The Annual Global Incidence Rate of Extreme Weather Event Disasters Appears Positively Correlated with World GDP, 1961–2020

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Abbreviations:
CRED: Center for Research on the Epidemiology of Disasters
DRR: disaster risk reduction
EM-DAT: Emergency Events Database
EWE: extreme weather event
GDP: gross domestic product
SDG: sustainable development goal
UN: United Nations
USD: US dollar

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Abstract

Objective: This study compared the per capita annual global incidence rate of disasters caused by natural hazards with the annual world real gross domestic product, GDP (per global capita), as reported during 1961 through 2020.

Methods: Sixty (60) values for the world real GDP per global capita (in constant 2015 $USD) were compared to corresponding annual values for global incidence rates for five natural disaster subgroups and then for a total of twelve individual disaster types that comprise the subgroups; each expressed as an annual global incidence rate (in terms of annual incidence per 100,000 persons). Calculations of multiple linear regression, ANOVA, and Pearson's correlation coefficient were performed for comparing population-adjusted values for GDP to corresponding values.

Results: Four out of five hydrological and meteorological disasters were found to have a positive correlation with GDP. Results of the analysis revealed a relatively high degree of correlation between world GDP and the annual incidence of flood and storm disasters ($P = 6.21 \times 10^{-10}$ and $P = 4.23 \times 10^{-4}$, respectively). The annual incidence of heat waves and cold weather disasters also appeared to correlate with GDP ($P = .002$ and $P = .019$, respectively). In comparison, wet landslides indicated no such correlation ($P = .862$). No significant associations were found among the seven other individual biological, climatological, and geophysical disasters and GDP.

Conclusion: The global incidence of four extreme weather (hydrometeorological) disasters appear to be positively associated with world real GDP during 1961-2020. These findings contradict previous postulates that the risk of disaster incidence is inversely associated with the capacity of the population.

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Introduction

The Anthropocene epoch is the newest planetary geological age, the period during which human activity has been the dominant influence on the earth. During this same time, human development has achieved remarkable gains involving life expectancy, poverty, and child mortality. However, this development also includes maladaptive elements such as the overuse of natural resources, pollution, and biodiversity loss, as well as the negative impacts of energy sources.[1]

Global warming is predicted to result in an increased number of extreme weather events (EWEs).[2] It is now thought to be virtually certain that heat waves will increase in frequency in the future.[3] Predicted increases in precipitation frequency and intensity are also associated with a high degree of certainty. And the number of compound events is also expected to increase.[3]

Burkle observed that crises vary greatly across global regions, their economic, environmental, ecological social, and disease aspects that "are increasingly under the influence of widely integrated global changes and forces arising primarily from climate extremes, rapid unsustainable urbanization, critical biodiversity losses, and scarcity in water, food, and energy."[4] While slow moving crises, they are increasingly severe, affect larger populations

Disaster Subgroup	Definition	Disaster Types
Biological	Pertaining to living organisms	Epidemic
		Insect Infestation
Climatological	Pertaining to the climate – long-term atmospheric phenomena	Drought
		Wildfire
Geophysical	Pertaining to the short- and long-term physical phenomena of the earth	Earthquakes
		Volcanic Eruptions
		Dry Landslides
Hydrological	Pertaining to water - in the atmosphere and on the earth	Floods
		Wet Landslides
Meteorological	Pertaining to weather – short-term atmospheric phenomena	Storms
		Cold Weather Events
		Heat Waves

Table 1. Definitions and Examples for Five Subgroups of Disasters caused by Natural Hazards

across many borders, and lead to the emergence of population-based, preventable public health emergencies related to water, sanitation, food, shelter, energy, and related health issues, and ultimately global health security.[4]

These EWEs are known to cause disasters that create significant public health needs often exceeding the local capacity to respond without excess morbidity or mortality, resulting in the declaration of disaster. So-called "natural" disasters have been subgrouped into five main categories according to the climatological, hydrological, meteorological, geophysical, and biological hazards that cause the disaster.[5] Table 1 provides definitions and examples for each of the five subgroups of disasters caused by natural hazards, along with a list of 12 corresponding disaster types included in this study.

Within the Anthropocene age, humanity's impact on earth's geology and ecosystems has been called "The Great Acceleration." This characterization represents the simultaneous increase in a large range of human activity, first recorded in mid-20th century.[6] Planetary health is a new multi-disciplinary field focused on addressing the impacts of human disruptions to earth's natural systems on human health and all life on earth. The underlying goal of planetary health is a world where all people thrive by protecting and regenerating earth's natural systems. This study is intended to evaluate the impact of "The Great Acceleration" on the global incidence of disasters as a measure of the earth's planetary health.

Methods

Data Collection

The World Meteorological Organization (WMO; Geneva, Switzerland) describes 30-year "standard reference periods" for use by the international community to maintain consistency in the calculation of climate statistics across the world. This study includes the two most recent standard reference periods ranging from 1961 to 2020.[7]

Data summaries for 15,566 separate disaster events that occurred during 1961-2020 were downloaded from the Emergency Events Database (EM-DAT), a widely used source of aggregate disaster data.[8] A historical database was created to include all reported disasters caused by natural hazards. The data were entered into a Microsoft 365 Excel spreadsheet, Version 16.0 (Microsoft Corporation; Redmond, Washington USA). Incidence data associated with the COVID-19 pandemic were excluded.

The EM-DAT is a global database on natural and technological disasters containing essential core data on the occurrence and effects of disasters in the world from 1900 to present. It is maintained by the Center for Research on the Epidemiology of Disasters (CRED) at the Catholic University of Louvain, School of Public Health, in Brussels, Belgium. Established in 1973, CRED has collaborative status with the United Nations (UN) Department of Humanitarian Affairs (New York USA), the European Union Humanitarian Office (Brussels, Belgium), the International Federation of the Red Cross and Red Crescent (Geneva, Switzerland), the US Office of Foreign Disaster Assistance (Washington, DC USA), as well as with non-governmental agencies such as the International Committee of the Red Cross and Red Crescent (Geneva, Switzerland).[8]

The EM-DAT database is comprised of information from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes, and press agencies. The entries are constantly reviewed for inconsistencies, redundancy, and incompleteness. Data are consolidated and updated daily by CRED. A further check is made at monthly intervals, and revisions are made at the end of each calendar year.[8]

For a disaster to be entered into the EM-DAT database, at least one of the following criteria must be fulfilled: (1) ten (10) or more people reported killed; or (2) one hundred (100) or more people reported affected; or (3) declaration of a state of emergency; or (4) call for international assistance.[8] The annual global incidence rates were calculated for five natural disaster subgroups (ie, biological, climatological, geophysical, hydrological, and meteorological) reported during 1961-2020. These five subgroups were then analyzed in more detail to include all 12 individual disaster types listed in Table 1.

World economic data summaries for 1961-2020 were downloaded from the World Bank (Washington, DC USA) Open Data Catalog website.[9] A historical database was created for annual world real gross domestic product, GDP (in constant 2015 dollars), and GDP was collected for 60 years beginning in 1961 and extending to 2020. These annual productivity rates were then divided by the annual global population to express the annual world real GDP in US dollars ($USD) per 100,000 of global population.

The GDP is the total monetary or market value of all the finished goods and services produced within a specific period. Here, GDP is here considered as a broad measure of global economic development during 1961-2020.

The World Bank Data Catalog is designed to make World Bank's development data easily accessible to the public. It includes data from the World Bank's microdata, finances, and energy data platforms, as well as datasets from the open data catalog.[9]

Data Analysis

Annual disaster incidence rates and annual world GDP rates were each adjusted per capita by dividing each by the annual global population to express: (1) the annual global incidence rates (in units of number of disasters per 100,000 of global population); and (2) the annual world GDP rates (in units of $USD GDP per 100,000 of global population).

Sixty (60) values for the world real GDP per global capita (in constant 2015 $USD) were compared to corresponding annual values for per capita global incidence rates for five natural disaster

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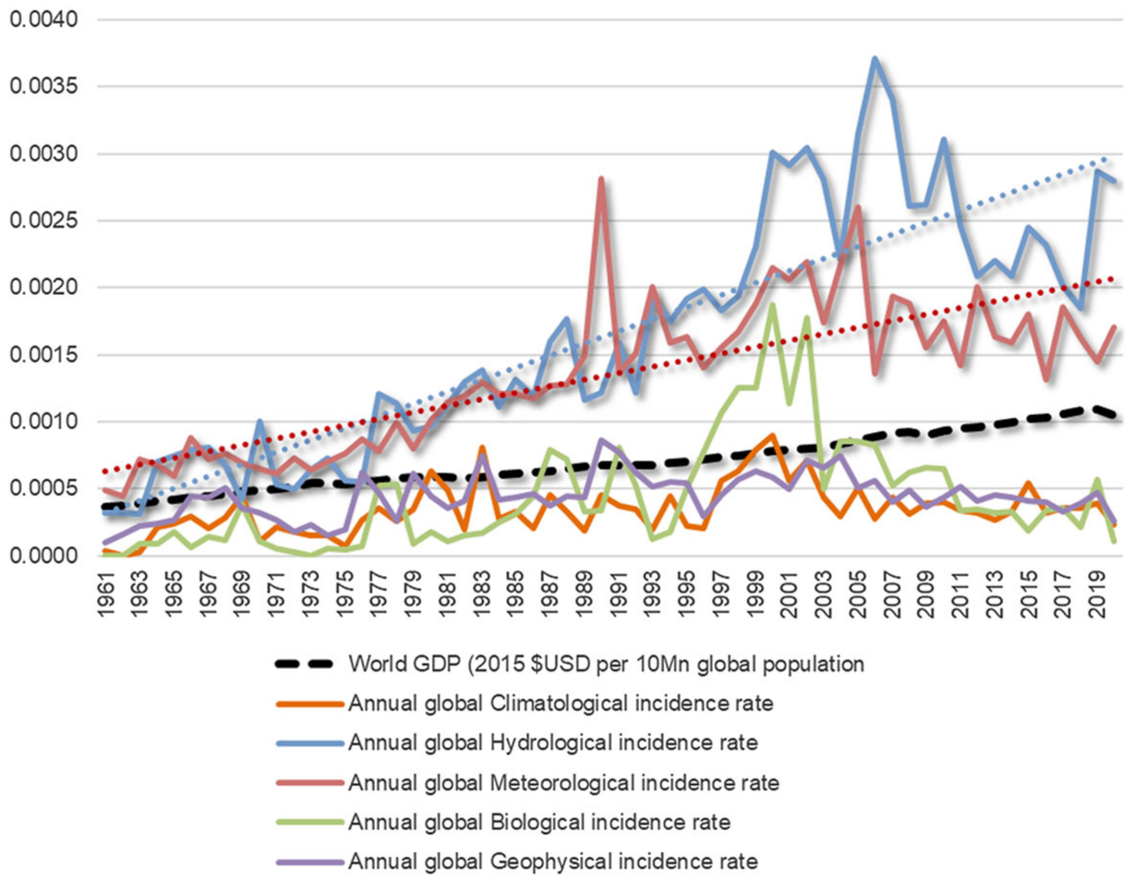

Figure 1. Annual Global Incidence Rate for Five Disaster Subgroups (Per 100,000 Persons) Compared to World GDP (Constant 2015 $USD per 10 Million Global Population).
Abbreviation: GDP, gross domestic product.

subgroups and then for the individual disaster types for each subgroup.

Calculations of multiple linear regression, ANOVA, and Pearson's correlation coefficient were performed for comparing population-adjusted values for GDP to per capita global annual incidence rates for individual sets of two to three disaster types comprising each of the five subgroups (Table 2).

Results

Table 2 represents the results of calculations involving the five disaster subgroups and the 12 corresponding individual disaster types associated with these subgroups. The following equation was calculated for each disaster subgroup, *i*:

$$Annual\ Incident\ Rate\ (per\ Capita)_i = \alpha + \beta * Real\ GDP\ (per\ Capita).$$

Figure 1 illustrates the degree of association between world real GDP (black line) and the global incidence of weather-related (hydrological and meteorological) disasters (red and blue lines) during 1961-2020. Climatological, biological, and geophysical disaster subgroups are depicted as orange, green, and purple lines, respectively.

Regression calculations including all five disaster subgroups revealed a relatively low degree of overall variability ($R^2 = 0.762$) and a high degree of overall significance (f-sig = 1.02×10^{-16}). Hydrological and meteorological disaster subgroups were found to have a strong positive correlation with GDP. The biological subgroup of disasters indicated a negative correlation with per capita GDP during the same time. However, a more detailed analysis revealed a high degree of variability ($R^2 = 0.016$) and a low overall significance (f-sig = 0.584) when the two types of disasters that comprised the subgroup (ie, epidemics and infestations) were compared to GDP.

Findings from regression calculations involving the 12 disaster types also revealed a low degree of variability ($R^2 = 0.61$ and $R^2 = 0.553$, respectively) and a high degree of overall significance (f-sig = 4.67×10^{-10} and f-sig = 4.23×10^{-4}, respectively) for hydrological and meteorological disasters.

Population-adjusted values for annual global incidence rates of flood and storm disasters appeared to have a high degree of positive correlation with world GDP. The annual global incidence rates of heat waves and cold weather disasters also appeared to correlate positively with world GDP ($P = .002$ and $P = .007$, respectively).

Four out of five hydrological and meteorological (hydrometeorological) disasters were found to have a positive correlation with GDP. All four of these hydrometeorological disasters pertain exclusively to atmospheric conditions. The incidence of a fifth hydrometeorological disaster studied (wet landslides) is known to depend not only on atmospheric conditions, but is also influenced by inherent characteristics of the earth's surface (eg, topography and geology). This disaster type indicated no significant correlation with GDP (P = .862). No significant associations were found among the seven other individual types of biological, climatological, and geophysical disasters and GDP.

Discussion

Acceleration of Earth's Water Cycle

The hydrologic (ie, water) cycle represents the continuous circulation of water in the earth and atmosphere. It is a complex system that involves movement of water from the ground to the atmosphere and back again. Of the many processes involved in the hydrologic cycle, the most important are evaporation, transpiration, condensation, precipitation, and runoff.

Climate change is likely causing parts of the hydrologic cycle to speed up as warming global temperatures increase the rate of evaporation world-wide.[10] More evaporation is causing more precipitation (and more resultant floods and storms) on average world-wide. More evaporation is also responsible for causing drought in the more arid areas of the world. Warmer ocean surface waters intensify tropical storms and cyclones. Warmer land temperatures generate heat waves and energize severe storms, like thunderstorms and tornadoes.[10]

In the short term, this speeding up of the earth's water cycle has been predicted to result in a higher frequency of weather-related (ie, hydrometeorological) disasters, like floods and storms. Over the long term, this phenomenon is associated with climatological disasters like drought and wildfires. This study suggests an increased incidence of hydrometeorological disasters during 1961 through 2020 that are, in turn, consistent with outcomes of the earth's accelerated water cycle.

Disasters and Sustainable Development

The World Bank has coined the phrase "natural hazards, but unnatural disasters" in recognition that disasters are symptoms of dysfunctional development, resulting from human acts of omission and commission.[11] Prevention is possible and cost-effective. Economists emphasize self-interest to explain how people choose prevention. This study suggests that the risk of disaster incidence is associated with economic development. Economic self-interest is therefore dependent upon sustainable development that reduces the risk of disaster.

During the past century, human development has made great strides (eg, life expectancy, poverty, and child mortality). But these accomplishments have not come without a cost. Economic development has also exploited planetary resources at an unprecedented rate, creating new and burgeoning health threats. Along with progress, human development (proxied here in this study as world real GDP) has also included maladaptive practices like uncontrolled industrialization, rapid urbanization (often creating high population densities in high-risk locations), globalization of hazards, explosive population growth, industrialized conflict, and increasing degrees of poverty in low- and middle-income nations. Anthropogenic actions are known to have damaged earth's planetary systems to create more disaster hazards (eg, climate change) while also creating built environments that result in high levels of hazardous exposures (eg, impoverished mega-cities in high-risk zones).[1,10]

These long-standing dysfunctional practices correspondingly require long-term, sustainable approaches that include consideration of planetary health and "health in all policies."[1,12] Heeding Dennis Mileti's visionary warning that "We design our own disasters," notice should now be taken that *we also design our own planet.*[13] The health and safety of this planet and its inhabitants are inextricably linked to human development. Sustainable development protects planetary health which, in turn, sustains human health.

Sustainable development can be defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs.[14] It is an organizing principle that, like planetary health, is intended for advancing human development while also sustaining the ability of natural systems to provide the resources and services upon which the society depends. There are now 17 UN Sustainable Development Goals (SDGs) that provide a roadmap for human development.[14] These SDGs address the root causes of dysfunctional development and maladaptation that are also (not coincidentally) the root causes of disasters.[14]

Disaster Risk Reduction as a Means for Climate Change Adaptation

Disaster risk does not occur randomly. Risk occurs when vulnerable assets (eg, populations) are exposed to an environment containing hazardous agents. Risk (in this case, expressed as the likelihood of mortality) can be increased over time by: (1) an increase in the frequency of the disaster type (eg, flood); (2) an increase in the number of people exposed; and/or (3) an increase in population vulnerability to that hazard.

All disease (including disaster-related illness and injuries) is caused by a complex interaction between the person (host), the disease agent (hazard), and the environment (exposure).[15] Recently, the overall approach to emergencies and disasters has shifted from post-impact activities (ie, ad hoc relief and reconstruction) to more systematic and comprehensive process of pre-impact disaster risk reduction (DRR; ie, prevention, preparedness, and mitigation) as well as post-impact humanitarian and development action (ie, recovery and resilience):[16,17] "The underlying drive of disaster management is to *reduce risk* both to human life and to systems important to livelihood;"[18] "Climate change adaptation needs to become part and parcel of comprehensive disaster risk management."[16,18]

Derived from Wharton's risk equation, disaster risk is thought to occur when vulnerable populations are exposed to dangerous hazards that overwhelm their collective capacity to prevent damages or loss.[19,20] In the past, it has been postulated that increases in societal capacity (the combination of all the strengths, attributes, and resources available) result in a reduced risk of disaster incidence.[21] However, the results of this study appear to contradict this notion. Instead, these findings suggest that an increasing societal capacity (here measured in terms of GDP) has been associated with six decades of increasing risk of disaster incidence, not a reduction. In addition, modern gains in health status suggest an overall lessening of vulnerability among the world's population, not an increase. It could therefore be posited that the global incidence of disasters during the past century may be largely attributable to increasing frequency of hazards along with rising levels of population exposure to these hazards that are associated with maladaptive economic development.

The results of this study suggest that disaster risk is not reduced by increasing capacity alone. To reduce the risk of climate-related disasters, societal capacity must be applied in ways that target the elimination or avoidance of disaster-related hazards and exposures. In other words, societal capacity must be appropriated for DRR. The goal of sustainable development is to utilize this same economic capacity to establish preventive control over disaster risk as a cost-effective, "no regrets" approach for climate change adaptation.

Climate change has been called the "greatest threat to global public health."[22] Sustainable development prioritizes long-term growth that will reduce the risk of disasters over time. Decisions regarding economic development should therefore also include a "health in all policies" approach that recognizes the dependency of human development on planetary health.

Study Limitations

In general, disaster events are the subject of gross approximations and aggregations that have a great deal of imprecision. A time bias has been reported in the EM-DAT data before the year 1995.[23] The availability and quality of data has reportedly increased since the inception of EM-DAT in 1973 and improved over time with the use of multiple data sources.

In comparison, other disaster databases (ie, DesInventar dataset) reportedly have a greater number of recorded events than the EM-DAT for certain hazards.[23] On the contrary, EM-DAT shows larger mean disaster damages along with a higher statistical range compared to the DesInventar dataset. Further, in DesInventar dataset, consistent data are available for a select 70 countries until 2013 only (as compared to 120 countries until 2020 in EM-DAT).[23] The basic structure of the datasets and the data collection methods may influence the magnitude of the recorded damages along with possible human errors while data entering.

However, such events are likely to remain unknown or unrecorded, which could contribute to an uncertain degree of under-estimation of disaster incidence. While 60 years of trend data appear to be sufficient for statistical power in this preliminary comparison, improved reporting of disaster incidence would improve the accuracy of the data and the validity of such conclusions. The findings of this study further highlight the need for a more systematic and standardized disaster database.

Conclusion

The global incidence of four weather-related (hydrometeorological) disasters appear to be positively associated with world real GDP from 1961-2020. These findings contradict previous postulates that the risk of disaster incidence is inversely associated with the capacity of the population.

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Calculations Comparing GDP and Disaster Subgroups												
Adjusted R-Square	0.762											
F-Significance	1.02×10^{-16}											
Disaster Subgroup	Biological		Climatological		Geophysical			Hydrological		Meteorological		
P Value of Disaster Subgroup	.0012		.503		.211			5.59×10^{-10}		.013		
Calculations Comparing GDP and Disaster Types												
Adjusted R-Square	–0.016		0.143		0.057			0.61		0.553		
F -Significance	0.584		0.005		0.098			4.67×10^{-13}		1.73×10^{-10}		
Disaster Types According to Subgroup	Epidemic	Infestation	Drought	Wildfire	Earthquake	Volcano	Dry Land-Slide	Flood	Wet Land-Slide	Heat	Cold	Storm
P Value of Disaster Type	.302	.631	.794	.004	.066	.242	.354	6.21×10^{-10}	.862	.002	.007	4.23×10^{-4}
Correlation Coefficient	–0.241	0.207	0.058	0.822	0.359	0.730	–1.245	0.187	0.034	0.996	0.444	0.179

Table 2. Results of Regression Analysis Comparing world GDP to Five Subgroups and 12 Corresponding Types of Natural Disasters, 1961–2020
Abbreviation: GDP, gross domestic product.