Pandemic Rescue: Economic Impacts of Pandemics (Team 194 Victor Lai, Roberto Romo, Rahel Stewart)

Introduction

While pandemics bring negative economic effects that impact every person in the globalized society, there is little easy to understand data-based research for businesses to refer to. We aim to identify which US economic sectors are most impacted and have the slowest rate of recovery from pandemics and develop an action-defensive plan. Current analyses are limited to general economic indicators such as GDP and stock performance but do not account for health and technological influences. These limitations will be addressed through relief index scores to further insights from traditional economic analyses.

Literature Survey

(1) This book chapter focuses on the Ebola outbreak in West Africa and the resulting economic and political impacts in the region and its surrounding areas. It is useful as it provides a detailed analysis divided by country on the direct and indirect effects of the Ebola virus on countries in West Africa. However, the book chapter has a limited geographic scope, only analyzing three West African countries. We will improve this by analyzing effects in areas not exclusive to the pandemic's source.

(2) This book chapter addresses the impact of numerous viral outbreaks on the tourism industry in Asian countries and details how the industry can adapt and recover. The chapter identifies specific strategies that the tourism market uses to reduce the pandemic's negative impact on the economy and the utilization of travel applications to determine each traveler's risk level. While the chapter does a great job analyzing different regions in Asia, the focus is entirely on tourism, whereas we will account for all market sectors.

(3) This study describes how the Vietnamese government effectively managed multiple waves of COVID-19 infections to reduce economic impact and lead to rapid recovery. Its insight into specific strategies utilized to reduce a pandemic's impact on a national scale is highly useful. The book chapter's focus is on only one virus, so it cannot differentiate which strategies will be effective for all pandemics. Our improvements will address strategies across multiple pandemics.

(4) This book focuses on evaluating the economic impact of the COVID-19 pandemic. The various sections explore topics such as China's economic growth during the pandemic, the impact on the S&P 500 index sectors, trade effects in Africa, stock market performance, implications for SMEs in Pakistan, and the virus's influence on G8 countries' financial indices. This book provides good leverage for comparing markets across the world. Given that we are trying to implement actionable steps that can be taken to recover from another pandemic, it would be helpful to see what other countries did to recover. The book lacks data quality, which our team will improve for more accurate ML models.

(5) This book studies unstructured data from coronavirus-related news and the underlying sentiment during its real-time impact on global financial markets. It discusses how AI-driven machines capture and analyze news sentiment, investigates prevalent sentiment during the pandemic, and explores the differences between the COVID-19 crisis and the 2008 Global Financial Crisis. The book highlighted many important parts of a country's economy that were affected by the pandemic, but the data only accounts for initial stages of the pandemic. We will expand it to all stages of a pandemic.

(6) This book examines the repercussions of the pandemic across various dimensions, questions existing systems, highlights economic and supply chain disruptions, and underscores the need for self-reliance. The book calls for restructuring, advocating a paradigm shift toward sustainability and collective well-being. In summary, it urges us to rethink and build a more resilient world. The book outlines aspects of an economy that build resilience, sustainability, and best practices when recovering from a pandemic. The book highlights the health and agricultural sectors but other sectors were left out in the analysis.

(7) The research project focuses on analyzing the recovery of the U.S. stock market after the COVID-19 pandemic by employing statistical methods. It is useful because it provides a comprehensive analysis of the U.S. stock market's recovery and has prediction and comparison capability. The limitation of data heterogeneity and a limited time horizon of six months are things we will expand on.

(8) The study investigates the impact of COVID-19 on the economies of BRICS nations by analyzing the associations between pandemic-related growth variables and economic indicators using SVAR models. The study helps by providing a comprehensive analysis of the economic repercussions of COVID-19. A potential shortcoming of the study is its observational nature, as it analyzes time series data without

establishing causal relationships. We will improve the research with methods that establish causal links between COVID-19 and socio-economic variables in the context of BRICS nations.
(9) The paper proposes a novel approach to understanding the recovery of the consumption sector post-COVID-19, introducing the concept of somatosensory consumption, a digital consumption index, and a roller conduction effect. It explores the valuation of different sensory-based consumption categories and suggests a comprehensive index to track digital consumption's impact on economic recovery. The paper lacks details on the econometric models and empirical research on the roller conduction effect. We will do further validation on the quantification of weights for sensory-based consumption categories.

Data and Data Sources

Initial Exploratory Data Analysis:

- Significant Flus: Our World In Data Pandemic Article
- Start Dates of Pandemics: CDC Past Flu Pandemics Report
- S&P 500 Data: Kaggle from user Myungchan Kim and NASDAQ stock database
- Employment Ratio: St. Louis Federal Reserve Economic Research Online database
- GDP: From St. Louis Federal Reserve database

COVID-19 Exploratory Data Analysis:

- E-commerce Data: sourced by US Census
- Digital Ad Spending: sourced by eMarketer
- Currently Hospitalized Patients and Weekly % Test Positivity: sourced from US CDC

Index Relief Data:

- Economic Relief: St. Louis Federal Reserve Economic Research Online database
- Health Relief Index: https://ourworldindata.org/coronavirus
- S&P 500, Tech Stock and ETF Sector Data: https://finance.yahoo.com

Methods

Our approach will be to analyze historical economic data during notable pandemics and identify any clear relationships. This exploratory data will set the background for which economic or pandemic influences by identifying which economic or pandemic factors businesses must respect to reduce pandemic impact. These factors will be determined through relief scores that model their relationships with the economy. This approach can solve the problem of limited business-centric pandemic research and guidelines by clearly determining which market sectors are most impacted and what actions will best reduce the pandemic impact. By incorporating the relief scores, our research will be far more comprehensible to businesses and readers can more easily apply our research to make individual customized solutions compared to other methods of research.

Exploratory data will be normalized economic data against numerous economic indicators, such as GDP or the S&P 500. The data will be sourced from government or financial websites and the time frame will follow the start dates given by the CDC. The pandemics chosen are the 1957 H2N2 virus, the 1968 H3N2 virus, the 1977 Russian flu, the 2009 H1N1 virus, and the 2019 COVID-19 virus due to their significance in US history and extensive CDC documentation. The economic indicators used were the S&P 500 index, employment ratio, and US GDP. For each economic indicator, a comparative analysis of the impact of the pandemics over three years following the start date of each pandemic was done. This timeframe effectively captures the immediate to medium-term economic responses to the pandemics while minimizing the inclusion of trends attributable to unrelated factors. The time series data for the SP500 and GDP were normalized for direct comparison and provide simple and easily comprehensible insights into each pandemic's influence on the three economic indicators.
Relief index scores to assess the impact on economic sector recovery will be split into technological relief, economic relief, health relief, and subsets of the tech index (e-commerce, cloud computing, etc). The main objective of this exercise is to reduce the dimensionality of multiple time series that represent a "solution". This approach will provide values representing degrees of impact for research and results clarity. The technology relief index incorporates relevant stock categories like e-commerce, remote work solutions, telemedicine, cloud computing services, and cybersecurity. Daily stock data for 2015-2025 was

downloaded online from Yahoo Finance. The economic relief index includes US Federal Reserve data on currency in circulation and the monthly federal fund rate from 2000-2024. The data is from the St. Louis Federal Reserve. The health relief index covers vaccinated individuals, testing rates, and the stringency index from March 2020 to 2024. The data is downloaded from the World Economic Data. The way the algorithm works is by normalizing data, obtaining lagged datasets, and training neural networks to predict future values, these in place are aggregated to form the index. This composite index encapsulates the underlying patterns and dynamics present across the multiple time series

List of Innovations

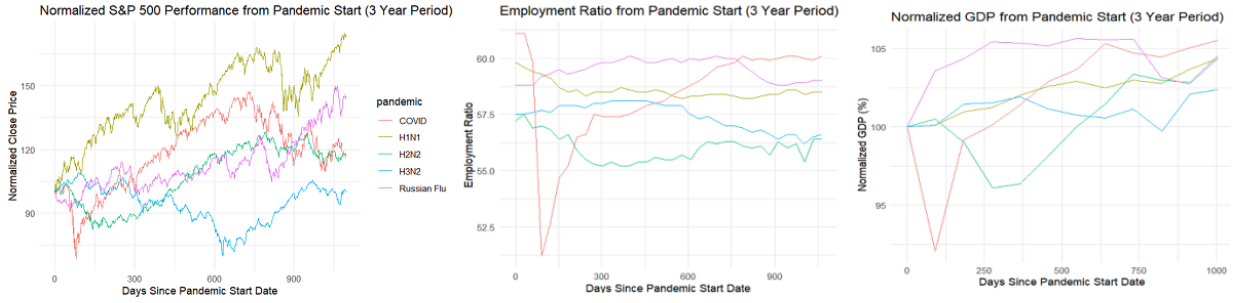
1. Tech Relief Index by Market Sector (Algorithmic): Novel due to utilization of neural networks to pioneer a relief index containing multiple tech stocks that grew significantly during pandemic.
2. Health Relief Index by Market Sector (Algorithmic): Novel due to utilization of neural networks to pioneer a relief index containing 3 main time series. (people vaccinated, stringency index (measure close downs) and number of people tested).
3. Economic Relief Index by Market Sector (Algorithmic): Novel due to utilization of neural networks to pioneer a relief index containing economic data related to currency in circulation and fed fund rates 2 key components to reactivate economy during pandemic.
4. Pandemic Relief Indexes from Wavelet Coherence (Visualization): Novel due to use of wavelet coherence, a statistical tool to analyze the relationship between two time series at different frequencies (number of samples taken per unit), on the unique relief indexes in different market sectors and produce a simplified visualization.
5. D3.js Interactive Dashboard including relief insights from our models (Visualization): Novel because the dashboard combines multiple economic indicators into a simple visual dashboard that enables businesses to easily analyze the relationships between pandemics and the US economy.

Experiments and Results

The overarching goal is to provide businesses with easy to understand information on pandemics and how they impact their business. We want to answer:

- What pandemics should we study to ensure applicability in the future?
- To what extent did the pandemics impact the US economy?
- In Finance, indexes are usually utilized to expose capital to a specific theme. How can we replicate this concept into a thematic pandemic relief solution?
    - How to leverage neural networks to predict time series using lagged data?

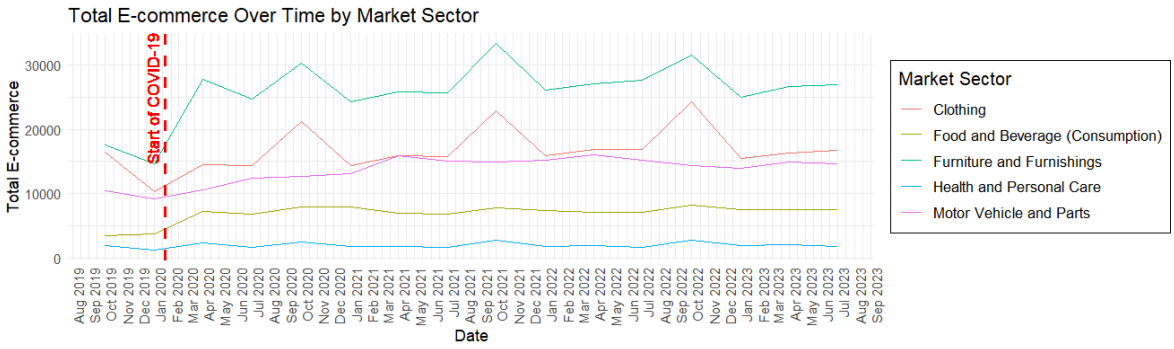
The graphs below are the normalized performance of the economic indicators S&P 500, employment ratio, and normalized GDP for each pandemic. From the graphs, it is clear that COVID-19 had the most significant initial impact, showing clear unprecedented dives shortly after the start. Regardless of the pandemic, the S&P 500 remains stable if not growing. The graph of employment ratio relative stability for all pandemics other than COVID-19, which received a massive initial dip. The graph of GDP shows during COVID-19, GDP also received a significant dip for COVID-19. In conclusion, the three graphs show only COVID-19 had a significant impact on the three economic indicators. This is likely due to COVID-19's greater severity, causing 27 million deaths worldwide compared to the other pandemics only causing up to 2 million deaths. Since the other pandemics had little noteworthy impact on the economic indicators, COVID-19 should be the focus of our research since the graphs show only pandemics of extreme severity can significantly impact the economy.



A dataset was created to study the influence of e-commerce and specific technological and pandemic aspects on GDP change per market sector. This dataset included market sector, date, percent change to real gross domestic product (RGDP), estimated total store and non-store sales, total e-commerce, e-commerce over total sales, percent total employed (employment rate), median age of employed, digital ad spending, hospitalized COVID-19 patients, and weekly percent test positivity for COVID-19. Since the aim was to explore the influence of technology on economic indicators (dependent variables) concerning a pandemic, total e-commerce, digital ad spending, hospitalized COVID-19 patients, and weekly percent test positivity for COVID-19 were selected as independent variables, and percent change to RGDP and employment rate were selected as dependent variables.

Regression models were utilized to determine statistically significant factors affecting the economic indicators. A linear regression model and a LASSO model were developed for percent change to RGDP. In the linear model, only total e-commerce was found to be statistically significant with a coefficient of -2.794e-05 and a p-value of less than 0.05. In the LASSO regression model, total e-commerce was also the only statistically significant factor with a coefficient of -2.342597e-06. Variance inflation factor analysis was used and none surpassed the threshold of 10, meaning multicollinearity is not an issue. A standard linear regression model, a stepwise regression model, and a LASSO regression model were used against percent total employed. In each of the regression models, only total e-commerce was statistically significant with a p-value of 0.05. The VIF values for the regression model did not surpass the threshold of 10, so multicollinearity should not be an issue here either. Every regression model indicated total e-commerce is highly correlated with the state of the economy during a pandemic.

A time series plot of total e-commerce over time by market sector was created to further study and visualize technology's impact on business during a pandemic. The plot clearly shows that all market sectors saw an increase in e-commerce during the start of the COVID-19 pandemic. This makes sense since consumers will still wish to purchase products and services but will not want to compromise their health by going to stores in person. Another key observation is each market sector has seen growth in total e-commerce throughout the pandemic. While some market sectors like clothing and furniture were highly volatile, each market sector showed a higher total e-commerce value towards the end as compared to the start of the pandemic. However, the increase in the Health and Personal Care industry is negligible as the e-commerce in that industry remained extremely stable throughout the pandemic. While products such as masks and COVID-19 testing kits became more prominent products to buy, the stability is likely due to the availability of free masks and testing.



In conclusion, all models showed the only statistically significant factor affecting the economic indicators during COVID-19 to be total e-commerce. Businesses should invest in e-commerce during a pandemic due to its historical growth in all market sectors, meaning it is a safe investment in maintaining revenue.

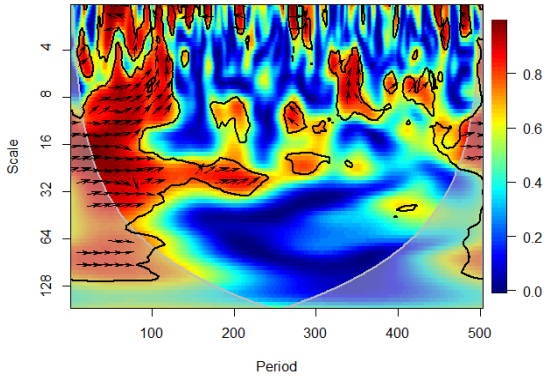
Upcoming experiments include additional analysis on the impact of remote employment and automation on economic indicators. A better understanding of this technology can help determine what economic damage mitigation methods businesses can use to balance effectiveness with realistic solutions.

As we explore potential relief measures, we aim to consolidate multiple time series into clustered or indexed formats. By indexing using neural networks, we reduce the dimensions. This involves

amalgamating three distinct time series such as the number of vaccinated individuals, the number of tests conducted, and a stringency index — into a single composite index termed the Health Relief Index. Similarly, we undertake this approach for the Technology and Economy sectors, selecting stocks pertinent to these domains and economic incentives like the Fed Fund Rate. To demonstrate the efficacy of Neural Networks in dimensionality reduction, we employ Principal Component Analysis (PCA) and analyze the variance distribution between PCA1 and the constructed index. Notably, our findings reveal that the index often captures more variance than PCA1, thereby showcasing the advantage of utilizing the index as a reduced-dimensional representation over PCA1. The limitation that was found using this method was the number of constituents used. The less constituents, the better the PCA over the NN method is.

Index	Technology Index Relief	Economic Index Relief	Vaccine/Testing Index Relief	Ecommerce Index Relief	Remote Index Relief	Cloud Computing Index Relief	Telemedicine Index Relief	Streaming Index Relief	Fintech Dig Payment Index Relief	Cyber Index Relief	Education Tech Index Relief	Health Care Tec Index Relief	Robotics Automation Relief
Variance % Share (Neural Network)	94%	45%	34%	84%	80%	81%	100%	85%	81%	83%	70%	76%	78%
Variance % Share (PCA)	62%	40%	93%	86%	78%	75%	100%	79%	78%	71%	46%	57%	56%
Constituents	28	2	3	4	3	4	1	5	3	5	3	5	5

Multiple approaches were analyzed using Wavelet Coherence (shown to the right and below) which is a statistical tool to analyze relationships between two time series at different frequencies (number of samples taken per unit). Using this analytical tool we compared all 10 sectors (Energy, Communication, Utilities, Real Estate, etc.) including S&P along with each relief index.



Sector/Index	Technology Index Relief	Economic Index Relief	Vaccine/Testing Index Relief	Robotics Automation Relief	Ecommerce Index Relief	Remote Index Relief	Cloud Computing Index Relief	Telemedicine Index Relief	Streaming Index Relief	Fintech Dig Payment Index Relief	Cyber Index Relief	Education Tech Index Relief	Health Care Tec Index Relief
S&P	High Interrelation	Medium Interrelation	High Interrelation	High Interrelation	High Interrelation	Medium Interrelation	High Interrelation	Medium Interrelation	High Interrelation	High Interrelation	Medium Interrelation	Low Interrelation	High Interrelation
Communication	High Interrelation	Medium Interrelation	Medium Interrelation	High Interrelation	High Interrelation	Medium Interrelation	High Interrelation	Medium Interrelation	High Interrelation	High Interrelation	Medium Interrelation	High Interrelation	High Interrelation
Consumer S	Medium Interrelation	High Interrelation	Medium Interrelation	Medium Interrelation	Low Interrelation	Medium Interrelation	Medium Interrelation	Low Interrelation	Medium Interrelation	High Interrelation	Low Interrelation	Low Interrelation	High Interrelation
Energy	Low Interrelation	Medium Interrelation	High Interrelation	Medium Interrelation	Low Interrelation	Low Interrelation	High Interrelation	Low Interrelation	Medium Interrelation	High Interrelation	Low Interrelation	Low Interrelation	High Interrelation
Financial	Low Interrelation	Medium Interrelation	Medium Interrelation	Medium Interrelation	Low Interrelation	Medium Interrelation	High Interrelation	Medium Interrelation	Medium Interrelation	High Interrelation	Low Interrelation	Low Interrelation	Medium Interrelation
Health	Medium Interrelation	Medium Interrelation	Medium Interrelation	Medium Interrelation	Medium Interrelation	Low Interrelation	High Interrelation	Low Interrelation	Medium Interrelation	High Interrelation	Low Interrelation	Medium Interrelation	High Interrelation
Industrials	Medium Interrelation	Medium Interrelation	Medium Interrelation	High Interrelation	Low Interrelation	Low Interrelation	High Interrelation	Medium Interrelation	Medium Interrelation	High Interrelation	Low Interrelation	Low Interrelation	Low Interrelation
Real Estate	Low Interrelation	Negligible Interrelation	Medium Interrelation	Negligible Interrelation	Negligible Interrelation	Medium Interrelation	Low Interrelation	Medium Interrelation	Medium Interrelation	Negligible Interrelation	Negligible Interrelation	Negligible Interrelation	High Interrelation
Technology	High Interrelation	Medium Interrelation	Medium Interrelation	High Interrelation	High Interrelation	High Interrelation	High Interrelation	High Interrelation	High Interrelation	High Interrelation	High Interrelation	High Interrelation	High Interrelation
Utilities	Medium Interrelation	Low Interrelation	Medium Interrelation	Medium Interrelation	Low Interrelation	Medium Interrelation	High Interrelation	Medium Interrelation	Low Interrelation	Medium Interrelation	Low Interrelation	Medium Interrelation	High Interrelation
Number of High (3)	3	1	2	4	3	1	8	1	3	8	1	2	8
Number of Medium (2)	4	7	8	5	1	6	1	6	6	1	2	2	1
Number of Low (1)	3	1	0	0	5	3	1	3	1	0	6	5	1
Number of Negligible (0)	0	1	0	1	1	0	0	0	0	1	1	1	0
	20	18	22	22	16	18	27	18	22	26	13	15	27

Upon assessing the complete set of 14 x 10 Wavelet Coherence visualizations, we qualitatively interpreted the graphs, categorizing interrelation as High, Medium, Low, or Negligible. We assigned scores of 3, 2, 1, and 0 to these categories, respectively. Hence, we derived our Pandemic Relief Score. The robust interrelations observed in the cloud computing, fintech, and healthcare technology relief indices signify their pivotal roles in driving economic vitality. These sectors, characterized by higher relief index scores, have demonstrated their capacity to provide essential tools and solutions that fuel innovation, efficiency, and resilience within the economy.

Looking ahead, the integration and further development of these technologies will likely play a crucial role in shaping our response to future pandemics and global challenges. Embracing digitalization

and innovation across sectors can enhance preparedness, response, and recovery efforts, ultimately fostering a more resilient and sustainable economy and society.

Conclusions

The 1957 H2N2 virus, the 1968 H3N2 virus, the 1977 Russian flu, the 2009 H1N1 virus, and the 2019 COVID-19 virus were analyzed. The S&P 500 market index, employment ratio, and gross domestic product were the three economic indicators selected for exploratory analysis to determine the pandemics' impacts on the US economy. Each economic indicator was normalized and plotted by the dates from the start of the pandemic to three years after the start date. The plots showed COVID-19 was the only pandemic to have a significant impact on the economic indicators. COVID-19 had a massive dip in each economic indicator while all other pandemics had little to no impact on the economic indicators. Therefore, the team determined COVID-19 should be the only pandemic to be extensively studied.

In the exploratory data analysis for COVID-19, regression models were used to form a basic analysis of the impact of technology on the economy during the pandemic. The regression techniques used were standard linear regression, LASSO regression, and stepwise regression and the economic indicators used were employment ratio and gross domestic product. In all of the models, the only statistically significant factor was total e-commerce. A plot of total e-commerce of five market sectors was formed. Each market sector experienced an immediate increase in total e-commerce sales at the start of COVID-19. Moreover, each market sector saw growth from the start of the pandemic to mid-2023 when the data ends. Other than the health and personal care industry, all of the market sectors had substantial growth. Since total e-commerce spikes during the initial stages of a pandemic regardless of industry and grows throughout the pandemic, businesses should leverage this information and implement e-commerce whenever a pandemic is expected to hit.

Currently, there are limitations in usable data for the COVID-19 dataset. As of spring 2024, COVID-19 is technically still an ongoing pandemic, so a holistic study is currently not possible. Future teams can expand on the exploratory analysis of COVID-19 by incorporating the time series data of the economic indicators of the dates following the end of the COVID-19 pandemic. Moreover, future teams can also expand the analysis to include more data on different market sectors, e-commerce data, weekly time-series data (rather than quarterly), or digital advertising success (such as click-through rate or acquisition rate). As for the relief index, the main limitation of our method is the assumption that the chosen stock data price completely represents the specific sector or the specific technological sub-sector. Therefore, clustering is an issue and future teams should explore better clustering methods.

Initial Plan of Activities

Team Members	Task	State	Start Time	Duration
Victor, Rahel	Compile a list of questions we want answered	Complete	3/23/2024	1 week
Romo, Ashwin	Explore and compile a list available economic datasets that fulfill needs of the project	Complete	3/23/2024	1 week
All team members	Validation of identified datasets - data sufficiency, quality, and completeness	Complete	3/23/2024	1 week
Romo, Ashwin	Data preparation - Missing values, removal of outliers, normalization	Complete	3/23/2024	1 week
Victor, Rahel	Compilation of data related to key events/markers through the timeline	Complete	3/23/2024	1 week
All team members	Exploratory analysis - understand characteristics, relationships	Incomplete	3/23/2024	1 week
All team members	Analysis and interpretation	Incomplete	3/23/2024	1 week
Romo, Ashwin	Build Visualizations	Incomplete	3/23/2024	1 week
Victor, Rahel	Report and presentation	Incomplete	4/1/2024	3 weeks

Revised Plan of Activities (Overhauled due to Ashwin dropping the course [3 members remaining])

Team Members	Task	State	Start Time	Duration
Victor	Exploratory Analysis of Pandemics on US economy	Completed	3/23/2024	1 week
Victor	Exploratory Analysis on COVID-19 on Economic Indicators	Completed	3/23/2024	1 week
Roberto	Analysis and Development of index scores	Completed	3/23/2024	1 week
Rahel	Interactive Visualizations	Completed	3/23/2024	1 week
Everyone	List of Innovations	Completed	3/23/2024	1 week
Victor	Plan of Activities and Proofreading/Formatting	Completed	3/23/2024	1 week
Everyone	Final Poster, Report, and Slides	Completed	4/1/2024	3 weeks

All members put in a similar amount of effort.

Citations

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