

The Consequences of COVID-19 Disruption on Sustainable Economy in the Top 30 High-Tech Innovative Countries

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Abstract

This study aims to investigate the effects of the COVID-19 pandemic on the innovation index, Gross Domestic Product (GDP), high technology exports, and human development (HDI) in the world's leading 30 high-tech innovative countries. Using grey relational analysis models, the association between COVID-19 and other economic development indices was investigated. The model selects the country least affected by the pandemic from the top 30 innovative countries through a conservative (maximin) method based on grey association values. Data was collected from World Bank databases and analyzed to compare pre- and post-COVID-19 periods (2019, 2020). The outcomes of this study provide essential recommendations for industries and decision-makers with suitable action plans to preserve economic systems from further harm caused by the global COVID-19 outbreak. The ultimate goal is to boost the innovation index, GDP, high-tech exports, and HDI of high-tech economies and pave the way for a sustainable economy. To the author's knowledge, this is the first study to develop a multidimensional framework to assess COVID-19's impact on the sustainable economy of top 30 high-tech innovative countries, and to conduct a comparative analysis to identify the strong and weak effects of COVID-19 on sustainable economic growth.

Keywords: Covid-19, Economic sustainability, Exports of high technology, Gross domestic product (GDP), High-tech Innovative countries, Human Development Index (HDI)

Paper type: Research Paper

1. Introduction

On November 16, 2019, the virus was detected in Wuhan, China. Despite other countries' efforts to block its introduction, the virus soon spread around the world. The World Health Organization (WHO) officially proclaimed a worldwide pandemic on March 11, 2020.

The pandemic's impact has been felt first on the human capital by millions of infections and thousands of fatalities every day. Some countries' national health systems, such as Italy's, have failed. The government's primary aim has been to find a balance between social, economic, and healthcare concerns. (Priya et al., 2021)

Due to operational restrictions implemented by governments from various countries, the virus's propagation had an economic impact worldwide. This was the first time in many years that a sanitary crisis had caused a global financial impact. (Vitenu-Sackey & Barfi, 2021). The decrease in output, the loss of human capital, the closing of businesses and the bankruptcy of others, the disruption of international trade, and the annihilation of tourism have all affected the global economy.

Investors lost their confidence in markets and economic activities have slowed to the point where it has practically come to a halt in certain regions of the world. (Song et al., 2020)

Actions to restrict trade had a detrimental influence on the economy of such 30 nations. They were most obvious in the form of intra- and inter-country production and trade losses. The pandemic has had an impact on the staple sectors of various nations' economies, which has an impact on their GDP.

The Covid-19 epidemic is an exceptional public health concern with significant economic consequences. It has proven that the healthcare system is far more important than the financial one. Coping with a financial crisis is difficult but dealing with a health crisis is considerably harder since it impacts humans. (Pak et al., 2020)

Throughout history, it has been recognized that distinct events have both advantages and downsides. Their negative side is that they generate social and economic stresses and crises, but their positive side is that they create new technical opportunities and promote innovation and research, and development. In this environment, the covid 19 epidemic has pushed the world into technical changes, resulting in numerous breakthroughs that have already had a short-term impact and have the potential to have a long-term influence. (Zimmerling & Chen, 2021)

Through its innovation index, the World Intellectual Property Organization (WIPO) indicated that corporations and governments around the globe invested in research and development during covid 19. The effect of the pandemic has resulted in disparity among sectors and nations. Only developed economies have increased their R&D spending, according to the ranking (UN., 2021)

The overall influence has been different ways of dealing with businesses. The GII's Global Innovation Tracker indicates that enterprises producing software, information and communications technology, hardware and electrical equipment, medicines, and biotech boosted their R&D and innovation spending (GII., 2021).

Covid 19 has paralyzed economic activity across the world. The Global Innovation Index, announced in September 2020, the likelihood of a possibly strong downward impact of the pandemic on the technology industry, whether in terms of investment or international trade (WIPO., 2021).

However, as recent forecasts show, more people are working from home as a result of COVID-19. High-tech commerce may overtake product trade because of an expansion in communications, computing, processing, and data storage technology aimed at remote and mobile workers (Singh et al., 2022).

Could the COVID-19 pandemic catalyze innovation? It's worth considering. Many major technology companies have the financial resources and expertise to continue researching new ways to improve industry efficiency, enhance comfort, and protect the environment. These companies are unlikely to give up on these efforts, especially since they have the resources to pursue them. In addition, the heightened concern for health and safety has increased public pressure on environmental issues, potentially leading key industries such as transportation and logistics to more quickly adopt environmentally neutral practices, which may only be achievable through innovation (Ikram et al., 2022).

The recent epidemic caused chaos in the economy. Conditions are currently comparable to poverty rates last observed in the 1980s on several metrics of human development. On the other hand, the crisis had a significant impact on all aspects of human growth, including income

earnings (UNDP, 2021). The long-term socially and economic implications of the COVID-19 outbreak, as per UNDP, would widen the gap between people dwelling in rich and poor countries (2020). With disadvantaged countries bearing the brunt of COVID-19 cases and associated mortality, the 2030 Agenda asks for strong policy measures to ensure that no one falls behind (SDG Integration, 2021).

All these factors put governments under intense pressure to plan for the COVID-19 pandemic's post-crisis phase. Finally, the development of a free trade zone is necessary to shield the economy of the nations from the grab of global insecurity in the price of vital products. A variety of industries is critical and should be viewed as an industrial policy for governments (Gondwe, 2021).

The goal of this study is to evaluate the impact of Covid-19 on the economic growth of the world's 30 most innovative countries, as evaluated by the innovation index, GDP, high-tech exports, and HDI. This study is unique since no assessment has previously been conducted using the indices, notably the grey analysis technique. This study aims to investigate the impact of COVID-19 on the innovation progress of the top 30 high-tech countries, which are major contributors to the global economy. To do so, we have developed an integrated framework and used the novel Grey Relational Analysis method to examine the relationship and influence of COVID-19 on Gross Domestic Product, high-tech exports, and the Human Development Index. One of the main advantages of grey models is that they can be applied to small and incomplete data sets. To the best of our knowledge, this is one of the first studies to analyze the disruption caused by COVID-19 on the sustainable economy of the top 30 high-tech countries. The results of this study provide valuable insights for policy and decision-makers on how to restore innovation performance and create action plans for handling similar crises in the future. We believe that by finishing this study, we will understand:

Q1. What is the extent of the disruption to the sustainable economies of high-tech, innovative countries due to COVID-19??

Q2. What recommendations or precautions can be put in place based on the study's findings to prevent or mitigate the impact of future pandemics?

The paper is organized as follows: In Section 2, we review the literature on the effects of COVID-19 on the Human Development Index, high-tech exports, Gross Domestic Product, and the innovation index. In Section 3, we describe the Grey Relational Analysis models and data collection. The results and discussion are presented in Section 4. Finally, in the last section of the study, we present the conclusion and limitations of the study.

II. Literature

Unlike past coronavirus outbreaks, such as SARS or MERS, which mostly afflicted certain parts of the world, the new coronavirus, COVID-19, is affecting nations all over the world. This article examines the worldwide phenomenon's impact on specific technologies. It investigates both the influence of viral propagation on technology exports and use, as well as the impact of this on the economic growth of the nations that employ such technologies. Given the possibility of another epidemic, this paper also considers how these tools could be useful in the future. For this goal, the technological obstacles, related creative logic, and their societal repercussions are investigated. (Brem et al., 2021)

The current coronavirus outbreak is a major public health issue with disastrous economic effects such as inadequate nutrient supply and healthcare. The findings of previous research indicate that the current pandemic would exacerbate wealth disparity, and they are among the first analyses of the pandemic's marketplace and welfare consequences in developing countries (Das et al., 2022; Serbulova et al., 2020; Shahriar et al., 2022).

The current viral outbreak has serious economic consequences for the affected countries. Owing to early death, workplace absenteeism, and lower productivity, the 2020 epidemic has had a direct impact on income, as well as an inverting input shock, with industrial economic work reducing due to global mishaps and plant closures. In China, for example, the output index decreased by over than 54% in February compared to the preceding.

In contrast to the impact on income-generating activities, consumers' purchasing patterns have shifted significantly downward, owing to decreasing income and finances, as well as the dread and panic connected with the epidemic. As a result, travel, tourism, hospitality, and transportation have all suffered significant losses. According to the International Air Transport Association (IATA, 2020), airlines have lost up to \$314 billion in revenue from passenger transportation alone. Eateries, travel and mobility, leisure, and delicate industries are among the businesses most impacted by containment constraints put by the virus pandemic. In April 2020, the advanced seasonally adjusted insured unemployment rate in the United States reached a new high of 11 percent. (Pak et al., 2020)

1. Covid-19 and Innovation

The earliest body of literature investigates the connection between Covid-19 propagation and innovation. Greater information was offered about state tendencies during emergencies vs. regular times, focusing on which tools were used quite often during the Covid-19 period versus normal times, such as formal consultative process and experts; research grants and postgraduate loans and scholarships; connectivity and participatory platforms; and dedicated support to research infrastructures. (Patrucco et al., 2021). The technology sector faced significant challenges due to lockdown measures, driving demand for telecommunication services. The Coronavirus has greatly impacted the semiconductor industry, a key component of technology, due to its globally dispersed supply chain. Semiconductor companies have had to manage rising costs, extended lead times, and supply shortages while meeting customer demand, with most of their production happening overseas (Hasan et al., 2023)

During difficult situations, such as a pandemic emergency, the viral epidemic appears to be the spark for unprecedented disruption in health and educational institutions. While abstracted has been demonstrated that tabletop exercises and apocalyptic works might forecast our current situation, who among us could have foreseen a pandemic in the near future? Innovations that have existed for years or decades but have gone unnoticed have now become the standard. (Rahman et al., 2020., Woolliscroft, 2020).

However, the COVID-19 pandemic has uncovered flaws in the US healthcare system and underlined the need for greater innovation. In this Invited Commentary, I discuss a few instances of inventive answers. (Ahuja et al., 2020).

During the COVID-19 pandemic, flexible manufacturing systems have enabled some companies to rapidly alter their production processes and produce urgently needed tools for hospitals, such as ventilators for patients and hand sanitizer for medical staff (Ambrogio et al., 2022). Ventilators are important for treating coronavirus, as it is a respiratory disease that can cause severe complications for some patients. In severe cases, a ventilator is needed to oxygenate the air in the lungs and help remove carbon dioxide. Many countries have faced a shortage of ventilators during the crisis, often because they did not have sufficient stockpiles or because production had been outsourced to other countries. Even if existing ventilator manufacturers had increased production in the early months of the pandemic, there would still have been a shortage of ventilation and breathing equipment (Moosavi., 2022).

Prior to the sanitation crisis, technology was already considered a threat to human jobs and economic dominance. The problem of robotics is emerging as millions of people lose their jobs and millions more see their working conditions degrade. Machine intelligence computers that function as effective "social agents" may pose a severe threat to human labor (Talapatra et al., 2022).

Interactional and artistic machinery has been employed to imply that the creative class has strong reasons to re-evaluate their vocation. In the face of such predicted advances in general automated, computing will become a notably touchy matter within the creative economy, serving as both a helper and a competitor. (Nobre, 2020; Talapatra., 2022)

What we can conclude from this is that the epidemic cleared the way for scientific innovation, as seen by the advancement of digital technology, and artificial intelligence, as well as the rapid advancement of vaccine production (UN, 2021).

The literature unanimously agrees that innovation is the "lifeline" of a thriving and advanced society. As per Joseph Schumpeter, long-term economic success requires innovation, and new innovative items will kill old ones, a concept known as "creative destruction." (Farinha et al., 2018). Four distinct techniques have been taken in the literature to investigate the link between innovation and economic development. To begin, the resource hypothesis of the innovation growth connection says that Granger innovation leads to economic growth. The economic basis for it is that new findings and innovations will result in new goods and increased company productivity, all of which will contribute to economic growth. (Woolliscroft, 2020). Innovation in entrepreneurship is crucial for preparing goods/services for the market and improving production and dissemination, especially during the COVID-19 pandemic. Entrepreneurial ventures require various forms of support, starting with financial needs that vary based on the scale, innovation, human capital, and growth timeline of the initiative (Polas et al., 2021).

Furthermore, the demand following theory of the innovation growth relationship says that economic expansion Granger creates innovation. The economic explanation for this is that countries with great growth in the economy want to invest more resources in boosting innovation to remain competitive globally. (Furman et al., 2002; Grossman & Helpman, 1991).

Furthermore, according to the innovation growth nexus's spillover concept, both innovation and economic boom indirectly cause each other. Lastly, the neutral concept of the innovation performance link says that technology and economic growth are not indirect causes of one another. Many proponents of this idea believe that economic advancement is determined by traditional co-products rather than by innovation (Pradhan et al., 2020).

Advancement has emerged as a vital part of the global market and economic growth, with a considerable impact on the Gross Domestic Product of advanced nations (GDP) (Serbulova et al. 2020).

As has already been stressed in current history, an expanding number of research studies have presented experimental evaluations of the viability of global and subnational economies. The World Economic Forum's (WEF) Global Competitiveness Report (GCR) is a significant output with a globally recognized reputation (Brem et al. 2021).

Since 1979, the WEF has issued the Global Competitiveness Report (GCR). The number of nations covered in the worldwide comparison is now 148, with these countries accounting for more than 97% of global GDP (Farinha et al., 2018).

Moreover, countries consider innovation methods to be beneficial in terms of leveraging scientific and technological resources to develop ideas quickly and in limited time intervals. Considering the many styles of innovation policies used by various governments, we found that some mechanisms are more successful than others in developing and promoting innovation for faster disaster response. (Patrucco et al., 2021).

3. Covid-19 and economic growth (GDP)

The economic consequences of the COVID-19 outbreak are mostly due to a drop in demand, which means that fewer people are ready to buy the commodities and services that are available in the global economy. This dynamic was readily visible in businesses that were highly impacted, such as travel and tourism. Governments have imposed border controls to slow the spread of the virus, and many people have been unable to book flights for vacations or business trips. Airlines lost expected revenue due to the decrease in customer demand, and as a result, they had to cut costs by lowering the number of flights they performed (Statista, 2021).

At the beginning of the virus propagation, there was no way to tell exactly what the economic damage from the global COVID-19 coronavirus pandemic will be, there was a widespread agreement among economists that it will have a severe negative impact on the global economy. Early estimates predicted that, should the virus become a global pandemic, most major economies will lose at least 2.9 percent of their gross domestic product (GDP) over 2020 (Statista, 2021a). The COVID-19 pandemic has caused the global economy to shrink, expected to hit major economies that import from innovative textile

products. World Footwear (2020) predicts a 22.5% decrease in global footwear consumption due to the pandemic's effects. The FSC is grappling not only with an economic downturn but also with social sustainability issues brought on by the COVID-19 impact (Sarkar et al., 2021).

The pandemic has caused chaos in people's lives in all countries and communities and will have a negative impact on global economic growth in 2020 unlike anything seen in nearly a century. According to estimates, the virus slowed global economic growth in 2020 to roughly -3.2 percent on an annualized basis, with a recovery of 5.9 percent expected in 2021. Global trade is expected to shrink by 5.3 percent in 2020, but to grow by 8.0 percent

the following year the impact of the COVID-19 pandemic on the world economy has been severe, having already exceeded the expected GDP loss. According to the International Monetary Fund (IMF), global GDP contracted by 3.9 percent from 2019 to 2020, the worst slump since the Financial Crisis. While the global economy is expected to recover in 2021, the recovery has been uneven, and gaps in vaccination access and coverage may jeopardize progress in many parts of the world (KFF, 2021).

The World Bank claimed in its preliminary evaluation of the global economic forecast for 2022 that the world economy would not resume this year. It forecasts that worldwide development will slow from 5.5 percent in 2021 to 4.1 percent in 2022, 3.2 percent in 2023, and 3 percent in 2024. Unless that pent-up consumption is fading, and fiscal and monetary support is being reduced globally (World Bank, 2021).

4. Covid-19 and Exports of High Technology

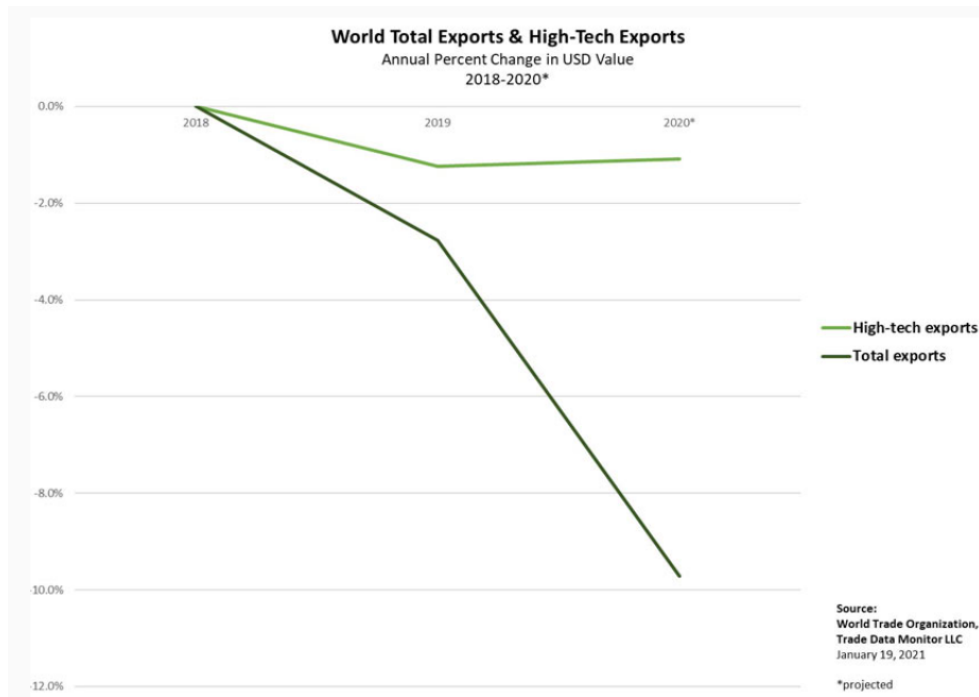
As per earlier research, Exports account for almost half of Commonwealth member nations' worldwide commercial trade, with 35 items accounting for more than 80%. The pandemic shock was described as a worldwide negative shock that harmed all industries and marketplaces. Indeed, according to the estimations in this research, commodity exports to destination markets have declined by \$98 billion in 2020 when compared to business as usual (CNUCED, 2020).

When the pandemic began, high-tech economies had to make a difficult choice: implement lockdowns and risk increasing poverty or refrain from lockdowns and allow the virus to spread. Fortunately, advanced economies were able to mitigate the social and economic effects of the pandemic-induced recession thanks to their efficient social welfare systems and a higher percentage of employment in virtual service industries. Nearly 90% of the \$9 trillion invested in responding to the crisis has gone to G20 countries, which make up 65% of the global population. Meanwhile, the most vulnerable countries have received only \$1 trillion (Espitia et al., 2022). Countries with effective public health systems were able to better manage the pandemic and minimize its human and economic consequences. Many other countries, however, struggled to deal with the emergency and faced shortages of medical personnel, equipment, and expertise. The COVID-19 crisis has exacerbated the gap in GDP per capita between the Global North (advanced economies including Australia and New Zealand) and the Global South (all emerging economies), reversing much of the progress made in the past decade (Verschuur., 2021).

According to consensus estimates, this corresponds to a 19% to 24% drop in exports. All destinations are characterized by epidemic estimates that are lower than their corresponding hypotheticals. Exports to the United States have suffered the most, amounting to \$41 billion to \$50 billion, followed by exports to the European Union (\$33 billion to \$41 billion) and China (\$18 billion to \$26 billion) (WIPO, 2021).

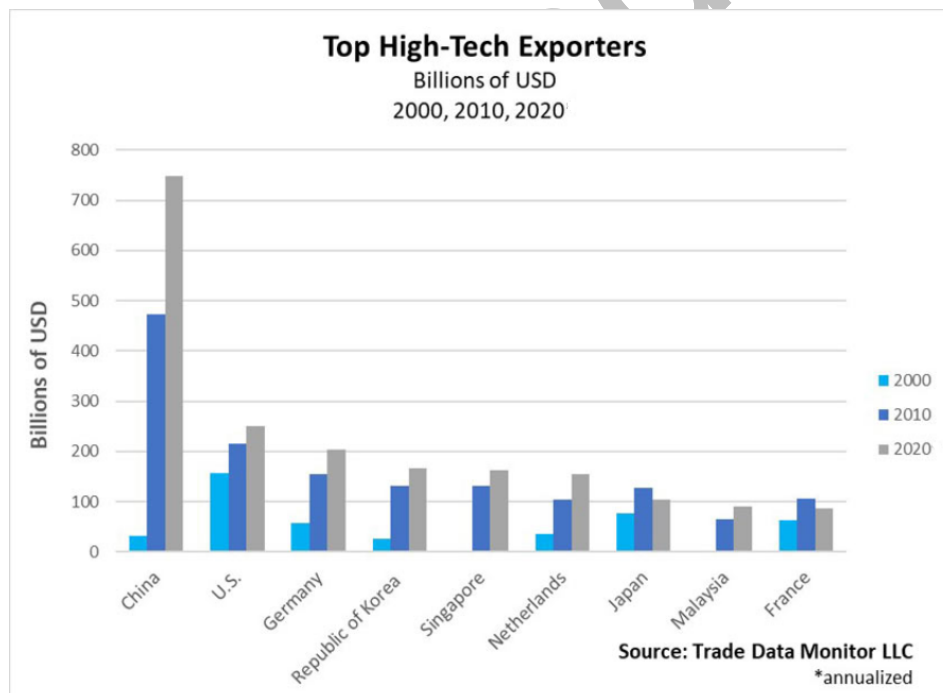
Furthermore, despite a general decline in exports, high technology exports were able to surpass merchandise trade during the pandemic due to an increase in distant working caused by multiple government restraint periods. The graph below compares total export trends to high-technology export trends (Saha et al., 2022).

World Total High-technology exports



The graph below depicts the ranking of high technology exports of the world's top high exporters for the year 2020.

Top High-Tech Exporters



Since the onset of the COVID-19 pandemic, the world economy has taken a significant hit. The World Commerce Organization (WTO) forecasted in April 2020 that an optimistic scenario would result in a 12.9 percent decrease in world trade in 2020, while a pessimistic scenario would result in a 32 percent decrease. In October 2020, the WTO presented a freshly updated prediction considering the changed scenario, estimating a 9.2 percent drop in global merchandise trade. This pandemic has a long incubation period, a high transmission rate, and rigorous controls over persons gathering and moving. As a result, given the new circumstances, the impact of the pandemic on the industry is projected to be

bigger than that of SARS in 2003, and the influence on the reorganization and layout of the domestic economy in China, Japan, and South Korea would be more significant. (Wei, 2021)

5. Covid-19 and HDI

The COVID-19 pandemic is more than a global health catastrophe; it is a systemic human development crisis, reflecting our relationship with the ecosystem in which we live, which is already having an extraordinary impact on the economic and social elements of development. Individuals and society must be able to better weather and recover from shocks if policies to reduce vulnerabilities and strengthen crisis-fighting capacity are implemented, both in the short and long term (UNDP, 2021).

As per the latest UNDP analysis, the lengthy social and economic consequences of the COVID-19 epidemic will expand the difference between people living in affluent and poor countries. With impoverished countries bearing the burden of COVID-19 cases and death, the 2030 Agenda calls for strong policy decisions to ensure that no one is left behind (SDG Integration, 2022).

The poverty gap between countries is projected significantly widen one year after the outbreak. As per UNDP, by 2030, almost eight out of ten persons forced into poverty as a result of COVID-19 will live in low-income nations, with Africa bearing the brunt of the burden (SDG Integration, 2022).

Some researchers believe that the global COVID-19 epidemic can be predicted by considering macro variables such as population size, the Human Development Index (HDI), and migration rate. Infectious diseases and respiratory infections have higher mortality rates in countries with lower HDIs (Heo et al., 2022; Mirahmadizadeh et al., 2022). However, a study in Italy found that HDI was directly related to both infection rates and COVID-19 mortality rates (Fabiani et al., 2021). COVID-19 has created a significant burden worldwide and understanding the incidence and mortality of the disease and its associated risk factors can help us better understand the nature and course of the disease. Despite extensive research on the etiology of COVID-19, there are still many unknown aspects of the disease, and its socioeconomic elements have received less attention. Previous studies have only looked at the changes in HDI components after COVID-19, rather than the effect of HDI components on the disease. HDI is also a factor that affects the incidence and mortality of patients, but there is little evidence of the role of social development in controlling COVID-19. Previous studies have not examined the role of HDI and its components on global cumulative cases, in top high-tech export countries. Therefore, this study aims to investigate the association and influence of COVID-19 and HDI.

The UNDP's second flagship research lays out real policy alternatives in governance, social protection, the green economy, and digitalization to assist practitioners in carrying out these pledges and designing fundamentally new futures. The assessment produced in partnership with the University of Denver's Pardee Centre for International Futures expands on a core research study. The study assesses the effects of three distinct COVID-19 outcomes on the SDGs, concentrating on countries with low or medium Human Development Indexes (HDI) The Human Development Indicator (HDI) is a composite index that assesses average achievement in four major pillars of social progress: living a long and healthy life, obtaining knowledge, and enjoying a fair standard of living.

6. Covid-19 and Exports of High Technology

As per earlier research, resources account for almost half of Commonwealth member nations' worldwide commercial trade, with 35 items accounting for more than 80%. The pandemic shock was described as a worldwide negative shock that harmed all industries and marketplaces. Indeed, according to the estimations in this research, commodity exports to these five destination markets are likely to decline by \$98 billion to \$123 billion in 2020 when compared to businesses as

usual. COVID-19 and commodities: Assessing the impact on exports from Commonwealth countries (CNUCED, 2020).

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Since the onset of the COVID-19 pandemic, the world economy has taken a significant hit. The World Commerce Organization (WTO) forecasted in April 2020 that an optimistic scenario would result in a 12.9 percent decrease in world trade in 2020, while a pessimistic scenario would result in a 32 percent decrease. In October 2020, the WTO presented a freshly updated prediction in light of the changed scenario, estimating a 9.2 percent drop in global merchandise trade. This pandemic has a long incubation period, a high transmission rate, and rigorous controls over persons gathering and moving. As a result, given the new circumstances, the impact of the pandemic on the industry is projected to be bigger than that of SARS in 2003, and the influence on the reorganization and layout of the domestic economy in China, Japan, and South Korea would be more significant (Wei, 2021).

III. Data and Methodology:

This study aims to explore the potential impact of COVID-19 on Innovation, Exportation of high technology (current US\$), GDP, and HDI. We chose and ranked the top 30 countries according to the innovation index before the pandemic to highlight the influence on innovative countries. In terms of economic growth, we used the GDP index, with values calculated in the current USD. The value of high-technology exports is calculated in the current USD. The human development index was used to do a multidimensional assessment of human development (HDI). In our study, we looked at the innovation index, high-tech exports, GDP, and human development index for the years 2019 and 2020, which correspond to the pre-Covid-19 and post-Covid-19 periods, respectively. Finally, the total number of COVID-19 instances in the 30 innovative countries was tallied from January 1, 2020, to December 31, 2021.

Table 1: Description of study variables

<i>VARIABLES (CODE)</i>	<i>DESCRIPTION OF VARIABLES</i>	<i>MEASUREMENT</i>	<i>DATA SOURCES</i>
COVID-19	Covid-19 confirmed cases	Total number of Covid-19 confirmed cases	Our world in data
GII	Global Innovation Index	Innovation Index, ranking of countries by their capacity for, and success in, innovation	World Intellectual Property Organization
High-Technology Exports	High-Technology Exportations	Exportations of High-Technology in current US\$	The World Bank Data
GDP	Gross domestic product	Taking the quantities of all goods and services produced in each country	The World Bank Data
HDI	Human development Index	Life expectancy, education, and GNI per capita	UNPD / The Global Economy

The current COVID-19 pandemic is a once-in-a-generation event. It happened at the start of the second decade of the twenty-first century when global economic uncertainty was at an all-time high. Understanding these uncertainties is critical for analyzing the pandemic's impact on the global economy, assessing the effectiveness of policy measures in combating the pandemic and reviving the global economy, and forecasting the post-pandemic economic recovery trajectory (Song et al., 2020).

To test the inter-relationship between COVID-19 case numbers and the economic indicators, we went with an Absolute GRA (AGRA) model, since it is one of the best models that deals with uncertain systems or events such as the Covid-19 pandemic that we are living in.

Grey relational analysis

GRA models, or grey relational models, have garnered a lot of attention in recent years because of their usage in a range of fields such as management, engineering, finance and economics, environmental engineering, and conventional medicine (Xu et al., 2018). The currently available absolute grey relational analysis (Absolute GRA) model, commonly known as the absolute degree grey incidence analysis (ADGIA) model, is more suited to dealing with uncertain systems represented by uncertain data. It can handle both linear and nonlinear data arrays with consistent and inconsistent motion directions at the same time. (Javed & Liu, 2019)

The approach provides a grey relational degree, which is a composite measure of the relationship's direction and strength. GRA effectively handles tiny sets of data, as well as grey values, and produces optimal results (Ikram et al., 2021). The work is significant both conceptually and practically, particularly for data analysts concerned with the ambiguous linkages between diverse data arrays in general and grey systems analysts. (Zang et al., 2018). In this study, we employed a novel approach called Grey Relation Analysis (GRA) to analyze our dataset. GRA is known for its ability to produce persuasive findings and mitigate endogeneity issues when acquiring variables. Additionally, GRA is particularly relevant for this study due to its high precision when working with limited datasets (Ikram et al., 2020). Another advantage of GRA is its ability to handle missing information without compromising the results of the analysis. To further strengthen the validity of our findings, we also utilized the conservative maximin criteria method to evaluate the impact of our variables.

Our GRA approach will consist of four major steps in this research. During the first step, we retrieved all of the necessary data for the analyses from several sources. The data was then run through the GRA model in the second phase to analyze the relationships between COVID-19 instances and the innovation index, high-tech exporting, GDP, and HDI among the world's top thirty innovative nations. The third step includes using the GRA ranking technique, which uses the weights created in the second stage and assigns them to the alternatives after setting the choice criteria. The conservative model goes through the analytical findings in the last and fourth stages to determine the most optimum solution (the variable or collection of variables), which significantly demonstrates how the top thirty creative nations in the globe were influenced by the COVID-19- epidemic.

There are three types of proximities in GRA models. If Deng's GRA model relates partial closeness/proximity, then absolute GRA relates integral closeness/proximity between two data sequences, whereas the second synthetic GRA aims to reveal a more comprehensive closeness or inclusive proximity (Ikram et al., 2020). Based on the SS degree of grey connection values, a conservative model was employed to examine which nations had the least intensifying effects among the top 30 creative countries.

The data for this study came from Our World in Data, the World Intellectual Property Organization, The World Bank Data, and UNPD / The Global Economy. To apply Deng's relational grey analysis approach, you must use the appropriate procedures, which include assessing two subsets of data ω_0 and ω_η (Sheikh et al., 2019).

And to do so, you must work with a system that is separated into the five sections listed below:

The first procedure is to calculate Deng's GRA, which displays the equation of our two datasets δ_0 and δ_η , $i=1, 2, 3, \dots, m$, where

$$\omega'_\eta = \frac{\omega_\eta}{\omega_\eta(1)} = (\omega'_\eta(1), \omega'_\eta(2), \dots, \omega'_\eta(n)); \eta = 0, 1, 2, 3, 4, \dots, m. \quad (1)$$

The second action is to determine the difference between the δ'_0 and δ'_t sequence, where $\eta = 1, 2, 3, 4, \dots, m$ and presented as:

$$\eta(I) = \|\omega'_0(I) - \omega'_\eta(I)\|, \Delta = (\Delta\omega(1), \Delta\omega(2), \dots, \Delta\omega(n)), \eta = 1, 2, 3, \dots, m. \quad (2)$$

The following phase attempts to determine the highest and lowest points, where:

$$M = \max_{\eta} \max_i \Delta_{\eta}(\mathfrak{T}), \quad (3)$$

$$m = \max_{\eta} \max_i \Delta_{\eta}(\mathfrak{T}), \quad (4)$$

Grey incidence coefficients are measured at this phase using the following formula, where 0.5 is the value of the characteristic coefficient ς .

This last stage involves calculating the Grey Relational Degree (GRG) using the following expression.

$$\xi_{0\eta} = \sum \mathfrak{T} = 1/n(\xi_{0\eta}(\mathfrak{T}) \times \omega\mathfrak{T}); \eta = 1, 2, 3, 4, \dots, m. \quad (5)$$

In equation (5), $\sum \omega\mathfrak{T}=1$ and $\frac{1}{n}$ represent equally distributed criteria.

Absolute degree of GRA model

Using Deng's GRA model, makes it is possible to analyse the relationships between research variables more effectively rather than using typical statistical approaches (Ikram et al., 2021). Using this rigorous econometric method in research allows for insights into the geometric closeness between the sequential study arrangement and the data on study parameters and their relationship to the intended structure.

To analyse the GRA in the research model we need access to 2 time periods ω_0 and ω_η .

This analysis is composed of three phases:

- Use the different time intervals ω_0 and to measure the base point ω_0^0 and ω_1^0 .
- Estimate $|\gamma_0|$, $|\gamma_1|$ and $|\gamma_1 - \gamma_0|$.
- Calculate the μ_{01} ADGRA different period using the δ_0 , δ_1 sequence.

After these performing steps, we have the formula to estimate ADGRA which is: $\mu_{01} = \frac{1+|\gamma_0|+|\gamma_1|}{1+|\gamma_0|+|\gamma_1|+|\gamma_1-\gamma_0|}$ (6)

Deng's degree of GRA

Deng's suggested GRA model that involves adopting Deng's degree known as Grey Relational Grade (GRG) or Degree of Grey Incidence Analysis (DGRA) after the absolute GRA. The mathematical form of DGRA is shown in equations (7) and (8) that follow (8), in which $\xi_{0\eta}(\mathfrak{T})$ is grey relational coefficient (GRC).

$$\xi_{0\eta} = \sum_{i=1}^n (\xi_{0\eta}(\mathfrak{T}) \times \lambda_i); \eta = 1, 2, 3, 4, \dots, m, \quad (7)$$

Or

$$\xi_{0\eta} = \frac{1}{n} \sum_{i=1}^n (\xi_{0\eta}(\mathfrak{T})); \eta = 1, 2, 3, 4, \dots, m, \quad (8)$$

Equation (7) shows the weighted DGRA, while equation (8) represents the non-weighted scheme.

The formula for weight measurements is given below,

$$\beta_{01} = \frac{1 + |\gamma_0| + |\gamma_1|}{1 + |\gamma_0| + |\gamma_1| + |\gamma_1 - \gamma_0|} \quad (9)$$

If the data sequence of the system behaviour is represented as $\omega_\eta = (\omega_\eta(1), \omega_\eta(2), \dots, \omega_\eta(n))$ and that $\mathcal{C}$ denotes the operator of the sequence, such that satisfies $\delta_\eta(L)\mathcal{C} = (\omega_\eta(L)\mathcal{C} - \omega_\eta(1)); \mathfrak{T} = 1, 2, 3, \dots, n$. Then, $\mathcal{C}$ is a point operator starting from zero and $\delta_i\mathcal{C}$ known as zero-scale point image of δ_i . $\delta_i\mathcal{C}$ is often written:

$$\omega_{\eta} \mathcal{C} = \omega_1^0 = (\omega_{\eta}^0(1), \omega_{\eta}^0(2), \dots, \omega_{\eta}^0(n)) \quad (10)$$

According to Liu et al. (2017), if we suppose that the length of variables δ_i and δ_j are same of one-time-interval sequences and δ_i and δ_j are zero-starting point images follow as:

$$\omega_{\eta}^0 = (\omega_{\eta}^0(1), \omega_{\eta}^0(2), \omega_{\eta}^0(3) \dots, \omega_{\eta}^0(n)) \quad (11)$$

$$\omega_{\theta}^0 = (x_{\theta}^0(1), \omega_{\theta}^0(2), \omega_{\theta}^0(3) \dots, \omega_{\theta}^0(n)). \quad (12)$$

Then it is considered that:

$$|\varsigma_{\eta}| = \left[\sum_{i=2}^{n-1} \omega_{\eta}^0(\mathfrak{T}) + \frac{1}{2} \omega_{\eta}^0(n) \right] \quad (13)$$

$$|\varsigma_{\theta}| = \left[\sum_{i=2}^{n-1} \omega_{\theta}^0(\mathfrak{T}) + \frac{1}{2} \omega_{\theta}^0(n) \right], \quad (14)$$

$$\begin{aligned} |\varsigma_{\eta} - \varsigma_{\theta}| &= \left[\sum_{i=2}^{n-1} (\omega_{\theta}^0(\mathfrak{T}) - \omega_{\eta}^0(\mathfrak{T})) + \frac{1}{2} (\omega_{\eta}^0(n) - \omega_{\theta}^0(n)) \right], |\varsigma_{\theta}| \\ &= \left[\sum_{i=2}^{n-1} \omega_{\theta}^0(\mathfrak{T}) + \frac{1}{2} \omega_{\eta}^0(n) \right], \end{aligned} \quad (15)$$

Second Synthetic Degree of Grey Incidence Analysis model

Now next approach is to use Second Synthetic Degree of Grey Incidence Analysis (SSDGRA) to estimate how close the two curves are using the previously provided data sequences. This model can be estimated through the following equation (Javed and Liu, 2018):

$$\beta_{\eta\theta} = \delta \epsilon_{\eta\theta} + (1 - \delta) \varpi_{\eta\theta}; \delta \in [0,1], \quad (16)$$

In which:

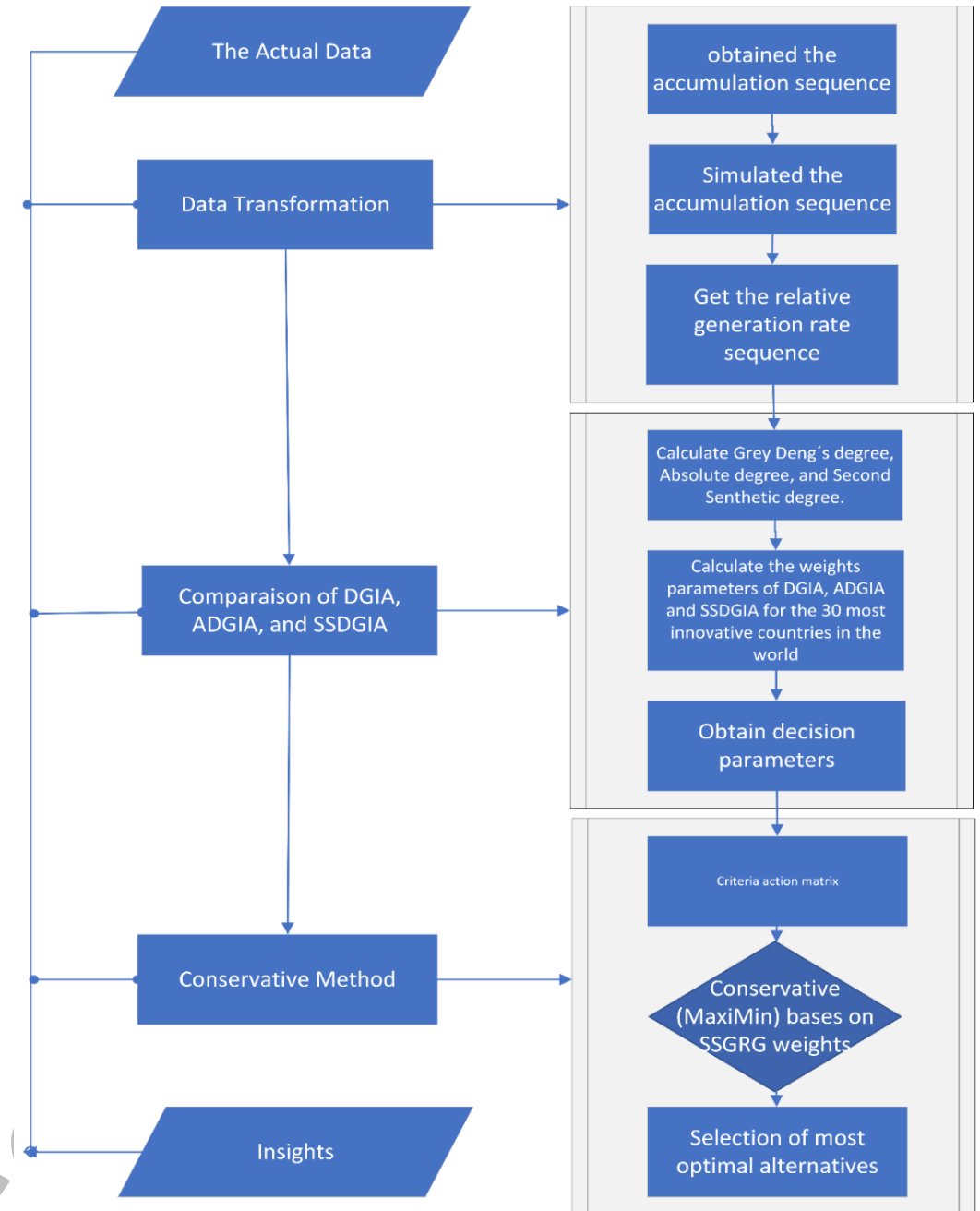
$\beta_{\eta\theta}$ = SS degree of grey relation (SSGRG),

$\epsilon_{\eta\theta}$ = Absolute Degree of grey relation (absolute GRG)

$\varpi_{\eta\theta}$ = Deng's degree of grey incidence/grey relation (GRG).

The figure below depicts the overall description of the research analysis.

General framework of the study



IV. Results and Discussion:

Table 2: The association between the number of COVID-19 cases and the innovation index (INV) for the 30 most innovative countries in the world is seen in Table 2. Absolute GRG statistics indicate that Estonia achieved the highest ranking with a score of (0,90781), indicating that it was severely affected by COVID in 2020. The United States and the Republic of Korea ranked second and third, respectively, based on their association scores: (0.90684) and (0.90684). (0.892489). According to the absolute GRG results, Canada, Austria, and Australia were the least impacted nations. They scored (0,23898), (0,5396), and (0,5704).

According to the findings of the Deng's GRG study done on the 30 most innovative countries in the world, China, the Czech Republic, and Singapore were rated with the highest values (0,79171), (0,74711), and (0,68274), respectively. indicating that these are the top three nations affected by COVID-19 in terms of innovation. In contrast, the Deng's GRG research revealed that Germany, New Zealand, and Spain were the least impacted nations, with scores of (0,4611), (0,46705), and (0,48727), respectively.

The SSGRG model, on the other hand, exhibited a combination of the two preceding GRG series of sorting patterns between the number of people affected by the pandemic and the innovation index for the 30 most innovative countries in the globe. Japan (0.818435), Switzerland (0.76253), and France (0.73286) were the most afflicted nations by the virus, indicating that they were the least innovative among the 30 most innovative countries in the globe owing to the effect of the covid-19 outbreak. On the other side, the SSGRG data revealed that Cyprus, Norway, and Denmark were the least affected nations, with respective scores of (0,37628), (0,533055), and (0,5451).

The WIPO Global Innovation Index recognized the likelihood of a possibly strong negative effect of the virus crisis on innovation expenditure and trading in September 2020. Even though Japan is one of the top 30 most inventive countries in the globe and has made major contributions to virus-preventive innovation, the pandemic had a detrimental impact on Japan, as its innovation index decreased from 54.7% in 2019 to 52.7% in 2020 (GII, 2021).

The Global Innovation Index illustrates how the epidemic has affected several enterprises. Overall, businesses in the fields of programming, hardware, internet and communication technologies, and household devices, as well as medicines and biochemistry, expanded their innovation and development expenditures. On the other hand, sectors that were severely impacted by pandemic preservation efforts and whose business models relied on human activities, such as transportation and tourism, had to reduce their expenditure on innovation-related themes.

The first year of the pandemic brought both positive and negative changes compared to the pre-pandemic year. Specifically, business sophistication in Romania showed a decline compared to the pre-pandemic year. This suggests that many businesses in the country suffered significant losses and the impact was felt in multiple areas. In terms of knowledge workers and absorption, the pandemic had a negative impact on businesses, with the most significant impact being on innovation linkages. This finding is consistent with the work of Zahra (2021), who argued that the COVID-19 crisis was unprecedented in both its health and economic impacts and resulted in global economic losses of up to \$90 trillion as people were "staying at home" for extended periods.

Governments and businesses throughout the globe have increased their efforts in innovation in response to the tremendous human and economic casualties of the COVID-19 epidemic. Nonetheless, the effect of the pandemic spread was so severe that most nations saw a drop in their innovation score. France is one of these nations, and even though it has improved its innovation ranking from 12th to 16th in 2019, its innovation index has decreased from 54,2 to 53,7 (GII, 2021).

GRA assessment for COVID-19 and Global innovation index (GII) in the 30 most innovative countries in the world for the year 2020

Countries	Absolute GRG	Deng GRG	SS GRG
Japan	0,8595	0,6062	0,7329
Switzerland	0,8713	0,5400	0,7056
France	0,7168	0,5496	0,6332
UK	0,8672	0,5359	0,7015
Iceland	0,7383	0,5087	0,6235
Luxembourg	0,7021	0,6019	0,6520
Germany	0,8111	0,4611	0,6361
USA	0,9068	0,5323	0,7196
Hong Kong	0,8593	0,5618	0,7106
Italy	0,6929	0,5919	0,6424
China	0,8452	0,7917	0,8184
Estonia	0,9078	0,5064	0,7071
Spain	0,6283	0,4873	0,5578
Republic of Korea	0,8925	0,5451	0,7188

Czechia	0,6762	0,7471	0,7116
Ireland	0,6842	0,5224	0,6033
Canada	0,2390	0,5136	0,3763
Israel	0,7217	0,4907	0,6062
Sweden	0,6291	0,4873	0,5582
Singapore	0,8423	0,6827	0,7625
Netherlands	0,8487	0,6041	0,7264
Belgium	0,6428	0,4892	0,5660
Malta	0,8585	0,5156	0,6871
Australia	0,5704	0,5255	0,5479
Austria	0,5396	0,5265	0,5331
New Zealand	0,6232	0,4671	0,5451
Finland	0,6695	0,4881	0,5788
Denmark	0,7782	0,5058	0,6420
Norway	0,6599	0,4981	0,5790
Cyprus	0,6772	0,5691	0,6231

Table 3: The table shows the correlation between the number of COVID-19 cases and high-tech exports in current US dollars for the 30 highly innovative countries in the globe. The COVID epidemic has had the greatest impact on the high-tech exports of the following countries, according to absolute GRG data: the Netherlands (0,952236), the United States (0,948990), and Spain (0,94857). The nations whose high-technology exports were least harmed by the COVID-19 viral spread were Denmark, New Zealand, and Germany, with Absolute GRG ratings of (0,51992), (0,640473), and (0,803818), respectively.

We discovered that Japan, with a score of (0,695312), Spain, with a score of (0,68678), and Israel, with a score of (0,67976), were the countries most impacted by the pandemic in terms of high technology exports based on the results of Deng's GRG analysis performed on the world's 30 most innovative countries. Denmark (with a score of 0.447467), Estonia (with a score of 0.451477), and Australia (with a score of 0.490898) were the least affected nations in terms of high-technology exports.

The SSGRG analysis, from the other hand, exhibited a mixture of the two preceding GRG series regarding the extent to which the COVID-19 pandemic influenced the world's 30 most innovative countries' high-technology exports. Table 3 clearly reveals that the most impacted nations are the United States (0,817675), the United Kingdom (0,8153475), and Switzerland (0,81148). Hong Kong, Australia, and Austria, on the other hand, were the least affected nations, with scores of (0,4836935), (0,5864505), and (0,633318).

Imports have increased faster than manufacturing capacity in the United States, indicating that key macroeconomic mechanisms are contributing to these imbalances. The overall US export deficit remained negative at roughly 8% in November 2021, while the import gap was filled in May 2021 and stabilized at positive 1.8 percent in November (OECD, 202). In the first 11 months of 2020, the USA boosted imports of tablets and laptops by 20.9 percent to USD45.2 billion (WIPO, 2021). At the end of 2021, significant imbalances among trade partners and goods continued, most notably a rising merchandise trade surplus in Asia and a growing merchandise trade deficit in the United States and Africa (OECD, 2021).

Due to the unusually large amount of disruption to both supply and demand, as well as the rise in trade prices caused by the lack of workers, transportation problems, and travel restrictions, the COVID-19 accident seems to have had a large, close-by effect on trade flows in the United Kingdom. The crisis has shown how fragile many global supply networks are, which has led to a drop in exports.

The COVID-19 pandemic had a significant impact on high-tech supply chains in 2020, with factory closures, slowed shipping lines, and reduced consumer demand causing significant damage. It seemed that global businesses were facing an existential threat. However, as the year progressed, manufacturers and logistics managers were able to adapt and make their businesses work. Sales rebounded in the summer and autumn as demand increased, partly due to strong sales of work-from-home technology. In March 2020, exports by China, the world's top high-tech manufacturer, fell to USD54.5 billion, a decline of 8.1% from the previous year. Shipments to the US from China declined 21.7% to USD7.5 billion in March. The impact was widespread, with exports of phones decreasing 7.8% to USD8.4 billion, data processing machines down 14.3% to USD6.9 billion, and routers decreasing 12.9% to USD3.2 billion (Jin et al., 2022).

Switzerland was indeed experiencing a historic economic decline. In response to the epidemic, some nations imposed severe restrictions on their communities and businesses. Similarly, the Swiss government shut down most of the country's civic spaces; this had a substantial influence on the local economy, resulting in a large loss in worldwide commerce and demand for Swiss exports owing to a 25 percent drop in industrial production (Deloitte, 2021).

Since the COVID-19 pandemic has disrupted normal business operations, many governments have implemented policies such as tax reductions and funding subsidies to support corporate development and stimulate their economies (Song et al., 2020). Azoulay and Jones (2020) argued that governments should encourage research and development (R&D) activities in the fight against COVID-19. China, for example, has increased investment in high-tech industries (such as 5G telecommunications, big data, cloud computing, e-commerce, online education, and advanced medicine manufacturing), which have played a critical role in the fight against COVID-19 (Austermann et al., 2020). Examining China's high-tech industries can provide insight into the important role of R&D investment in addressing the COVID-19 pandemic.

GRA assessment for COVID-19 and High Technology exports in the 30 most innovative countries in the world for the year 2020

Countries	Absolute GRG	Deng GRG	SS GRG
USA	0,9490	0,6135	0,7812
UK	0,8359	0,5830	0,7095
Switzerland	0,8942	0,6546	0,7744
Sweden	0,8318	0,5789	0,7054
Spain	0,9486	0,6868	0,8177
Singapore	0,8689	0,6296	0,7492
Republic of Korea	0,8249	0,6227	0,7238
Norway	0,9274	0,6640	0,7957
New Zealand	0,6405	0,5324	0,5865
Netherlands	0,9522	0,5576	0,7549
Malta	0,9089	0,6591	0,7840
Luxembourg	0,9263	0,6616	0,7939
Japan	0,9354	0,6953	0,8153
Italy	0,8038	0,5716	0,6877
Israel	0,9432	0,6798	0,8115
Ireland	0,8533	0,5963	0,7248

Iceland	0,9258	0,5690	0,7474
Germany	0,8038	0,5716	0,6877
France	0,9161	0,5736	0,7449
Finland	0,8926	0,5450	0,7188
Estonia	0,8152	0,4515	0,6333
Denmark	0,5199	0,4475	0,4837
Czechia	0,9098	0,6571	0,7835
Cyprus	0,8928	0,5555	0,7242
China	0,8469	0,5236	0,6853
Canada	0,9289	0,6309	0,7799
Belgium	0,8244	0,5563	0,6903
Austria	0,8371	0,5782	0,7076
Australia	0,8414	0,4909	0,6662
Hong Kong	0,9102	0,5960	0,7531

Table 4: This table demonstrates the connection between Covid 19 instances and Gross Domestic Product (GDP) for the 30 most innovative nations in the globe. Absolute GRG data indicate that the economic system (0,896159), Australia (0,886752), and Germany (0,88299) have suffered the most from the covid-19 epidemic. Estonia, Switzerland, and Sweden, with corresponding ratings of (0,42769), (0,43469), and (0,44299), have seen the least negative effect of the epidemic on their GDP in comparison.

According to the findings of the Deng's GRG study done on the 30 most innovative countries in the world, Austria (0,94363), Republic of Korea (0,89873), and Spain (0,89463) were the countries most affected by the covid pandemic in terms of GDP within our sample. Canada with a Deng's GRG score of (0,44673), Italy with a Deng's GRG value of (0,46049), and Luxembourg with a Deng's GRG value of (0,48008) were the countries that were least affected by covid-19 in terms of their gross domestic product.

The SSGRG approach, on the other hand, clearly demonstrated that Norway, with a score of 0.826919, Republic of Korea, with a score of 0.814046, and Singapore, with a score of 0.809244, are the countries that saw the biggest influence on their Gross domestic product (GDP) from pandemic propagation among the top 30 most innovative nations in the world. Israel, Ireland, and Iceland, with respective values of (0,44711), (0,49486), and (0,529795), were the least affected nations, according to the SSGRG analysis.

Most economies experienced a decline in GDP growth in the first quarter of 2020. The United States, the world's largest economy, saw a 1.3% drop in GDP growth during the January to April quarter compared to the previous quarter. The US implemented regional restrictions on movement due to the pandemic in mid-March, but the first quarter only captured two weeks of the lockdown. The impact of the lockdown was more significant in the second quarter due to increased outbreaks of COVID-19 and restrictions in different states. Mexico faced a similar situation, with restrictions implemented in mid-March and a 1.6% decline in GDP growth in the first quarter of 2020 (Bojorquez et al., 2021).

In 2020, when the coronavirus broke out, many Norwegian businesses made a point of saying that they had fewer ventures and more closings. In March 2020, 68 percent of organizations had less demand, which put them at risk of going out of business (Statista, 2021). Additionally, in January, household expenditure decreased by 3.1%. The largest contributor to the total decline was a 4.4 percent decline in the quantity of products purchased. In January 2021, fewer automobiles were purchased. The steps adopted to prevent infections, which were the primary emphasis of the month, decreased service use by 0.9%. All of these factors contributed to a snowball effect that decreased the Norwegian GDP as a whole (SSB 2022).

South Korea never implemented a complete quarantine, instead relying on intensive testing and contact tracing, mask-wearing, and further safety precautions to stop the spread of COVID-19. Nevertheless, the virus delivered a serious damage to the world

economy, including South Korea. The outcome was a 0.85% decline in South Korea's GDP in 2020 (Statista, 2021).

In 2020, the pandemic produced substantial worldwide economic problems. The economy of Singapore had its worst full-year slump since statehood. During the year, the industry faced both supply and demand shocks, such as a decline in external demand for Singapore-produced goods and services due to the stagnation in advanced economies and global border controls, supply disruptions, and the application of curfews (MTI, 2020).

As a result of supply and demand shocks and disruptions industrial activities, In the second quarter of 2021, the GDP decreased by 1.4%. The Singapore Economy Has Gone through Several Phases of Adjustment during the COVID-19 Pandemic Phases of Economic Contraction and Expansion. Countries that rely heavily on tourism and the service industry, such as France and Spain, were most severely impacted by the COVID-19 pandemic. Asian countries, on the other hand, saw modest growth from January to March. India's GDP grew 2.38% in this quarter compared to the previous quarter, though India implemented a nationwide lockdown on March 25th, so this growth does not reflect the full impact of the lockdown. Instead, it reflects the already slowing economy prior to the outbreak of COVID-19. Interestingly, air pollution, a byproduct of economic activity, decreased during this period (Anbarasan and Sushil., 2021). The Japanese economy, meanwhile, contracted by 0.5% from January to March compared to the previous quarter, marking the second straight quarter of economic decline due to reduced exports amid the US-China trade war and a slump in consumer spending.

GRA assessment for COVID-19 and Gross domestic Product (GDP)

in the 30 most innovative countries in the world for the year 2020

Countries	Absolute GRG	Deng GRG	SS GRG
Norway	0,8529	0,7438	0,7983
Republic of Korea	0,4991	0,8987	0,6989
Singapore	0,7722	0,6971	0,7347
Spain	0,4950	0,8946	0,6948
Sweden	0,4430	0,5467	0,4949
Switzerland	0,4347	0,6803	0,5575
UK	0,8331	0,6835	0,7583
USA	0,8962	0,7223	0,8092
Hong Kong	0,7678	0,8861	0,8269
Australia	0,8868	0,7148	0,8008
Austria	0,5182	0,9436	0,7309
Belgium	0,6270	0,5341	0,5806
Canada	0,4475	0,4467	0,4471
China	0,5346	0,6404	0,5875
Italy	0,5991	0,4605	0,5298
Japan	0,7744	0,7334	0,7539
Luxembourg	0,6171	0,4801	0,5486
Malta	0,7433	0,6894	0,7164
Netherlands	0,6274	0,5942	0,6108
New Zealand	0,8742	0,6242	0,7492
Cyprus	0,8135	0,8146	0,8140
Czechia	0,8187	0,6626	0,7407
Denmark	0,5906	0,5675	0,5791
Estonia	0,4277	0,6826	0,5552
Finland	0,8151	0,7975	0,8063
France	0,5890	0,7004	0,6447
Germany	0,8830	0,7342	0,8086

Iceland	0,7218	0,7324	0,7271
Ireland	0,7606	0,5409	0,6507
Israel	0,6964	0,5026	0,5995

Table 5: The interaction between the number of COVID-19 cases and the human development index (HDI) for the 30 most innovative countries on the globe is seen in Table 5. In terms of human development index, the absolute GRG data suggests that Cyprus 0,810049, Denmark 0,800642, and the United States 0,79688 were the countries most affected by COVID-19 in our sample. The data also indicates that Iceland, the Netherlands, and Malta have respective Absolute GRG scores of (0,34158), (0,34858), and (0,35688), which means they were the least affected countries during this period. According to the results of the Deng's GRG analysis performed on the world's 30 most innovative countries, Estonia, with a Deng's GRG score of (0,95486), Italy, with a Deng's GRG score of (0,90996), and Luxembourg, with a Deng's GRG score of (0,90586), had the most affected human development index by the COVID-19 epidemic. France, Norway, and Singapore, on the other hand, were the least impacted nations, scoring (0,45796), (0,47172), and (0,49131), respectively.

The SSGRG model, on the other hand, exhibited a mix'ure of the two preceding GRG series, with China having the highest SSGRG score (0,789479), Italy and Japan having the second and third highest SSGRG scores of (0,776606), and (0,771804). In contrast to this, Austria, Australia, and Hong Kong, with SSGRG values of (0,40967), (0,45742), and (0,492355), are the nations with the least impaired human development index, according to the data.

The viral outbreak began in China, and the country has been hit with a health scare as the number of infected people has topped 100,000. In response to the COVID-19 outbreak in December 2019, China implemented a number of behavioral and therapeutic techniques to tackle the worldwide pandemic. It has been consistently shown that during epidemics, healthcare consumption reduces owing to transportation restrictions, social distancing efforts, and worries about viral transmission inside public hospitals. Each of these factors has had a substantial impact on the fluctuation of China's human development index (UNDP, 2021).

During the first months of the viral pandemic, Italy ranked third globally in total number of illnesses and first in total number of fatalities (Onder et al., 2020). This is mostly due to the fact that the Italian demographic differs from that of other nations; around 23% of the Italian population is aged 65 or older, and COVID-19 is more fatal in older individuals (Gallo et al., 2021), this extremely high death rate has placed Italy's human development index on a downward trend through 2020.

COVID-19 pandemics can be controlled more effectively in countries with HDI due to better detection in those areas. Previous research has also shown that there is a negative correlation between literacy and gross national income with the case fatality rate for COVID-19. However, this same research also found that an increase in the mean number of school years was associated with an increase in both the incidence and mortality rate for COVID-19. This may be because higher health literacy and awareness of the early symptoms of the disease can lead to earlier diagnosis. Overall, HDI explains a significant amount of the variance in the cumulative incidence rate of cases, the number of COVID-19 tests performed, and the cumulative incidence rate of death in countries with populations of 10 million or more. HDI explains approximately 53%, 44%, and 37% of the variance in the number of COVID-19 tests performed, the cumulative incidence rate of cases, and the cumulative incidence rate of death, respectively. However, other factors may also contribute to these indices.

The pandemic has generated a human development crisis not seen since the Global Financial Crisis of 2007-2009, since it has negatively impacted health, education, and income. The number of COVID-19-related deaths in Japan has surpassed 30,000 as of today; these damages are record-breaking occurrences that reverse human development advancement (UNDP, 2021).

GRA assessment for COVID-19 and Human development index (HDI) in the 30 most innovative countries in the world for the year 2020

Countries	Absolute GRG	Deng GRG	SS GRG
China	0,7667	0,7550	0,7609
Italy	0,4130	0,9100	0,6615
Japan	0,6861	0,7084	0,6972
Luxembourg	0,4089	0,9059	0,6574
Malta	0,3569	0,5580	0,4574
Netherlands	0,3486	0,6916	0,5201
New Zealand	0,7470	0,6948	0,7209
Cyprus	0,8100	0,7336	0,7718
Czechia	0,6817	0,8973	0,7895
Denmark	0,8006	0,7261	0,7634
Estonia	0,4321	0,9549	0,6935
Finland	0,5409	0,5454	0,5431
France	0,3614	0,4580	0,4097
Germany	0,4485	0,6517	0,5501
Norway	0,5130	0,4717	0,4924
Republic of Korea	0,6883	0,7447	0,7165
Singapore	0,5310	0,4913	0,5112
Spain	0,6572	0,7007	0,6789
Sweden	0,5413	0,6054	0,5734
Switzerland	0,7881	0,6354	0,7117
UK	0,7274	0,8259	0,7766
Belgium	0,7326	0,6738	0,7032
Canada	0,5045	0,5787	0,5416
Iceland	0,3416	0,6939	0,5177
Ireland	0,7290	0,8088	0,7689
Israel	0,5029	0,7117	0,6073
USA	0,7969	0,7455	0,7712
Hong Kong	0,6357	0,7437	0,6897
Australia	0,6745	0,5521	0,6133
Austria	0,6103	0,5139	0,5621

In the overall analysis of this research, Japan demonstrated significant negative associations between COVID-19 and the Innovation Index, whereas the United States demonstrated a strong negative link between high technology export performance and COVID-19 among the 30 most inventive nations impacted by COVID-19. According to the second synthetic GRG shows that Norway's negative correlation between Covid-19 and GDP was the strongest. Also, China showed the strongest negative connection between Covid-19 and HDI.

We ranked the top thirty innovative countries based on the innovation index, high-tech exporting, GDP, and HDI, after generating weights utilizing GRA models. In the process stage, the analysis will determine which country has the least severe effect of the COVID-19 outbreak on its economy and industry. To do this, we developed the decision parameters indicated in Table 7. The result is $v(O_i, X_j)$, where $i = 1, 2, 3, 4$ and $j = 1, 2, 3, 4, \dots, 30$. Let S_1, S_2, S_3 , and S_4 represent the innovation index, high-tech exports, GDP, and HDI for the 30 most innovative countries in the world, respectively.

GRA examination of 30 most innovative countries in the world affected by COVID-19:

Variables	Grey Relational Model	Ranking
COVID-19 & Innovation Index	Second Synthetic GRG	Japan>Switzerland>France>Iceland>Luxembourg>Germany>Hong Kong>Italy>China>Estonia>Spain>Republic of Korea>Czechia>Ireland>Canada>Israel>Sweden>Singapore>Netherlands>Belgium>Malta>Australia>Austria>New Zealand>Finland>Denmark>Norway>Cyprus
COVID-19 & High Technology Exports	Second Synthetic GRG	USA>UK>Switzerland>Sweden>Spain>Singapore>Republic of Korea>Norway>New Zealand>Netherlands>Malta>Luxembourg>Japan>Italy>Israel>Ireland>Iceland>Germany>France>Finland>Estonia>Denmark>Czechia>Cyprus>China>Canada>Belgium>Austria>Australia>Hong Kong
COVID-19 & GDP	Second Synthetic GRG	Norway>Republic of Korea>Singapore>>Spain>Sweden>Switzerland>UK>USA>Hong Kong>Australia>Austria>Belgium>Canada>China>Italy>Japan>Luxembourg>Malta>Netherlands>New Zealand>Cyprus>Czechia>Denmark>Estonia>Finland>France>Germany>Iceland>Ireland>Israel
COVID-19 & HDI	Second Synthetic GRG	China>Italy>Japan>Luxembourg>Malta>Netherlands>New Zealand>Cyprus>Czechia>Denmark>Estonia>Finland>France>Germany>Norway>Republic of Korea>Singapore>Spain>Sweden>Switzerland>UK>Belgium>Canada>Iceland>Ireland>Israel>USA>Hong Kong>Australia>Austria

Decision parameters description:

Goal	Measuring grey relation (association) between innovation index, exportation of high-technology, GDP, and HDI within the 30 most innovative countries in the world
State of nature/criteria $a(X_j)$ $j=1,2,3,\dots,n$	Switzerland (S1), Sweden (S2), USA (S3), Netherlands (S4), UK (S5), Finland (S6), Denmark (S7), Singapore (S8), Germany (S9), Israel (S10), Republic of Korea (S11), Ireland (S12), Hong Kong (S13), China (S14), Japan (S15), France (S16), Canada (S17), Luxembourg (S18), Norway (S19), Iceland (S20), Austria (S21), Australia (S22), Belgium (S23), Estonia (S24), New Zealand (S25), Czechia (S26), Malta (S27), Cyprus (S28), Spain (S29), Italy (S30)
Alternative	Grey Relation of COVID-19 and innovation Index in 30 innovative countries (a1)

actions (a _i); i=1,2,...m	Grey Relation of COVID-19 and High-technology exports (current US\$) in 30 innovative countries (a2) Grey Relation of COVID-19 and GDP (current US\$) in 30 innovative countries (a3) Grey Relation of COVID-19 and HDI superior 30innovative countries (a4)
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Table 8: Show the SSDGRA, which allows us to decipher the links between the research elements to organize the variables and get the qualification result. Then, for the 30 most inventive countries, we utilize a modelling approach to analyses the impact of COVID-19 on the innovation index, high-tech exports, GDP, and HDI.

Finally, we used the conservative (maximum) model I (Ikram et al., 2019a, 2019b; Rehman et al., 2020) to identify the 30 most inventive countries in the world with the least severely affected countries, as shown in table 8. Since our key objective is to minimize the superior criterion, we aim to extract the smallest value of V from the SSGRG matrix model for each nation in this study. Following this operation, the conservative model produces the following optimal solution:

SSGRG criteria-based matrix:

SS GRG	a1	a2	a3	a4
S1	0,7625	0,8115	0,8008	0,5734
S2	0,6231	0,7957	0,8063	0,6073
S3	0,7106	0,8177	0,7583	0,5112
S4	0,6033	0,7744	0,6447	0,7634
S5	0,7264	0,8153	0,7983	0,5621
S6	0,5479	0,7095	0,5575	0,6972
S7	0,5451	0,7054	0,5806	0,7117
S8	0,6062	0,7840	0,8092	0,6574
S9	0,7116	0,7238	0,5486	0,6897
S10	0,6235	0,7449	0,4471	0,5177
S11	0,6424	0,7835	0,8140	0,6615
S12	0,6361	0,7248	0,4949	0,5201
S13	0,7071	0,4837	0,7539	0,4924
S14	0,7015	0,6877	0,7271	0,7895
S15	0,8184	0,7492	0,6989	0,7718
S16	0,7329	0,7188	0,5552	0,6935
S17	0,6332	0,6853	0,7309	0,5431
S18	0,7188	0,7531	0,6948	0,7712
S19	0,5331	0,7812	0,8269	0,6789
S20	0,7196	0,7242	0,5298	0,5416
S21	0,5582	0,6333	0,7407	0,4097
S22	0,5660	0,5865	0,7492	0,4574
S23	0,5790	0,6662	0,7347	0,5501
S24	0,6871	0,7076	0,5791	0,7032
S25	0,5578	0,7799	0,6108	0,7609
S26	0,6420	0,6903	0,5875	0,7165
S27	0,5788	0,7549	0,6507	0,7689
S28	0,3763	0,6877	0,5995	0,7209
S29	0,6520	0,7939	0,8086	0,6133
S30	0,7056	0,7474	0,7164	0,7766

Finally, we used the conservative MiniMax and MiniMin model to determine which countries among the top thirty COVID-19 affected high innovation countries have the least (or highest) intensifying impact of COVID-19. This was based on the results of the SSGRG matrix model. The MiniMax model yields the minimal value of V for each country, with the goal of minimizing the impact of COVID-19 on these countries. Ikram et al. (2019a, 2019b) and Javed & Liu (2018) and also used this model in their studies. The results are shown in Table 8.

$$\text{Min } a_i \{ \max X_j v(a_i, X_j) \} = \max a_i \begin{Bmatrix} 0,8115 \\ 0,8063 \\ 0,8177 \\ 0,7744 \\ 0,8153 \\ 0,7095 \\ 0,7117 \\ 0,8092 \\ 0,7238 \\ 0,7449 \end{Bmatrix} \begin{Bmatrix} 0,8140 \\ 0,7248 \\ 0,7539 \\ 0,7895 \\ 0,8184 \\ 0,7329 \\ 0,7309 \\ 0,7712 \\ 0,8269 \\ 0,7196 \end{Bmatrix} \begin{Bmatrix} 0,7407 \\ 0,7492 \\ 0,7347 \\ 0,7076 \\ 0,7799 \\ 0,7165 \\ 0,7689 \\ 0,7209 \\ 0,8086 \\ 0,7766 \end{Bmatrix} = 0.7076 \text{ (Estonia)}$$

The results show that the overall grey relation between COVID-19 and other factors is the strongest for Estonia. This indicates that the impact of COVID-19 on Estonia is the most significant compared to the other factors. The MiniMin model yields,

$$\text{min } a_i \{ \max X_j v(a_i, X_j) \} = \max a_i \begin{Bmatrix} 0,5734 \\ 0,6073 \\ 0,5112 \\ 0,6033 \\ 0,5621 \\ 0,5479 \\ 0,5451 \\ 0,6062 \\ 0,5486 \\ 0,4471 \end{Bmatrix} \begin{Bmatrix} 0,6424 \\ 0,4949 \\ 0,4837 \\ 0,6877 \\ 0,6989 \\ 0,5552 \\ 0,5552 \\ 0,6948 \\ 0,5331 \\ 0,5298 \end{Bmatrix} \begin{Bmatrix} 0,4097 \\ 0,4574 \\ 0,5501 \\ 0,5791 \\ 0,5578 \\ 0,5875 \\ 0,5788 \\ 0,4063 \\ 0,6133 \\ 0,7056 \end{Bmatrix} = 0.4063 \text{ (Cyprus)}$$

The results show that the overall grey relation between COVID-19 and other factors is the weakest for Cyprus. This indicates that the impact of COVID-19 on Cyprus is the least significant compared to the other factors. Thus, the Cyprus system is more resilient to the effects of COVID-19.

V. Conclusion and Policy Implications:

This research examines the effects of the real spread of the Covid-19 virus on the innovation index, high-tech exports, GDP, and HDI of the 30 most innovative countries in the world. To examine the probable link between the numerous indicators and the amount to which the pandemic has influenced the nation's economic structure, we chose to utilize unique, comprehensive computational methods, in particular the GRA methodology. To do this, the Absolute GRG, Deng's GRG, and Second Synthetic GRG were determined. This method proved helpful for identifying the most inventive countries to enhance commerce. We advocate using comparable methods for assessing other international commerce and comparing the results to our conclusions.

On a range of human development criteria, the global virus pandemic and its ramifications for human development are currently equivalent to the handicap levels seen in the 1990s. This viral epidemic exposed flaws and inequities in present national systems since it affected the world's most creative countries. Our findings about the severity of this outbreak's impact in the most inventive nations are detailed below.

No one understood what influence the epidemic would have on innovation when it struck. History suggested that innovation investments would be hard hit. According to the findings of the first index GRG, the viral outbreak has affected most of the top creative countries, with Japan being the most affected.

Throughout time, the detrimental effects of the pandemic condition become obvious. For instance, the epidemic has effectively halted all industrial and logistical activities. As a result, thousands of transactions were cancelled or delayed, resulting in

substantial losses and a detrimental impact on economic growth. In terms of high-tech exports, the United States and the United Kingdom suffered the most as a result. Because these were the countries who faced the brunt of the closure's repercussions. Proportional to GDP, our third indicator. We've seen that the preponderance of countries was hit, since their exports were limited during the suspension periods, and they faced considerable challenges. According to GRG analysis, because of the epidemic, Norway and the Republic of Korea have suffered a significant drop in their gross domestic output. Israel, on the other hand, was the least affected among the world's 30 most innovative countries.

The HDI has declined in all nations, with China suffering the most. Existing social efforts that have been proved to lessen inequality must be extended, and gaps and deficiencies must be addressed. People who are economically disadvantaged should be addressed while developing recovery and rescue plans and initiatives.

All the circumstances induced by the viral epidemic demonstrate that the virus constantly damaged most countries and that they all struggled throughout these eras. Therefore, the leaders and governments of these nations should consider the following policies to control the effects of Covid-19 this pandemic on their economic systems, and more particularly to mitigate the consequences to their innovation level, high technology exports, GDP, and HDI after the pandemic outbreak. The major policies are as follows:

First, governments must engage in more targeted and planned collaboration, especially with local and national stakeholders. Partnership should be strengthened by utilizing this to allow better coordinated and collaborative investments, reduce duplication and waste, and strengthen concerted actions for more successful local and national innovation programs. Furthermore, they must ensure and maintain an emphasis on the underprivileged and abandon no one alone. This involves the creation of appropriate structures and processes to ensure that innovation efforts and results are as inclusive as possible.

Second, governments may achieve a global agreement to give much more regularity and certainty on the accessibility of carrying value in international markets, as well as to generate trust that commerce will continue to flow to help future pandemic management. Arrangements might include ensuring transparency, decreasing tariffs on essential medical supplies, and enforcing export limitations. This might involve an agreement to limit export limits on certain categories of materials or to codify stringent usage conditions.

Third, governments must avoid unconsciously accumulated savings from becoming precautionary savings because of economic insecurity and unemployment. They must create an anti-bankruptcy shield that targets problematic industries and enterprises, as well as assist the buying power of low-income families, who have the highest proclivity to spend.

Finally, when it comes to the human development index, it must be regularly changed and adjusted to match the challenges of the day. It is not a question of abandoning its essential notions, which remain vital to tackling today's various problems, but rather of relying on them to lead us through the instability of the new geological period. If present HDI conditions are maintained, its people, including future generations, will have infinitely less alternatives rather than more. While various macroeconomic policies have been implemented in response to the COVID-19 pandemic, which have led to declines in global FDI, GDP, and trade, these measures may not be sustainable in the long term unless restrictions and containment measures are eased. High-tech economies are at risk of high government debt, which could hinder sustainable economic development. However, if pandemic control measures are lifted, there is the potential for an economic rebound if fiscal and monetary policies, consumer support, and investor confidence are restored. The COVID-19 pandemic has disrupted global value chains, demand, and supply, causing financial challenges for businesses. Governments can support multinational enterprises, particularly in high tech countries, by providing tax relief such as tax waivers, credits, and deferrals. Financial support in the form of grants, subsidies, and low-interest loans can also help compensate for reduced cash flow. Governments can also adopt a more flexible regulatory approach, including extending regulatory deadlines and waiving permit, license, and fee requirements, to reduce costs for businesses. Governments should also consider developing strategic economic policies to restore investor confidence and guide the transition to post-pandemic economic recovery. These efforts will be essential for ensuring FDI inflows, which are crucial for long-term economic growth and sustainability in

developing countries. Further research could examine the impact of COVID-19 on access to and costs of capital in global financial markets.

COVID-19 has had a significant impact on the sustainable economies of the top 30 innovative countries. The pandemic has disrupted supply chains, caused a downturn in economic activity, and brought about major shifts in consumer behavior. This article provides the practical implications of COVID-19 on the sustainable economies of the top 30 innovative countries and discuss ways in which these countries can adapt and recover in the face of these challenges.

One of the most significant impacts of COVID-19 on the sustainable economies of the top 30 innovative countries has been the disruption of supply chains. Many of these countries rely on global supply chains to produce and distribute goods, and the pandemic has disrupted these chains, leading to shortages of certain products and a decrease in overall production. This has had a negative impact on economic activity, as businesses have been forced to reduce their output or close entirely due to the lack of materials.

In addition to disrupting supply chains, the pandemic has also caused a downturn in economic activity as consumers have reduced their spending in response to the crisis. This has led to a decrease in demand for goods and services, further impacting the sustainable economies of the top 30 innovative countries.

To adapt to these challenges, the high tech innovative countries must find ways to rebuild and strengthen their supply chains, as well as stimulate demand through measures such as fiscal and monetary policies. They can also focus on supporting small businesses and promoting digital transformation, which can help to increase efficiency and reduce reliance on global supply chains.

Another practical implication of COVID-19 on the sustainable economies of the top 30 innovative countries is the shift in consumer behavior. The pandemic has led to a rise in online shopping and an increase in the use of digital payment methods, as consumers seek to minimize their exposure to the virus. This shift presents opportunities for businesses to adapt and meet the changing needs of consumers, such as by increasing their online presence and offering contactless payment options.

To further support the sustainable economies the, governments can invest in infrastructure and digital technologies that support the transition to a digital economy. This includes investing in broadband internet access, digital payment systems, and e-commerce platforms, as well as supporting the development of new technologies such as artificial intelligence and the Internet of Things.

Overall, the COVID-19 pandemic has had significant implications for the sustainable economies of the top 30 innovative countries. To recover and adapt to these challenges, these countries must focus on rebuilding and strengthening their supply chains, stimulating demand, and supporting the transition to a digital economy. By doing so, they can position themselves for long-term success in a post-pandemic world.

This study has a few limitations. Firstly, it only focuses on the top 30 innovative countries in the world and conducts a comparative analysis based on factors such as innovation, high-tech exporting, GDP, and HDI. Secondly, the data used in the study is from 2020, as there is a lack of published data on the dependent variable for the most recent year. Finally, the study only utilizes three GRA models (absolute GRA, Deng's GRA, and the second synthetic GRA model) to analyze the impact of COVID-19 on the economy of the top innovative countries.

There are a few potential avenues for future research based on the findings of this article. One possibility is to continue investigating the response of other countries to the COVID-19 outbreak and compare their experiences to those of the top 30 innovative countries examined in this study. Another option could be to conduct a comparative study to determine which countries were most effective in their response to the viral outbreak. Additionally, the impact of COVID-19 on other aspects of sustainable development, such as social certification, health and safety certification, renewable energy production, and access to electricity, could be explored using various analytical methods.

Ethics Declarations

Ethics approval

The data used in this study did not involve any human or animal subjects.

Conflict of 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.

Availability of Data and Materials

The data used in the current study retrieved from open source. Please see Table 1

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Key Questions:

1. How has COVID-19 affected the sustainable economy in the top 30 high-tech innovative countries?
2. What are the consequences of COVID-19 disruption on the sustainable economy in these countries?
3. In what ways has the pandemic impacted the sustainable economic development of the top 30 high-tech innovative nations?

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