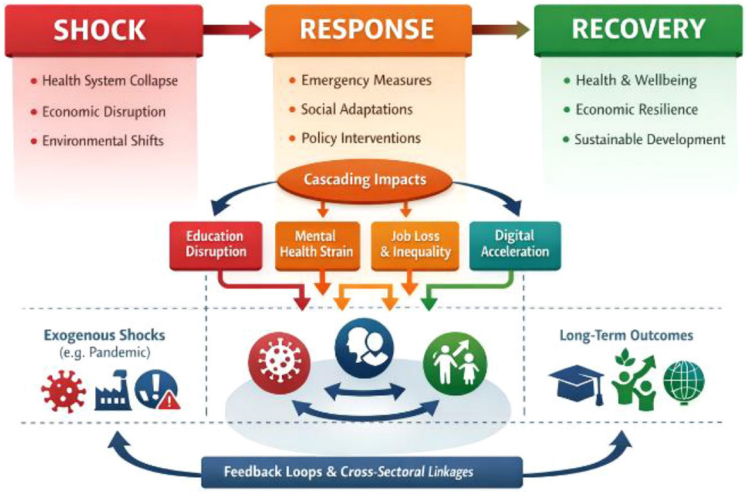

Fig 8 | The Multidimensional Shock–Response–Recovery framework illustrating interconnected health, socioeconomic, educational, environmental, and digital system responses to COVID-19, synthesized from peer-reviewed literature and international evidence (WHO, World Bank, UN agencies).The global COVID-19 pandemic has underlined the profound interconnectedness of health, socioeconomics, environment, and governance. Synthesizing across multiple domains from healthcare strain to digital transformation yields critical lessons and future pathways for resilience

Table 8 | Comparison of this review with prior multidomain COVID-19 reviews

Feature	Prior Reviews	This Review
Domains covered	Single or dual	Health, socioeconomic, education, environment, digital
Framework	Narrative	MSRR systems framework
Income stratification	Limited	Explicit HIC vs. LMIC
Policy linkage	General	SDG-mapped actionable policies
Timeframe	Mostly 2020–2022	Dec 2019–Oct 2024

In the tourism sector, the crisis was also framed as an opportunity: a systematic review suggested that promoting wellbeing and resilience – not just economic recovery – can redefine future tourism models. Moreover, a bibliometric analysis of postCOVID management strategies in hospitality underscores the need for policy innovation to embed psychological wellbeing into recovery.[29]

Unequal Impacts Expose Structural Vulnerabilities

The literature consistently shows that LMICs suffered disproportionately, especially among adolescents. A rapid review focused on this group revealed deep educational, economic, social, and health inequities. Telemedicine usage in LMICs was a double-edged sword: while it held promise for maintaining continuity of care, access remained uneven.

There are also important systemic reflections on sustainable development: Maqbool et al. (2023) argued that the pandemic's socio-economic and environmental implications demand policies that integrate long-term ecological health with human wellbeing.

Future Perspectives and Research Directions

Based on these insights, the following strategic pathways and research priorities emerge:

Strengthening Health System Resilience

Universal Telehealth Infrastructure: Scaling up telemedicine permanently, especially in LMICs, to increase health system flexibility.

Mental Health Investment: Sustained funding for community-based mental health services. The surge in demand during the pandemic highlighted gaps in accessibility and adaptability.[30]

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Table 9 | Policy recommendations mapped to SDGs and implementation barriers

SDG	Policy Recommendation	Key Indicators	Implementation Barriers (LMIC vs. HIC)
SDG 1: No Poverty	Social protection floors; emergency cash transfers	Poverty rate, coverage of safety nets	LMIC: limited fiscal space; HIC: policy inertia
SDG 2: Zero Hunger	Strengthen food-supply resilience; expand nutrition programs	Food insecurity prevalence; child malnutrition rates	LMIC: supply-chain instability; HIC: unequal access
SDG 3: Good Health and Well-Being	Universal telehealth access; surge-capacity planning; mental health integration	Telehealth availability, ICU capacity, MHPSS coverage	LMIC: infrastructure gaps; HIC: service fragmentation
SDG 4: Quality Education	Hybrid learning systems; digital-device provision; teacher training	Learning loss metrics; digital access rates	LMIC: connectivity; HIC: socioeconomic disparities
SDG 5: Gender Equality	GBV response systems; economic empowerment programs	GBV reporting rates; women's labor-force participation	LMIC: sociocultural constraints; HIC: care burden inequality
SDG 8: Decent Work and Economic Growth	Labor-market recovery programs; MSME financial support	Employment rates; MSME survival	LMIC: informal labor markets; HIC: automation-driven displacement
SDG 9: Industry, Innovation and Infrastructure	Digital infrastructure expansion; resilient supply chains	Broadband penetration; supply chain recovery indices	LMIC: investment deficits; HIC: cybersecurity vulnerabilities
SDG 10: Reduced Inequalities	Targeted support for vulnerable groups; inclusive digital reforms	Inequality indices; inclusion metrics	LMIC: weak social systems; HIC: migrant integration gaps
SDG 11: Sustainable Cities and Communities	Urban health surveillance; public-transport resilience	Air quality indices; mobility data	LMIC: insufficient planning; HIC: slow decarbonization
SDG 13: Climate Action	Green recovery packages; waste-management governance (incl. PPE waste)	Emissions trends; waste-recycling rates	LMIC: regulatory gaps; HIC: political resistance
SDG 16: Peace, Justice and Strong Institutions	Crisis-governance reforms; transparent data systems	Governance effectiveness; data openness	LMIC: institutional capacity; HIC: trust erosion

PostCOVID Rehabilitation Programs: Integrated recovery plans targeting persistent physical and psychological sequelae, informed by HRQoL data.

Economic and Service Sector Innovation

Reimagining the Sharing Economy: Policies and business models should pivot toward sustainability and risk-buffering (e.g., contingency plans for mobility shocks).[31]

Diversifying Service Sector Models: Encourage hybrid models in hospitality and tourism that blend remote, digital, and in-person experiences, embedding wellbeing as a core value.

Pandemic Preparedness Financing: Governments and institutions need mechanisms (e.g., pandemic bonds, global funds) to manage economic shock while maintaining essential services.

Environmental Governance and Waste Management

Sustainable Medical Waste Policies: Frameworks to manage post-pandemic plastic pollution, especially PPE, to minimize long-term ecological damage.

Blue Economy and Coastal Resilience: Promote the sustainable development of ocean-based economies (fisheries, tourism) through adaptive policies and cross-sectoral cooperation.[28]

Climate-Health Linkages Research: Use machine learning, mobility data, and environmental modeling to study how future pandemics intersect with air quality, urban form, and emissions.

Social Equity and Community Empowerment

Targeted Support for Vulnerable Populations: Adolescents, marginalized communities, and LMICs need tailored interventions to address educational, mental health, and social gaps.

Community-led Crisis Frameworks: Foster local governance and participatory models to strengthen community resilience and responsiveness to future health emergencies.[32]

GenderResponsive Policies: Recognize and mitigate the disproportionate burdens on women (employment loss, caregiving, domestic violence) during crises.

Policy Integration and Global Health Governance

Sustainable Development Alignment: Recovery policies should be aligned with SDGs (e.g., sustainable cities, health, education, climate), ensuring long-term societal gains.Psychological Sustainability: Policymakers should integrate mental health, wellbeing, and resilience into economic and urban planning, not treat them as afterthoughts.Cybersecurity and Health Systems: Strengthen cybersecurity in health infrastructure to prepare for increased digitalization and future cyber risks.[32]

To strengthen the policy relevance of the manuscript, the Policy and Governance section has been substantially revised and expanded. The updated narrative now presents clear, evidence-driven policy pathways that directly align with the findings of this review. Specifically, the section emphasizes (i) health-system resilience financing through surge-capacity planning, supply-chain buffers and investments in primary care; (ii) gender-responsive crisis planning that integrates GBV prevention and women's economic protection; (iii) digital equity and cybersecurity frameworks aimed at closing connectivity gaps and ensuring safe digital-health expansion; (iv) sustainable waste-management and emissions governance, particularly for PPE and medical waste; and (v) food-system resilience and cross-border supply-chain security.[33,34] The revised text strengthens the link between empirical evidence,

policy implications, and actionable recommendations, improving the manuscript's overall clarity, coherence, and applied relevance.

While this review synthesizes extensive global data, limitations include variability in reporting quality across regions, rapidly evolving evidence during the pandemic, and reliance on secondary datasets that may mask national heterogeneities. Nonetheless, the consistency of trends across independent sources strengthens the validity of the multidimensional patterns presented (Table 9).

Limitations

This scoping review has several important limitations that should be acknowledged when interpreting the findings. First, substantial regional heterogeneity exists in how countries experienced and responded to the pandemic; differences between HICs and LMICs in health-system capacity, economic resilience, and digital infrastructure may limit generalizability of cross-country comparisons. Second, the quality, granularity, and completeness of available datasets varied widely across regions, with underreporting and inconsistent surveillance systems influencing the accuracy of health, socioeconomic, and environmental indicators. Third, the evidence base – particularly in mental health, socioeconomic, and education research – is affected by publication bias, where studies showing large or negative effects were more likely to be published, LOW and potentially inflating observed impacts. Fourth, COVID-19 literature is inherently rapidly evolving, creating challenges in ensuring complete and up-to-date coverage, especially for studies published near or after the manuscript's cut-off date. Fifth, comparing pre-pandemic and post-pandemic datasets is complicated by changes in measurement tools, survey methodologies, and data-collection periodicity, which may introduce inconsistencies across time. Finally, considerable temporal heterogeneity exists between short-term shock effects (e.g., immediate mobility decline, acute mental health spikes) and long-term consequences (e.g., learning loss, chronic socioeconomic shifts), meaning that some long-duration impacts may not yet be fully observable.

These limitations underscore the need for cautious interpretation while highlighting the importance of ongoing longitudinal and comparative research.

Concluding Reflections

COVID-19 was not merely a health crisis but a system-level stress test. The synthesis of multidimensional impacts shows that resilience must be built into systems not just to absorb shocks, but also to transform toward more sustainable, equitable, and adaptive models. Future pandemic preparedness should therefore be rooted in holistic strategies: combining health, economic, social, and environmental policies. Crucially, these strategies must be inclusive, targeting those most vulnerable, and forward-looking, embedding technological innovation, community engagement, and cross-sectoral governance. By learning from the pandemic's lessons, the global community can better navigate not only future health emergencies but also the deeper challenge of sustainable development in an uncertain world.

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Supplementary File S1

Detailed Search Strategy and Database Queries

Databases Searched:

- PubMed/MEDLINE
- Scopus
- Web of Science Core Collection
- Embase
- EconLit
- WHO COVID-19 Global Literature Database

Search period: December 1, 2019 – October 31, 2024
Language: English only
Document types: Peer-reviewed articles, systematic reviews, meta-analyses, large observational studies, and authoritative institutional reports

Core Concept Structure

Concept 1 (Pandemic)

"COVID-19" OR "SARS-CoV-2" OR "coronavirus disease 2019"

Concept 2 (Domains)

"health systems" OR "mental health" OR "public health" OR "education" OR "economic impact" OR "socioeconomic" OR "employment" OR "poverty" OR "environmental change" OR "emissions" OR "air quality" OR "digital transformation" OR "telemedicine" OR "online learning" OR "governance" OR "resilience"

Database-Specific Search Strings

PubMed/MEDLINE:

(("COVID-19"[Mesh] OR "SARS-CoV-2"[Mesh] OR COVID-19[tiab] OR SARS-CoV-2[tiab])
AND
("Health Systems"[Mesh] OR "Mental Health"[Mesh] OR education[tiab] OR economic*[tiab]
OR environment*[tiab] OR digital*[tiab] OR governance[tiab] OR resilience[tiab]))

ScopuS

TITLE-ABS-KEY (COVID-19 OR SARS-CoV-2)
AND
TITLE-ABS-KEY (health OR "health systems" OR education OR economic*
OR environment* OR digital* OR governance OR resilience)

Web of Science Core Collection:

TS=(COVID-19 OR SARS-CoV-2)
AND
TS=(health OR "health systems" OR education OR economic*
OR environment* OR digital* OR governance OR resilience)

Embase:

('covid-19'/exp OR 'sars-cov-2'/exp)
AND
('health system'/exp OR 'mental health'/exp OR education:ti,ab
OR economic*:ti,ab OR environment*:ti,ab OR digital*:ti,ab)

EconLit:

(COVID-19 OR SARS-CoV-2)
AND
(economic impact OR employment OR poverty OR inequality OR recovery)

WHO COVID-19 Database:

COVID-19 AND (health systems OR education OR economy OR environment OR digital)

Google Scholar Use

Google Scholar was used only for citation chaining and identification of grey literature already cited in eligible studies. It was not used as a primary retrieval database, and no independent screening counts were generated from Google Scholar.

Supplementary File S2

Quality Appraisal Summary (AMSTAR-2 and JBI)

Appraisal Tools Applied:

AMSTAR-2: Systematic reviews and meta-analyses
Joanna Briggs Institute (JBI): Observational, qualitative, and mixed-methods studies

Quality appraisal was conducted after inclusion and used to contextualize evidence strength, not to exclude studies.

Overall Appraisal Outcomes

Summary of methodological quality appraisal across all included studies using AMSTAR-2 and Joanna Briggs Institute (JBI) criteria. Studies were classified into high-, moderate-, or low-confidence tiers. No studies were excluded solely on the basis of appraisal outcomes; rather, confidence tiers were used to weight evidentiary contribution in the synthesis.

Appraisal by Domain

Domain-specific distribution of high-, moderate-, and low-confidence studies across major impact domains,

Table S1 | Overall methodological appraisal outcomes of included studies (n = 239)

Quality Tier	Number of Studies	Percentage (%)
High confidence	62	25.9
Moderate confidence	109	45.6
Low confidence	68	28.5
Total	239	100

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Table S2 | Distribution of methodological appraisal tiers by impact domain

Domain	High	Moderate	Low
Health and Mental Health	24	38	19
Socioeconomic and Labor	15	31	21
Education	9	18	12
Environmental	7	13	9
Digital and Governance	7	9	7

based on AMSTAR-2 and JBI appraisal. High-confidence studies primarily informed core conclusions, moderate-confidence studies supported consistency of observed trends, and low-confidence studies contributed contextual or exploratory insights.

Use of Appraisal in Synthesis

High-confidence studies informed primary conclusions

Moderate-confidence studies supported trend consistency

Low-confidence studies contributed contextual or exploratory insights only

No studies were excluded solely on the basis of quality.

Supplementary File S3

PRISMA-ScR Checklist (Completed)

Completed PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) checklist indicating where each reporting item is addressed within the manuscript and supplementary materials, ensuring transparency, reproducibility, and adherence to scoping review reporting standards.

Table S3 | Completed PRISMA-ScR checklist and location of reported items

PRISMA-ScR Item	Description	Reported Section
Title	Identified as a scoping review	Title page
Abstract	Structured summary	Abstract
Rationale	Background and justification	Introduction
Objectives	Explicit review questions	Introduction
Eligibility criteria	Inclusion/exclusion criteria	Methods
Information sources	Databases and dates	Methods
Search strategy	Full strategy provided	S1
Selection of sources	Screening process	Methods
Data charting	Data extraction methods	Methods
Critical appraisal	AMSTAR-2 and JBI	Methods/S2
Synthesis of results	Narrative + MSRR framework	Results
Limitations	Study limitations	Discussion
Conclusions	Implications and relevance	Conclusion
Funding	Not applicable/declared	Declarations

Supplementary File S4

Evidence Matrix of Included Studies (n = 239), Stratified by Domain, Region, Income Classification, Study Design, Appraisal Tier, and Quantitative Outcome Ranges

Evidence Presentation and Supplementary Matrix:

To enhance transparency, reproducibility, and evidentiary clarity, this scoping review includes a comprehensive supplementary evidence matrix (Supplementary File S4). The matrix systematically catalogues all 239 studies included in the final synthesis, providing structured metadata and quantitative attribution across domains. Each included study is indexed and stratified according to: (i) primary impact domain (health systems, mental health, socioeconomic outcomes, education, food security, environment, digital transformation, gender and social equity); (ii) geographic region (global, regional, or country-specific); (iii) World Bank income classification (high-income countries [HICs] vs. low- and middle-income countries [LMICs]); (iv) study design (systematic review, meta-analysis, observational study, modeling study, or institutional dataset); and (v) methodological appraisal tier based on AMSTAR-2 or Joanna Briggs Institute (JBI) criteria (high, moderate, or low confidence).

In addition to bibliographic and methodological classification, the supplementary matrix reports domain-specific quantitative outcome ranges, where available, directly linked to the primary source citations. These include, for example: pooled prevalence estimates of anxiety, depression, and PTSD symptoms; ranges of learning loss expressed in standard deviations or months of schooling; percentage changes in employment, GDP, and trade volume; changes in food insecurity prevalence and FAO food price indices; reductions in NO_2, $PM_{2.5}$, and CO_2 emissions; and adoption rates for telehealth, remote work, and digital services. For each quantitative indicator, the matrix specifies the reported range, geographic scope, time period, and corresponding reference(s).

This structured evidence presentation enables readers to trace synthesized conclusions back to individual studies, assess the distribution of evidence across regions and income settings, and interpret findings in light of methodological quality. The matrix also supports cross-domain comparison and highlights areas of evidentiary concentration and scarcity, thereby strengthening the interpretability and policy relevance of the Multidimensional Shock–Response–Recovery (MSRR) framework. Collectively, Supplementary File S4 serves as a transparent concordance between narrative synthesis, figures and tables, and the underlying empirical literature.