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Negative Impacts on Gross Domestic Product Caused by Pandemics

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Negative Impacts on Gross Domestic Product Caused by Pandemics

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An abstract of
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Rollins School of Public Health of Emory University
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Abstract

Negative Impacts on Gross Domestic Product Caused by Pandemics

Over the past few decades, public health measures have fallen short in rapidly protecting human health and preserving economic growth during emerging and re-emerging infectious disease outbreaks. Acknowledging that economic impacts of pandemics exist in several forms, we seek to investigate known negative macroeconomic impacts with respect to gross domestic product (GDP) through a systematic review of the literature. We conducted a search in The Essential Reference Tool for Economics Literature (EconLit) database. The search string included search terms in the following areas: disease outbreak, epidemic, pandemic, cost analysis, gross domestic product, in addition to specific outbreaks such as SARS-CoV-2, Ebola, H1N1. We found 39 records eligible for this review and included them for analysis and discussion. Broadly, there were six different disease outbreaks reported: COVID-19 (n=22); HIV/AIDS (n=10); SARS (n=4); Pandemic Influenza (n=2); Mad Cow Disease (n=1); and Foot and Mouth Disease (n=1). The average percent change in GDP during 2020, the height of COVID-19, for all countries measured and reported on in this review was -7.07%. In all other disease outbreaks, GDP was negatively impacted, even in countries where the outbreak was not occurring. Other notable outcomes were sector related impacts, most commonly in agriculture, services, restaurants, tourism. During COVID-19, healthcare spending in the United States decreased, employment rates dropped during COVID-19 and Mad Cow Disease, and household consumption decreased during SARS in China. Lockdowns and closure of nonessential business led to declines in GDP. Although developed countries face greater impact, as evidenced by the data for GDP percent change and human development index values, pandemics may impact low-and-middle-income countries (LMIC) more substantially at an individual level. Large scale policy interventions need to be implemented early and with aggressive spending, since there is evidence to show that a short-term recession will give rise to strong recovery. Collaboration among public health officials, governments, non-governmental organizations, business professionals to invest in public-health systems now is critical to finding the balance between human and economic health during the next health emergency.

By Erin Holsted

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CHAPTER 1: INTRODUCTION

Background and Significance

Over the past few decades, public health measures have fallen short in rapidly protecting human health and preserving economic growth during emerging and re-emerging infectious disease outbreaks. Notable examples exist, including the 2009 H1N1, 2012 MERS-CoV, and 2014 Ebola outbreaks. However, none has had as large a human and economic impact as COVID-19. While the International Health Regulations (IHR 2005), the world's 'rulebook' for international collaboration during a public health response, has attempted to mitigate this, COVID-19 has shown it to be unfit for its purpose.

Global attention has been gripped by the COVID-19 pandemic; many have felt the economic consequences of public health containment measures, or lack thereof, at the individual level. (1) However, this is not the last time we will face a pandemic. As the global population soars, natural environments continue to be disrupted, leading to the increased risk of humans interacting with novel pathogens. (1) To improve how we navigate the next pandemic, we should gain a better understanding of the macroeconomic impacts of pandemics, which interventions and policy responses result in the greatest economic recovery, and which industries are impacted most heavily. This is so political and public health leaders, business professionals, and others can collaborate to respond appropriately.

Statement of the Problem

With increasing globalization comes increasing probability that an emerging or re-emerging infectious disease appearing in one country will rapidly spread to another. Historically, where risk is perceived high and control is perceived as poor, there is a fall in demand for tourism, transport, retail sales, and leisure entertainment activities. (2) Additionally, the fear of disease transmission through international travel can lead to a decrease in economic activity in countries unaffected by the outbreak. (2) It is important to understand the dynamics of how public health emergencies impact economics around the world, especially on a macroeconomic scale. To provide insight into impacts that disease outbreaks have on a large scale, we will review gross domestic product (GDP), combined with other macroeconomic indicators. GDP has become widely used macroeconomic indicator for the health of national and global economies; it provides information on the size of a given economy and how well it is performing. (3)

We should address what might need be changed in the public health fabric and economic landscape so that the intricate balance between the well-being of citizens and preserving economic growth is reached during the next pandemic.

Statement of Purpose

Acknowledging that economic impacts of pandemics exist in several forms, we seek to investigate known negative macroeconomic impacts with respect to GDP through a systematic review of the literature. In addition, we seek to understand the impact of disease prevention and mitigation strategies on the economic well-being of global communities and markets. In other words, this will provide context to understand what

was, what is, and what could be done in the future to better protect public health and preserve economic health.

Research Questions

1. What are the known negative macroeconomic impacts of pandemics with regard to GDP?
2. What impact do disease prevention and mitigation strategies, or lack thereof, have on the economic well-being of global communities and markets?

CHAPTER 2: LITERATURE REVIEW

World Health Organization and International Health Regulations

Established in 1948, The World Health Organization (WHO) is an agency within the United Nations responsible for international public health. (4) WHO, along with many global partners, plays a coordinating role in the implementation of the International Health Regulations (IHR). (5) The IHR can be traced back to the year 1851 as a series of Sanitary Conferences concerned with cholera, plague, and yellow fever. (6) In 1969, the World Health Assembly revised the International Sanitary Regulations to become the IHR. (7) Since then, there have been three editions, prompted by shifts in diseases of concern, and the latest (2005) due to an incident of delayed reporting of severe acute respiratory syndrome (SARS) cases during the 2002-2003 outbreak in China. (7)

The IHR is a legally binding instrument of international law that requires 196 countries, including 194 WHO member states (MS), to have the ability to detect, assess and report, and respond to public health threats and emergencies. However, delays in party compliance have resulted due to lack of positive or negative incentives to adhere to the agreement. Additionally, the historic pattern has been to accept continual delays in party compliance, as evidenced by the COVID-19 pandemic, thus perpetuating a cycle of no consequence. (7)

With the emergence of new infectious diseases with pandemic potential, critical attention should be brought to early detection and response to public health threats. A new revision of the IHR is critical to restoring the public health fabric so that human health can be protected, and economic growth is continued.

Gross Domestic Product

Simon Kuznets (1937), an economist at the National Bureau of Economic Research, presented the a measure to capture all economic production (by individuals, companies, governments) within a country. (8) This measure would rise in “good times” and fall in “bad times”. (8) Ever since then, gross domestic product (GDP) has been used as a standardized measurement tool for assessing the size and health of an economy. (3) The following equation simply depicts how GDP is calculated (9):

$$GDP = Consumption + Government\ Spending + Investment + Net\ Exports$$

GDP trickles down to the individual level through availability of employment and ability to save and invest. Additionally, studies have shown that GDP of a country is positively correlated with its’ population life expectancy. (10) According to the International Monetary Fund, when GDP is growing, workers and businesses are “generally better off than when it is not.” (3) Because GDP is one of the most often recorded indicators of the health of a country’s economy, this standardized measure is of interest in this study.

Overview of Past Pandemics and Outbreaks

A brief overview of the most serious epidemics, pandemics, and disease outbreaks in history –Mad Cow Disease, Foot and Mouth disease, HIV/AIDS, Influenza, SARS, and COVID-19 – is important to understand how epidemics impact not only people’s health, but also impact economic development throughout the world.

Mad Cow Disease

Bovine Spongiform Encephalopathy (BSE), or Mad Cow Disease affects cattle causing slow degeneration of the nervous system. (11) The human form of this disease, known as variant Creutzfeldt-Jakob disease (vCJD), presents similarly and is a continual threat

to human health due to processed meat consumption. (12) The first infections of BSE in cattle most likely occurred during the 1970s, however, the first two confirmed cases were identified in 1986. (11) Evidence now suggests that the outbreak spread throughout the United Kingdom cattle industry by feeding infected meat-and-bone meal to young calves leading to a BSE epizootic that peaked in January of 1993 with approximately 1,000 cases per week. (11) From Britain, it spread throughout Europe, and then around the globe; Japan had eleven cases since 2001 and as of 2003, positive cases have been confirmed in Canada and the United States. (12) According to the International Trade Commission, trade restrictions put in place due to the spread of mad cow disease cost the United States beef industry around $2 billion in annual revenue between 2004 – 2007. (13) Additionally, Japan and Korea lost $9.4 billion of the total $11 billion estimated total lost revenue due to mad cow disease trade border closures. (13)

Foot and Mouth Disease

Foot and Mouth Disease (FMD) is a severe and highly contagious viral disease that causes illness in cows, sheep, deer, goats, and other livestock animals. (14) Although not a public health threat or food safety threat to humans, it has serious impacts on livestock trade which can lead to significant economic losses; a single detection of an FMD case will most likely halt international trade for a given period of time. (14) The outbreak of FMD that occurred in 2001 in the United Kingdom resulted in approximately six million slaughtered animals and the outbreak cost the public sector three billion pounds and the private sector five billion pounds. (15) Additionally, the tourism industry was gravely impacted in 2001 because FMD affected areas were classified as exclusion

zones, meaning much of the countryside was off limits to the public. (15) FMD outbreaks have also been detected in Taiwan, Japan, and Republic of Korea, all of which required extensive control programs. (16) The Department of Agriculture, Water and the Environment in Australia continually monitors FMD because economic losses associated with a 3-month outbreak are estimated at $7.1 billion and at $16 billion for a 12-month outbreak. (16)

Human Immunodeficiency Virus, Acquired Immunodeficiency Syndrome (HIV/AIDS)

HIV is a bloodborne pathogen that attacks the body's immune system. (17) Studies indicate that this virus might have jumped from chimpanzees to humans in the late 1800s and has since spread across Africa and other parts of the world; the virus has existed in the United States since the 1970s. (17) The impact of this disease is severe enough to affect the world economy as a whole, largely through reducing the availability of human capital. HIV/AIDS reduces labor productivity, reduces income and savings capabilities due to significant medical costs, and therefore, rates of investment fall, leading to the decline in economic growth. (18) A 2008 study in Botswana concluded that HIV/AIDS significantly reduced economic growth and increased household poverty. (19) According to one study, "the economic impacts of HIV/AIDS at each level (sector, firm, or household level) will be modified through prevention and treatment interventions". (20) As the HIV/AIDS epidemic has progressed, concern for its economic impact remains, although there is ongoing research on cost effectiveness of prevention and treatment programs as a mechanism for restoring economic growth. (21)

Pandemic Influenza

Throughout history, influenza viruses have been the cause of pandemics: 1918 Pandemic (H1N1 virus); 1957-1958 Pandemic (H2N2 virus); 1968 Pandemic (H3N2 virus); and 2009 Pandemic (H1N1pdm09 virus). (22) Influenza viruses are constantly changing, making it possible that non-human influenza viruses can change in a way that makes them infectious to humans. For this reason, international health agencies conduct routine monitoring of influenza viruses and the U.S. Centers for Disease Control and Prevention (CDC) states that “surveillance systems are critical for the early identification of novel influenza A viruses that have pandemic potential”. (23) A study in Korea following the 2009 H1N1 pandemic found that costs of the pandemic were $1.09 billion, or 0.14% of the national gross domestic product. (24) The indirect costs totaled US$ 662.5 million, or 60.8% of total cost, indicating its broad impact on multiple industries, lost productivity, and lost lives. (24) Although there is a lack of economic data during the time period of the 1918 influenza pandemic, several newspaper articles from United States cities appeared in the fall of 1918 that referenced the economic impacts. (25) An article in the *Arkansas Gazette* titled “How Influenza Affects Business” says that merchants’ business declined forty percent and retail grocery business reduced by one-third. (25) Other common themes that appeared in the articles were church, school, and theater closings. (25) Each of the influenza pandemics, as well as seasonal influenza epidemics, that have occurred have resulted in economic burden and loss. (26)

Severe Acute Respiratory Syndrome (SARS)

SARS is a viral respiratory disease first identified Feb 2003 during an emerging outbreak in China. (27) Because the virus quickly spread to 29 other countries, this

outbreak could be considered the first instance of a “concurrent global concern for the economic impact that might result”. (2,28) Previous outbreaks, such as FMD and MCD, were primarily of national or regional concern. Although the global economic impact of SARS was not as severe as early models suggested, those with greatest burden of disease felt the greatest economic decline, and industries reliant upon movement and human interaction (i.e., tourism, hospitality, entertainment) were impacted significantly. (2)

COVID-19

Coronavirus disease (COVID-19) is a viral respiratory illness that emerged in late 2019. (29) As of March 25, 2021 there have been over 125,167,534 cases of COVID-19 and 2,749,085 deaths worldwide. (30) In addition to this tragedy of loss of life, many have felt the shock of this pandemic due to social isolation, job loss, and economic devastation. Markets around the world fell as the pandemic gained strength over time. (31) In March of 2020, soybean prices were off 6% from the high in January, copper by 10%, and oil by 30%. (31) GDP growth forecasts were constantly being adapted as the pandemic progressed, especially for countries with commodity economies. (31) Because this pandemic is still ongoing, it will be important to continually monitor economic data.

CHAPTER 3: METHODS

The protocol for this review was drafted and amendments after that time were documented. The review was not registered with PROSPERO as it does not meet the eligibility criterion of involving clinical health outcomes. This systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement. (32)

Search Strategy

We conducted a search in The Essential Reference Tool for Economics Literature (EconLit) database; It is published by the American Economic Association and focuses on literature in the field of economics. The search was for English-language literature, with a time limitation of 1993-present, as this was the time of the mad cow disease outbreak. The search string included search terms in the following areas: disease outbreak, epidemic, pandemic, cost analysis, gross domestic product, in addition to specific outbreaks such as SARS-CoV-2, Ebola, H1N1 (Appendix A).

Inclusion and Exclusion Criteria

Eligible articles were in English language, published in an academic journal after 1993, as we were interested in the economic impact of disease outbreaks following Mad Cow Disease. Studies must have contained relevance to a disease outbreak, pandemic, or epidemic (i.e., COVID-19, SARS, H1N1, Foot and Mouth Disease). Additionally, all measures of GDP were of interest, and therefore, were included. These measures could have been actual, expected, nominal, or real. Articles from any country around the globe were included, even if it was not the country of pathogen origin.

Selection of Studies

Two review authors independently screened all titles and abstracts using Covidence software (EH, RR). (33) When a title or abstract could not be rejected with certainty, the full text of the article was abstained for further evaluation. Any conflicts during title and abstract screening were resolved by a third review author (JF). EH and RR independently screened full-text articles for final assessment of eligibility. When full articles could not be obtained, authors were contacted to obtain further details of the study. Failing this, studies were classified as ‘awaiting assessment’ until further information is made available. Any disagreements of eligibility during the full text review stage were also resolved by a third review author, JF.

Data Extraction

EH extracted data from the eligible studies using a standardized abstraction form and data were checked for accuracy by another review author (RR). The following data were recorded in the abstraction form: Epidemic/Pandemic/Disease Outbreak, Public Intervention if applicable, year of measure, country of measure, sector involved, GDP measure, non-GDP measures (employment rate, sector data, stock market indicators, net export/import, etc.). If data values from graphs and figures were not reported in tables or in the text of the article, the figure was uploaded into *graphreader.com* to extract values from the graph image. (34)

Statistical Analysis

We conducted a meta-analysis for an outcome if more than one study assessed the same outcome within the same disease outbreak. This was only appropriate for COVID-

19 data. The average of reported GDP values was calculated for each country and for each UNICEF region. A weighted average was not necessary because all studies in this review had a sample size of the same weight, as it is country level GDP data. All other disease outbreaks contained diverse reporting of outcome variables, thus many results in this review are narrative.

CHAPTER 4: RESULTS

The search strategy yielded a total of 99 records; no duplicates were identified, therefore, 99 records remained for title and abstract screening. After title and abstract screening and full-text review, we found 39 records eligible for this review and included them for analysis and discussion (Figure 1). We included records, the outcomes reported, and disease outbreaks involved (Table 1). Broadly, there were six different disease outbreaks reported: COVID-19 (n=22); HIV/AIDS (n=10); SARS (n=4); Pandemic Influenza (n=2); Mad Cow Disease (n=1); and Foot and Mouth Disease (n=1).

Figure 1. Records Identified, Screened, and Included in Systematic Literature Review of Impact of Pandemics on Gross Domestic Product and Other Economic Indicators, 2021

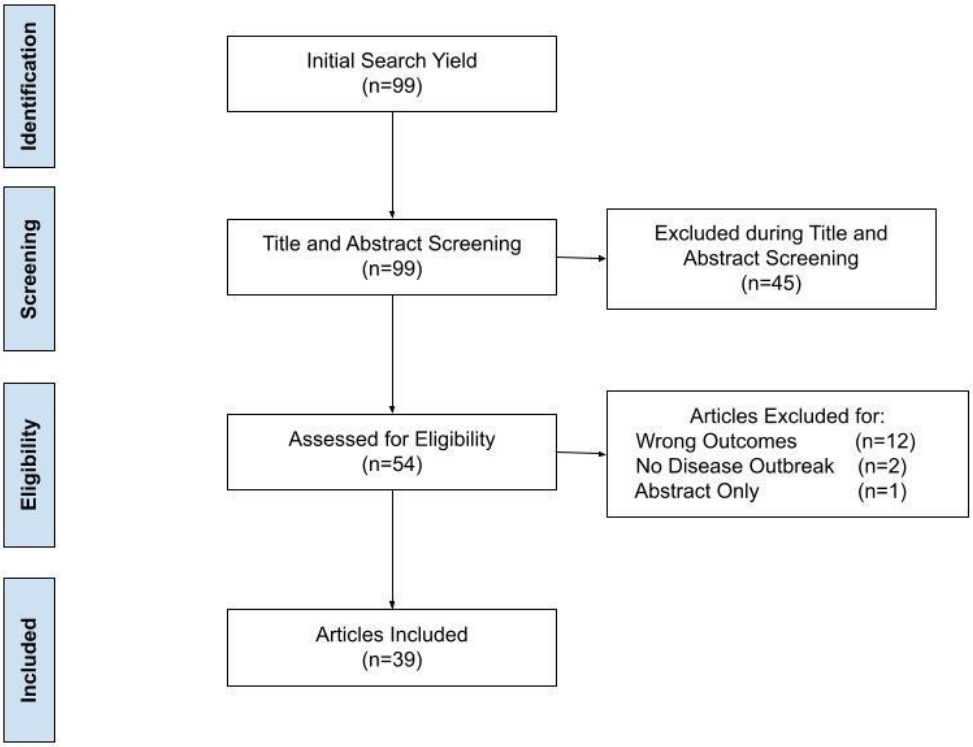


Table 1. Results of Systematic Literature Review of Impact of Pandemics on Gross Domestic Product and Other Economic Indicators, 2021

Citation #	Author(s)	Title	Year	GDP Outcomes	Other Outcomes
COVID-19					
(35)	Singh, *et* al.	Economic Impact of COVID-19 Pandemic: Who Are the Big Sufferers?	2020	GDP % change GDP growth rate	NA*
(36)	Kniesner and Sullivan	The Forgotten Numbers: A Closer Look at COVID-19 Non-fatal Valuations	2020	NA	Estimate non-fatal valuations as % of GDP
(37)	Del Rio-Chanona *et* al.	Supply and Demand Shocks in the COVID-19 Pandemic: An Industry and Occupation Perspective	2020	NA	Aggregate employment rate shock Aggregate shock wages Aggregate shock value
(38)	Amewu, *et* al.	The Economic Costs of COVID-19 in Sub-Saharan Africa: Insights from a Simulation Exercise for Ghana	2020	GDP % Change GDP Decrease # GDP Growth Rate	% Share of total GDP losses for intervention category
(39)	Oxford Economics	UK Forecast Overview	2020	GDP % Change	NA
(40)	Auerbach and Gale	The Effects of the COVID Pandemic on the Federal Budget Outlook	2020	Pre-Pandemic GDP During Pandemic GDP Post-Pandemic GDP	NA
(41)	Welfens	Macroeconomic and Health Care Aspects of the Coronavirus Epidemic: EU, US and Global Perspectives	2020	% Change in Real GDP Growth Forecasts	NA
(42)	Adam, *et* al.	After the Lockdown: Macroeconomic Adjustment to the COVID-19 Pandemic in Sub-Saharan Africa	2020	GDP % Change	NA
(43)	Malliet, *et* al.	Assessing Short-Term and Long-Term Economic and Environmental Effects of the COVID-19 Crisis in France	2020	GDP % Change	Employment rate Net export
(44)	Sparrow, *et* al.	Indonesia under the New Normal: Challenges and the Way Ahead	2020	GDP % Change Component of GDP Growth by sector (% year on year)	Household consumption Government consumption Investments Net export
(45)	Oxford Economics	World Economy	2020		GDP % Change
(46)	Rhyan, *et* al.	Tracking the U.S. Health Sector: The Impact of the COVID-19 Pandemic	2020	GDP minus healthcare services	Healthcare services spending
(47)	Slater	The Economic Cost of Coronavirus Lockdowns	2020	GDP % Change	
(48)	Carletti, *et* al.	The COVID-19 Shock and Equity Shortfall: Firm-Level Evidence from Italy	2020		Sector income
(49)	Fezzi and Fanghella	Real-Time Estimation of the Short-Run Impact of COVID-19 on Economic Activity Using Electricity Market Data	2020	GDP % Change	
(50)	Della Posta, *et* al.	A Market-Financed and Growth-Enhancing Investment Plan for the Euro Area	2020	GDP Growth Rate	
(51)	McKibbin and Vines	Global Macroeconomic Cooperation in Response to the COVID-19 Pandemic: A Roadmap for the G20 and the IMF	2020	GDP % Change GDP Decrease #	Change in trade balances of stimulating countries in % GDP
(52)	Oxford Economics	World Economy: Japan	2020	GDP % Change	Japan visitor arrivals JR Central hotels occupancy Net Export
(53)	Konig and Winkler	COVID-19 and Economic Growth: Does Good Government Performance Pay Off?	2020	Mean GDP growth revision Minimum GDP growth revision	

Citation #	Author(s)	Title	Year	GDP Outcomes	Other Outcomes
(54)	Gormsen and Koijen	Coronavirus: Impact on Stock Prices and Growth Expectations	2020	GDP % Change	
(55)	Altig, *et* al.	Economic Uncertainty before and during the COVID-19 Pandemic	2020	% deviation from GDP trend	Employment rate
(56)	Zhang	Five Basic Insights into the Economic Impact of the COVID-19 Outbreak	2020		Tourism income as % GDP
(57)	Slater	After the Pandemic: Medium-Term Growth Uncertainties	2020	Impact of Policy Response on GDP	Industrial output Retail sales Consumer spending
HIV/AIDS					
(58)	Burger and de Villiers	The Macroeconomic Impact of HIV/AIDS in South Africa: A Supply-Side Analysis	2005	GDP # GDP/capita	
(59)	Amiri, *et* al.	HIV/AIDS-GDP Nexus? Evidence from Panel-Data for African Countries	2012	Direction of causality between GDP and HIV	
(60)	Liu, *et* al.	Economic Costs to Business of the HIV/AIDS Epidemic	2004		Productivity loss
(61)	Nicholls	Modelling the Macroeconomic Impact of HIV/AIDS in the English Speaking Caribbean	2000	GDP % Change	Employment rate
(62)	Lovasz and Schipp	The Impact of HIV/AIDS on Economic Growth in Sub-Saharan Africa	2009	GDP fall/shrink rate	
(63)	Cuesta	How Much of a Threat to Economic Growth Is a Mature AIDS Epidemic?	2010	GDP % Change	
(64)	Anyanwu, *et* al.	Role of Fiscal Policy in Tackling the HIV/AIDS Epidemic in Southern Africa	2013		Domestically financed HIV/AIDS prevention and control as % of GDP Total spending as % of GDP
(65)	Bloom and Mahal	Does the AIDS Epidemic Threaten Economic Growth?	1997		Additional AIDS case and rate of per capita income growth
(66)	Cuddington and Hancock	Assessing the Impact of AIDS on the Growth Path of the Malawian Economy	1994	GDP growth rate	
(67)	Cuddington	Modeling the Macroeconomic Effects of AIDS, with an Application to Tanzania	1993	GDP % Change	
SARS					
(68)	Hanna and Huang	The Impact of SARS on Asian Economies	2004	GDP % Change	
(57)	Slater	After the Pandemic: Medium-Term Growth Uncertainties	2020	GDP % Change	
(69)	Yue, *et* al.	Risk Prediction and Assessment: Duration, Infections, and Death Toll of the COVID-19 and Its Impact on China's Economy	2020	GDP growth rate Pre-Pandemic GDP During Pandemic GDP Post-Pandemic GDP	
(56)	Zhang	Five Basic Insights into the Economic Impact of the COVID-19 Outbreak	2020	GDP % change	
PANDEMIC INFLUENZA					

Citation #	Author(s)	Title	Year	GDP Outcomes	Other Outcomes
(70)	Keogh-Brown, *et* al.	The Macroeconomic Impact of Pandemic Influenza: Estimates from Models of the United Kingdom, France, Belgium, and the Netherlands	2010	GDP % Change	
(71)	Keogh-Brown, *et* al.	The Possible Macroeconomic Impact on the UK of an Influenza Pandemic	2010	GDP % Change	Consumption
FOOT AND MOUTH DISEASE					
(72)	Blake, *et* al.	Quantifying the Impact of Foot and Mouth Disease on Tourism and the UK Economy	2003	GDP decrease #	Tourism income
MAD COW DISEASE					
(73)	Wieck and Holland	The Economic Effect of the Canadian BSE Outbreak on the US Economy	2010	GDP decrease #	Employment rate Labor Capital US Beef frozen imports US Beef fresh/chilled imports US Cattle imports

*NA = Not Applicable

COVID-19

All countries included in the review reported a negative percent change in GDP in the year 2020 except Egypt and Bangladesh. The average percent change for all countries was -7.07%. The average values for percent change in GDP for 2020 by UNICEF region were: Latin America and Caribbean -10.13%; East Asia and Pacific -9.73%; Eastern Europe and Central Asia -8.35%; North America -8.1%; Western Europe -7.54%; Sub-Saharan Africa -5.64%; Middle East and North Africa -2.27%; and South Asia -1.87%. Country specific values for the GDP percent change over the course of 2017-2022 are presented in Table 2 are visualized in Figure 2 and 3.

One study reported that The Interim Economic Assessment of the OECD (2020) from Mar 2, 2020 has shown that the year-over-year percent change in real GDP growth forecast for the world from 2019 to 2020 is -0.5%. (41) The article reported these values for 20 countries. Another study also reported on GDP growth revisions and concluded that the mean GDP growth revision for OECD countries was -9.419%, the minimum revision was -3.53%, and the maximum was -12.77%. (53) Additionally, a study reported on GDP growth rate and the values for 2020: Germany -6.5; Ireland -7.9; Greece -9.7; Spain -9.4; France -8.2; Italy -9.5; Portugal -6.8; Eurozone -7.7; United Kingdom -8.3; EU -7.4; United States -6.5; Japan -5.0. All countries and regions reported in this article had positive GDP growth rates prior to 2020. (50)

A projection for the U.S. GDP until the year 2030 showed that without the COVID-19 pandemic, the U.S. GDP in 2030 is projected as 27.169 trillion of 2019 dollars, and with the COVID-19 pandemic, the 2030 GDP will be 26.415 trillion of 2019 dollars. (40) One study used data on cumulative cases and hospitalizations from Jan 22, 2020 to Jul 27,

2020 to forecast economic losses due to COVID-19 cases that did not result in death (non-fatal economic losses) in the United States through Nov 2020. It reported that the non-fatal valuation is about $5.7 trillion or 30% of GDP. (36)

The Economist Intelligence Unit, the research and analysis division of Economist Group, created an index to rank the quality of the policy response to the COVID-19 pandemic across 21 OECD countries (74). Countries were assessed on quality of response and mitigation factors adjusted for pre-existing risk factors in the population.[1] (75) Table 3 shows the countries for which we had GDP % change data from the articles included in this review paired with the EIU index category, public health interventions utilized, and number of deaths per 100,000 population for each respective country.

It appears that countries with “good” and “fair” responses to COVID-19 did not have as great of a percent change in gross domestic product (Figure 4). In addition, both Japan and South Korea were indexed into “fair” response, however, had a low death rates and are the two countries in this figure to have the smallest percent change in GDP.

The Human Development Index (HDI) measures three dimensions of human development: life expectancy; years of schooling; and Gross National Income per capita. (76) Using data reported on GDP percent change during 2020 in this review and human development index values for corresponding countries, we found a weak negative correlation between the two variables (r = -0.436) (Figure 5).

[1]The report states “Countries are assessed against three “quality of response” criteria (number of tests, provision of non-Covid-19 healthcare and the number of above-average excess deaths). Three mitigating factors adjust scores to take pre-existing risk factors (share of older population, obesity prevalence and number of international arrivals) into account. The resulting index shows which countries have so far managed the pandemic best, given their risk profiles.” The full calculation method is shown in the report.

Table 2. Percent Change in Gross Domestic Product, by UNICEF Region and Country, 2017 – 2022

Citation	Country	Gross Domestic Product (% Change)					
		2017	**2018**	**2019**	**2020**	**2021**	**2022**
East Asia and Pacific							
Sparrow, *et* al. 2020	Malaysia	--	--	--	-17.0	--	--
Sparrow, *et* al. 2020	Philippines	--	--	--	-16.4	--	--
Sparrow, *et* al. 2020	Singapore	--	--	--	-13.2	--	--
McKibbin and Vines 2020	Australia	--	--	--	-10.8	--	--
Sparrow, *et* al. 2020 Singh, *et* al. 2020	Thailand	4.1	4.2	2.4	-8.5*	4.1	--
McKibbin and Vines 2020 Oxford Economics 2020 Singh, *et* al. 2020 Zhang 2020	China	6.8	6.6	6.1	-6.9*	8.0*	5.8
McKibbin and Vines 2020	Korea	--	--	--	-6.3	--	--
Oxford Economics 2020 McKibbin and Vines 2020 Singh, *et* al. 2020	Japan	2.2	0.3	0.7	-5.5*	3.2*	2.1
Singh, *et* al. 2020 Sparrow, *et* al. 2020 McKibbin and Vines 2020	Indonesia	5.1	5.2	5.0	-3.0*	4.8	--
Eastern Europe and Central Asia							
McKibbin and Vines 2020 Singh, *et* al. 2020	Russia	1.8	2.5	1.3	-10.7*	2.7	--
McKibbin and Vines 2020 Singh, *et* al. 2020	Turkey	7.5	2.8	0.9	-6.0*	5.0	--
Western Europe							
Oxford Economics 2020 McKibbin and Vines 2020	Italy	--	0.7	0.3	-10.9*	3.8	2.8
Oxford Economics 2020 Malliet, *et* al. 2020	France	--	1.7	1.3	-7.6*	4.4	2.5

Citation	Country	Gross Domestic Product (% Change)					
		2017	**2018**	**2019**	**2020**	**2021**	**2022**
McKibbin and Vines 2020							
Oxford Economics 2020 McKibbin and Vines 2020	Germany	--	1.5	0.6	-7.6*	4.7	1.4
Oxford Economics 2020 Oxford Economics 2020 McKibbin and Vines 2020	U.K.	2.29	1.1*	1.8*	-7.4*	8.6*	3.0*
Singh, *et* al. 2020	Poland	4.9	5.3	4.1	-4.2	2.8	--
Latin America and Caribbean							
McKibbin and Vines 2020 Singh, *et* al. 2020	Brazil	1.3	1.3	1.1	-12.9*	2.2	--
McKibbin and Vines 2020 Singh, *et* al. 2020	Argentina	2.7	-2.5	-2.2	-10.4*	2.1	--
Singh, *et* al. 2020 McKibbin and Vines 2020	Mexico	2.1	2.2	-0.3	-7.1*	3	--
Middle East and North Africa							
Singh, *et* al.2020	Iran	3.8	-4.7	-8.2	-5.3	2.1	--
McKibbin and Vines 2020 Singh, *et* al. 2020	Saudi Arabia	-0.7	2.4	0.3	-4.5*	2.5	--
Singh, *et* al. 2020	Egypt	4.2	5.3	5.6	3	2.1	--
North America							
Oxford Economics 2020 McKibbin and Vines 2020 Singh, *et* al. 2020	U.S.A.	2.4	2.9	2.3	-8.3*	5.9*	1.6
McKibbin and Vines 2020 Oxford Economics 2020	Canada	--	2	1.6	-7.9*	9.2	2
South Asia							
Oxford Economics 2020 McKibbin and Vines 2020 Singh, *et* al. 2020	India	7	6.5*	4.8*	-4.6*	6.0*	6.8
Singh, *et* al. 2020	Pakistan	5.2	5.5	1.9	-2.6	-0.2	--
Singh, *et* al. 2020	Bangladesh	7.3	7.9	8.2	1.6	1	--

Citation	Country	Gross Domestic Product (% Change)					
		2017	**2018**	**2019**	**2020**	**2021**	**2022**
Sub-Saharan Africa							
McKibbin and Vines 2020 Singh, *et* al. 2020	South Africa	1.4	0.8	0.2	-16.7*	2.9	--
Adam, *et* al. 2020	Kenya	--	--	--	-5.0	--	--
Adam, *et* al. 2020 Singh, *et* al. 2020	Nigeria	0.8	1.9	2.2	-4.6*	1.7	--
Adam, *et* al. 2020	Ghana	--	--	--	-4.3	--	--
Singh, *et* al. 2020	Angola	-0.1	-2.0	-0.9	-4.0	3.1	--
Adam, *et* al. 2020	Uganda	--	--	--	-2.5	--	--
Adam, *et* al. 2020	Ethiopia	--	--	--	-2.4	--	--

*Average of reported values

Figure 2. Global Percent Change in Gross Domestic Product during COVID-19 Crisis, 2020

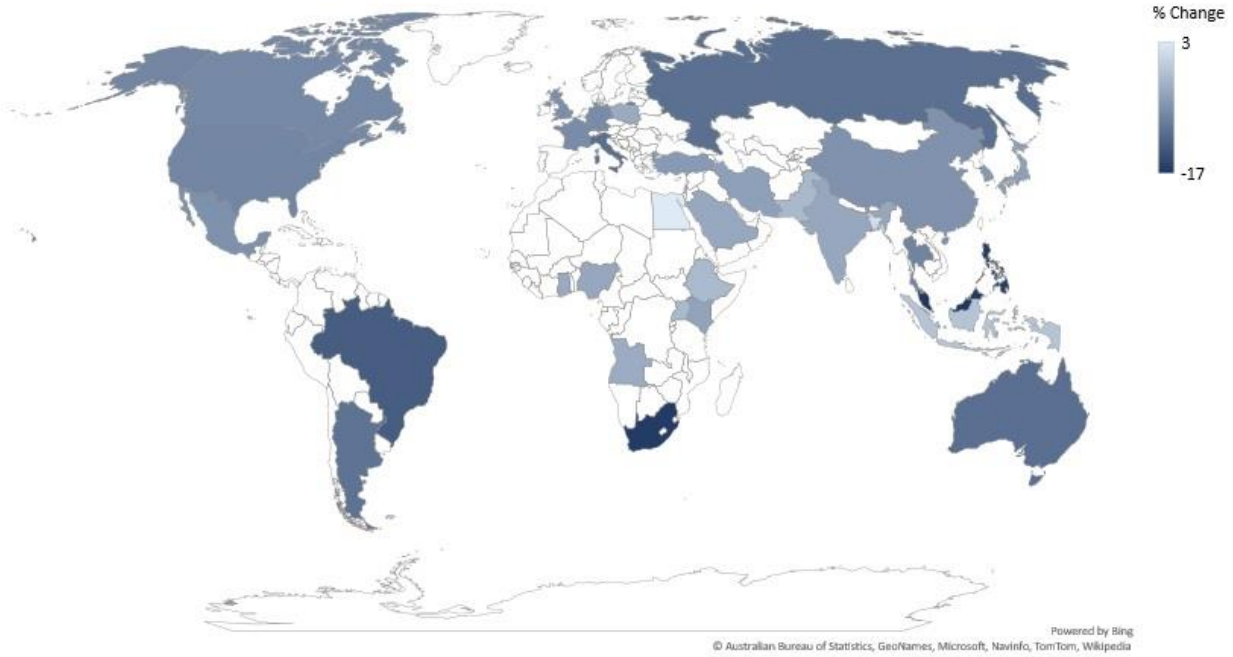


Figure 3. Trend of Percent Change in Gross Domestic Product, by Country, 2018 – 2021

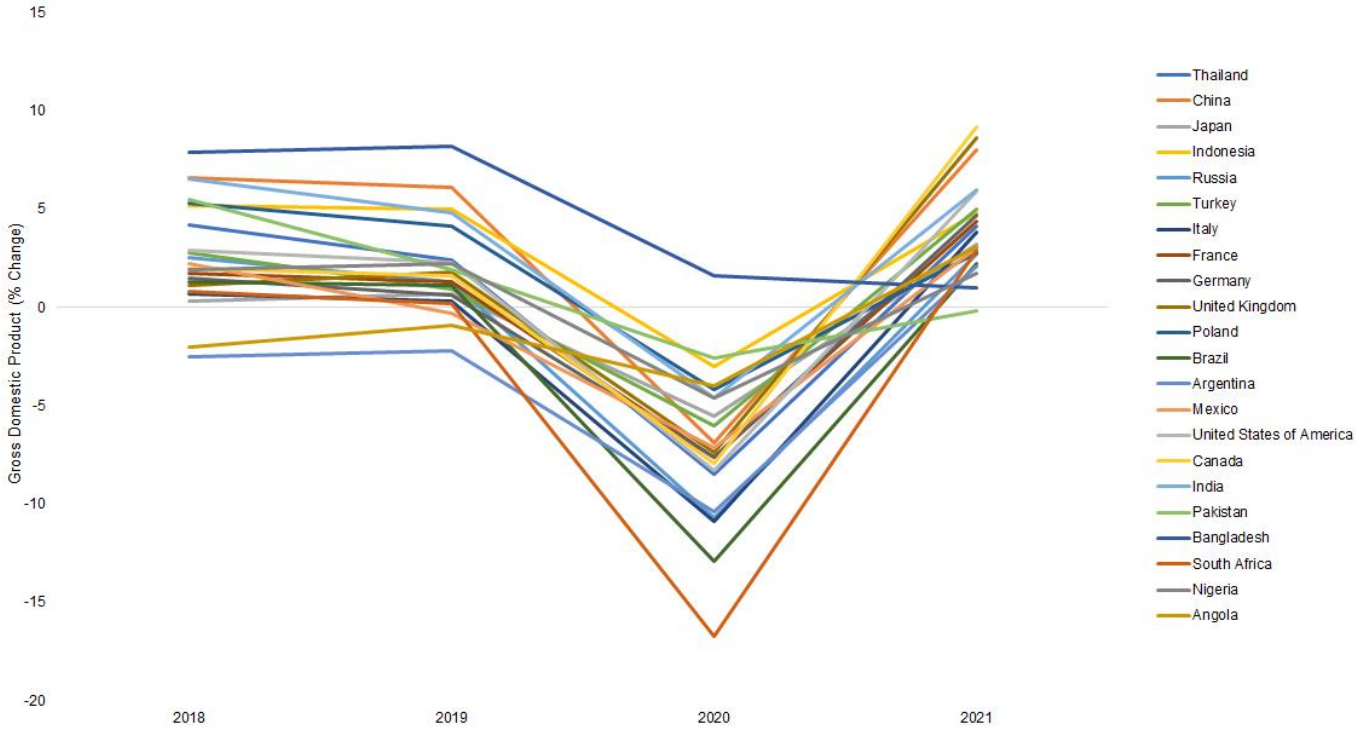


Table 3. Economist Intelligence Unit Index, GDP, and Utilized Public Health Interventions for countries included in the Organization for Economic Co-operation and Development and included the Systematic Review

Country	EIU Score	EIU index category	Interventions	2020 GDP % change	Deaths per 100,000[1]
Australia	3.44	Very good	-Early employment of aggressive control measures -Stay-at-home orders -Social distancing	-10.8	3.64
Germany	3.56	Very good	-Rapid case identification -Lockdown from 22 March until 3 May 2020 -Stimulus	-7.6*	90.15
France	3.11	Good	-Stay-at-home orders 17 March 2020 -Border closure 17 March 2020 -Financial support program	-7.6*	137.52
U.S.A.	3.11	Good	-Lack of large-scale societal mitigation strategies -State by state mask wearing -Social distancing -Fiscal stimulus	-8.3*	165.77
Japan	2.89	Fair	- Backward tracing (cluster tracing) -'3 C' campaign (avoid closed spaces with poor ventilation, crowded places, and close-contact settings) in March 2020	-5.5*	6.97
South Korea	2.78	Fair	-Early employment of aggressive control measures -Face masking -Social distancing	-6.2	3.29
Italy	2.22	Poor	-Slow response -Nationwide lockdown 9 March 2020	-10.9*	173.66
U.K.	2.22	Poor	-Full Lockdown -Payment of furloughed workers -Vaccine development	-7.4*	190.10

*Average of reported values

[1]Rates as of Monday, March 22, 2021 at 06:00 AM EDT

Figure 4. Percent Change in Gross Domestic Product Compared to COVID-19 Deaths, by Country, Indexed by the Economic Intelligence Unit, 2020

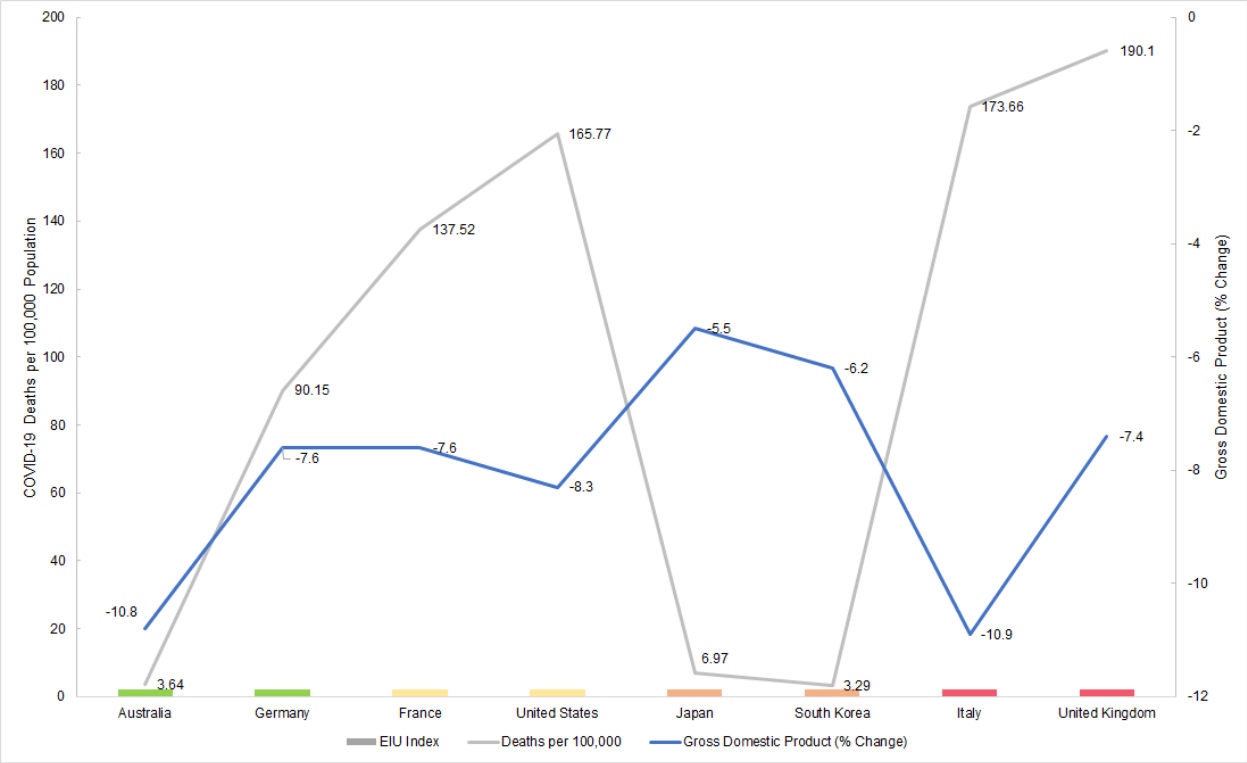
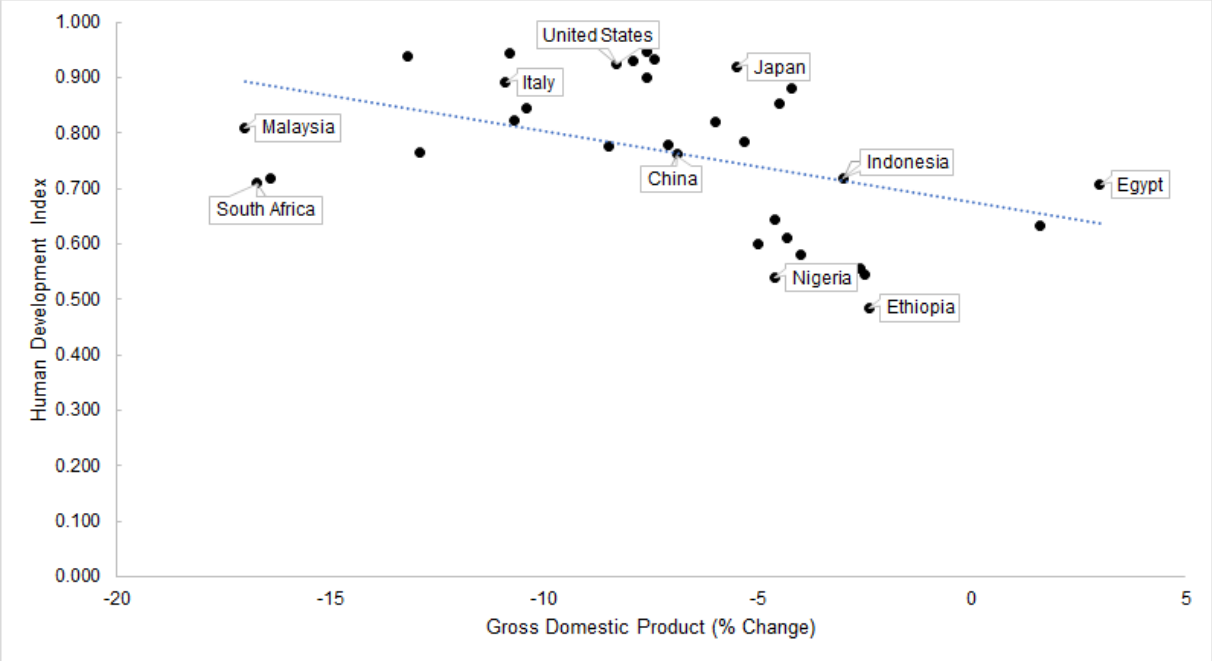


Figure 5. Relationship between Gross Domestic Product Percent Change and Human Development Index for Countries Included in the Systematic Review, 2020



HIV/AIDS

A wide range of outcomes related to GDP were reported in studies focused on HIV/AIDS. First, one study found that from measuring GDP and AIDS cases from 1980-1992 in 128 countries, each additional AIDS case per 1,000 persons per year is associated with 0.86 percentage point reduction in the average annual rate of per capita income growth. (65) Results from a modeling study from 1997-2005 show the GDP percent change in Trinidad and Tobago was -4.2% and for Jamaica was -6.4%. (61) Additionally, Lovasz and Schipp provided GDP fall rates per capita from 1997-2005 in sub-Saharan Africa with varying levels of HIV/AIDS prevalence. (62) For HIV/AIDS prevalence of 0.05, GDP fall rate/capita is -0.024 and for HIV/AIDS prevalence of 0.3, GDP fall rate/capita is -0.04.

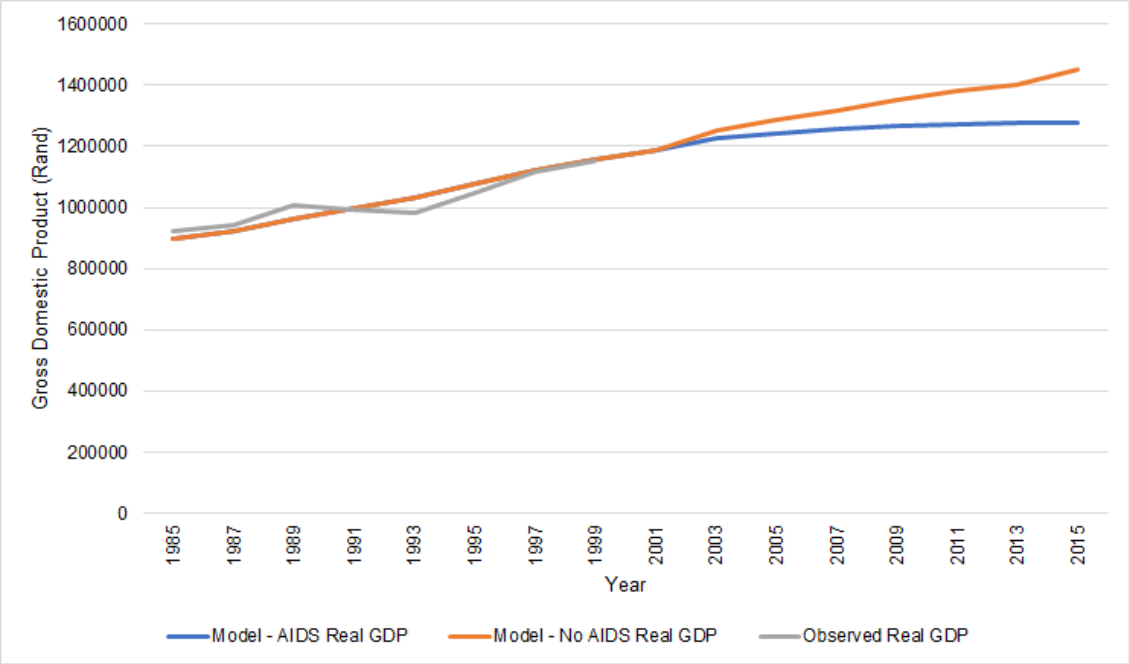
In Tanzania, in 2010 there was a real GDP percent change of -15%. (67) In another article by the same author, the size of the economy in Malawi was modeled using varying scenarios of HIV/AIDS severity. (66) The 2010 GDP will be reduced from a real GDP of 5.03 billion in 1985 Kwacha without AIDS to 4.814.77 billion Kwacha in the medium and extreme HIV/AIDS scenario. Using data from Honduras, the impact of a mature HIV/AIDS epidemic would be approximately 0.012% of GDP, and 0.027% GDP in a high prevalence situation. (63)

Amiri *et* al. (2012) investigated the direction of causality between GDP increase/decrease and HIV cases increasing/decreasing. (59) The combined result from 44 African countries was that the causal relationship is bidirectional. In Algeria, Benin, Burundi, Comoros, Congo, Egypt, Gabon, Ghana, Guinea-Bissau, Lesotho, Liberia, Madagascar, Malawi, Mauritania, Morocco, Niger, Nigeria, Swaziland, Tunisia, Uganda,

and Zambia there was no significant result for direction of causality. (59) For Angola, Botswana, Burkina Faso, Côte d'Ivoire, Djibouti, Equatorial Guinea, Mauritius, Namibia, Senegal, Sierra Leone, South Africa, Sudan, and Zimbabwe, the conclusion was that HIV/AIDS leads to GDP levels. In Gambia, Guinea, Rwanda, and Togo the causality was GDP levels to HIV/AIDS. (59) However, for Cameroon, Chad, Kenya, Mali, Mozambique the statistical results indicate bilateral causality. (59)

Lastly, Burger and de Villiers reported data on GDP from 1985-2015 in South Africa (South African Rand as the currency) using a model in which there were situations with no AIDS and with AIDS (Figure 6). (58)

Figure 6. Impact[2] on Gross Domestic Product with and without HIV/AIDS Epidemic in South Africa, 1985 – 2015



[2] Burger, R. P., & de Villiers, P. (2005). The Macroeconomic Impact of HIV/AIDS in South Africa: A Supply-Side Analysis. Journal for Studies in Economics and Econometrics Journal for Studies in Economics & Econometrics, 29(1), 1–14.

SARS

At the height of the 2003 SARS outbreak, it was predicted that the total cost of the epidemic in China would be 1.5% of GDP. (68) However, due to containment measures, the cost turned out to be only 0.5% of GDP. One study found that real GDP in China reduced from 34970.3 (100 Million RMB) during the fourth quarter of 2002 to 29825.5 (100 Million RMB) during the first quarter of 2003 (69). The same conclusions were drawn by Zhang. (56) After that time period, there was economic recovery so that the real GDP was back to 34544.6 (100 Million RMB) in the second quarter of 2004. (69) Another study reported a similar timeline of economic recovery for the world economy. (57)

Pandemic Influenza Modeling

Two studies modeled the effects of varying interventions (4-week school closure, 13-week school closure, 1-week prophylactic absenteeism, 4-week prophylactic absenteeism, 4-week school closure, and 1-week prophylactic absenteeism, or 13-week school closure and 4-week prophylactic absenteeism) and varying severities of the disease outbreak (base, increased case fatality rate, increased clinical attack ratio, or severe disease) on GDP. In summary, the more involved the public health intervention, the greater negative GDP change. However, disease severity did not have as great an influence on GDP change. (70,71)

Other Disease Outbreaks

Due to the Foot and Mouth Disease Outbreak in the early 2000s, the United Kingdom's economy shrank. In 2001 and 2002 the actual GDP values were 2.3 billion pounds and 1.5 billion pounds, respectively. The estimated GDP values for 2003 and 2004 were

both 0.5 billion pounds. (72) Additionally, as a result of a Mad Cow Disease outbreak, the U.S. GDP decreased by 1.7 billion USD from 2000-2003. (73)

Sector Related Impacts

Sector related data was only available in records focused on COVID-19, HIV/AIDS, and Foot and Mouth Disease. For all other disease outbreaks included in this review, this data was not reported or measured.

COVID-19

Disease outbreaks impact sector-related GDP as well as other macroeconomic indicators. One study on the COVID-19 pandemic showed that following a 3-week lockdown in Ghana, the GDP percent change for agriculture, industry, and services was -15.6%, -26.8%, and -33.1% respectively. (38) Another study reported component GDP growth by sector (% year over year) for 2020 in Indonesia. Transport and storage (-30.8%), accommodation and restaurants (-22%), business services (-12.1%), and wholesale and retail trade (-7.6%) saw the greatest negative impacts. However, some sectors saw growth during this time: information and communications (10.9%), healthcare and social work (3.7%), and real estate (2.3%). (44)

During the 3-month lockdown in Italy, profit for nonfinancial companies dropped 170 billion euros, which is roughly 10% of GDP. (48) Also, during the lockdown in Italy, assuming residential electrical usage did not change, GDP percent change related to the electricity sector decreased -13.7% in March 2020 and -21.7% in April 2020. The decrease in GDP continued to decrease through June 2020. (49)

In the United States, healthcare spending decreased -32.1% from Feb 2020 to Apr 2020; dental services spending decreased the most, followed by primary care physician

and clinical care. (46) The decrease in U.S. GDP followed the same linear/temporal trend as the decrease in healthcare spending. Industrial production GDP deviated -18.19% from the trend six months into the COVID-19 pandemic in the United States. After 12 months, the deviation was still -10%. (55)

Tourism in Japan was affected greatly; there was a 58.2% decrease in visitor arrivals during and a 15% decrease in JR Central hotel occupancy rate in January 2020. (52) In China, income from tourism dropped to the equivalent of -2% of GDP. (56)

HIV/AIDS

HIV/AIDS impacts productivity in the business sector. In one study, productivity loss was estimated as 59% of worker's wage compensation for a symptomatic HIV-infected employee, and 30% of worker's wage compensation for an asymptomatic HIV-infected employee. (60) In the United Kingdom, productivity loss from an asymptomatic HIV employee, symptomatic HIV employee, and or an employee with AIDS in 2000 was $6,515, $13,140, and $34,825 respectively. (60) For 2002, the productivity loss was $7,047, $14,212, and $37,667. In the United States, productivity loss from asymptomatic HIV and symptomatic HIV in 2000 was $11,544 and $22,703 respectively. For 2002, the values were $13,505 and $26,559. (60)

Due to the HIV/AIDS epidemic in Trinidad & Tobago, the employment rate dropped 3.5% in agriculture, 4.6% in manufacturing, and 6.7% in services from 1997-2005. (61) Similar rates were observed in Jamaica during the same time period. (61)

Foot and Mouth Disease

In the United Kingdom, tourism expenditure reduction was responsible for a reduction of GDP of 2 billion pounds in 2001 and 1.3 billion pounds in 2002. (72) Domestic tourism

income growth rate slowed; however, the international tourism income growth rate fell severely to -14.5 in 2001. (72)

Effect of Interventions

COVID-19

In Ghana, the effect of a 3-week lockdown would be a one-billion-dollar reduction in GDP. (38) If this lockdown was hypothetically extended by one, two, or three weeks, GDP would decrease by 1.8, 2.2, or 2.7 billion dollars. (38) The percent share of total GDP losses for intervention categories were also estimated: closing non-essential manufacturing operations (21%); limiting hotel and restaurant operations (17.6%); transport and passenger travel restrictions (11.3%); closing all schools in the country (6.2%); closing non-essential business services (5.9%); banning sports and other entertainment (3.5%). (38) Additionally, in a COVID-19 fast recovery scenario (fast lifting of restrictions), GDP growth rate is estimated to be -2.3%. (38) However, in a COVID-19 slow recovery scenario (slow lifting of restrictions), GDP growth rate is estimated to be -6.3%. (38)

A study in China reported that a 3-week lockdown would reduce consumer spending by five to eight percent. A 6-week lockdown would reduce consumer spending by nine to 16 percent, and a 12-week lockdown would reduce consumer spending by 18 to 32 percent. Consumption typically is 70% of GDP in advanced economies. (47) In another study by the same author, the impact of policy responses was modeled for any pandemic. In a high spending policy response scenario during the year of the outbreak, percent loss in GDP is estimated at -2.7% and five years on at -0.7 percent. In a low

spending policy response scenario during the year of the outbreak, percent loss in GDP is estimated at -2.83% and five years on at -3.99 percent. (57)

The Wuhan lockdown did not have any impact on GDP percent change in the United States, Eurozone, or Japan. During the Italy quarantine period, U.S. GDP increased 0.194%, Eurozone GDP decreased 0.2% and Japan GDP decreased 0.11%. During the EU travel ban, US GDP increased 0.081%, while Eurozone and Japan GDP dropped 0.7 and 0.43%. Even with fiscal stimulus in Apr 2020 in the United States, GDP dropped 5.43%. (54)

Mad Cow Disease

In the United States, following an import ban during Q1-Q3 of 2003 for all live cattle and beef products from Canada, U.S. Cattle imports fell to $0 from $294.25 million. Fresh/chilled beef imports fell from $284.27 million to $52.86 million. Frozen beef imports fell from $13.47 million to $3.92 million. (73)

Secondary Outcomes

Employment

As a result of the COVID-19 pandemic, several studies reported on employment rate decreases. (37) For example, one study reported an increase in unemployment rate in France of 2.9%. (43) Additionally, six months into the pandemic in the United States, the employment rate deviated -10.95% from the trend. (55) Due to the Mad Cow Disease outbreak from 2000-2003, 11,000 jobs were lost in the United States, primarily in jobs dealing with livestock and meat packing. (73)

Net Export/Import

In France, the goods and service demand variation between the COVID scenario and baseline was reported to be -8.03% for coking and refining, -8.51% transport equipment manufacturing, -4.44% manufacture of electrical, electronic and computer equipment. For some sectors like manufacture of food, beverages, and tobacco products, net export increased during 2020. (43) In Indonesia, net export decreased 11.7% during 2020 and net import decreased 17%. (44) In Japan, net export decreased 27.62% in 2020, however, is estimated to increase by 29.92% in 2021. (52) Italy, Turkey, India, Indonesia, Mexico, Argentina, Brazil, Russia, Saudi Arabia, and South Africa saw negative balances in trade during 2020. (51)

Other

During the COVID-19 pandemic, household consumption decreased 5.5%, government consumption decreased 6.9%, and investments decreased 8.6% in Indonesia. (44) Additionally, industrial output decreased 13% and retail sales decreased 20% in China during 2020. (47) From 2007-2008, 4.4% in Botswana, 2.6% in Lesotho, and 2.1% in Swaziland of government expenditure for HIV/AIDS prevention and control was domestically financed. (64)

CHAPTER 5: DISCUSSION

This systematic review showed that disease outbreaks and pandemics affecting humans and animals reduced GDP and slowed economic growth, not just in the country of disease origin. These effects are greater now that more than half of the world's countries (102 out of 189) and two-thirds of developing countries are dependent on commodities, according to the United Nations Conference on Trade and Development. (77) Although developed countries face greater impact, as evidenced by the data for GDP percent change and human development index values, pandemics may impact low-and-middle-income countries (LMIC) more substantially.

In 2009, the World Bank president stated, "The global economic crisis threatens to become a human crisis in many developing countries unless they can take targeted measures to protect vulnerable people in their communities. While much of the world is focused on bank rescues and stimulus packages, we should not forget that poor people in developing countries are far more exposed if their economies falter". (78) It could be helpful for countries to diversify their production and exports so that the impact of commodity dependence does not have to be detrimental in a crisis situation. (79) For example, energy and mineral export dependent countries, like Rwanda and Cameroon, have already started this process through expanding their agricultural products and exports. (79)

Our results showed that certain sectors are impacted more severely than others. Through every disease outbreak discussed in this review tourism, travel, entertainment, service industry, and trade were impacted by various public health control measures that were put into place. These sectors also faced the most shock in unemployment

rates. For this reason, it could be strategy for governments, if capable of doing so, to provide money transfers or state insurance for staff placed on unpaid leave and provide economic stimulus packages to boost the sectors struggling the most. (80)

Implications for Public Health Strategy

There is an intricate balance between well-being of citizens and preserving economic growth. Response to a disease outbreak or pandemic should be a “balanced approach,” meaning that population health should be protected across all health and well-being concerns across all populations during the specific time period. (81) Healthcare access and equity are critically important for building communities that can stay healthy and economically productive, especially during a pandemic. (82) Healthcare spending decreased -32.1% in the United States at the beginning of the COVID-19 pandemic. (46) Measures need to be put into place so that individuals still seek preventative and necessary healthcare during a pandemic so that population health does not falter in addition to the burden of disease with regards to the outbreak. This is also important so that the healthcare sector can continue to operate on sufficient income in a critical period of time.

The notion that basic public health measures are essential – effective public health surveillance, public health response, community trust – should be reinforced. This is critical to stopping the pandemic early, so that fewer lives are lost, and less economic damage is accumulated. There is evidence from this review that perhaps there is a balance between pandemic response and GDP reduction. Countries that were classified as having “fair” response by the Economic Intelligence Unit COVID-19 response index, had the lowest death rates of the countries included and are the two countries include to

have the smallest percent change in GDP. Countries that had “very good” and “poor” responses also had the largest decreases in GDP. Other studies included in this review give insight into what public health interventions lead to the best economic outcomes. Lockdowns and closure of nonessential business led to declines in GDP. (38) Although faster lifting of public health restrictions leads to better GDP growth rate projections, this is not beneficial for health outcomes and controlling the outbreak. (38) The key strategy, as evidenced by this review, is to implement a high spending policy response during the outbreak because the investment pays off economically. (57) Large scale policy interventions need to be implemented early and with aggressive spending, since there is evidence to show that a short-term recession will give rise to strong recovery. (57)

Lastly, we need to invest in public-health systems now, as COVID-19 or any of the pandemics above will certainly not be the last of their kind. (83) We should ensure that when the attention and horror of current pandemic ceases, we continue to focus our attention on public health so that outbreak detection and control measures to not deteriorate. (83) Professionals at McKinsey and Company have estimated that spending $70-$120 billion over the next two years and then $20-$40 billion annually following that could reduce the chance of a future pandemic. This seems large, however, the impacts of a pandemic on human health, economic well-being at the individual, country, and world level are far greater in consequence.

CHAPTER 6: CONCLUSION

Economic growth and health security can and should go hand in hand. Collaboration among public health officials, governments, non-governmental organizations, business professionals is critical to finding the balance between human and economic health during the next health emergency. Early investment in public health measures will help give rise to strong economic recovery. As globalization continues to rise, so does the increasing probability that an emerging infectious disease that appears in one country will rapidly spread to another. We must be prepared with public health and fiscal measures so that we can protect vulnerable populations who feel the highest impact of a faltering economy.

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APPENDIX A: SEARCH STRING

Set#	Concept	Search String
S1	Cost and GDP	(Gross Domestic Product) OR (GDP) OR (cost analysis)
S2	Epidemic or Pandemic	(Disease Outbreak) OR (Epidemic) OR (Pandemics)
S3	SARS-CoV-2	(COVID 19) OR (2019-nCoV Infection) OR (SARS CoV 2) OR (Severe Acute Respiratory Syndrome Virus)
S4	SARS-CoV	(SARS-CoV) OR (Coronavirus)
S5	H1N1	(H1N1 Virus) OR (Swine-Origin Influenza A H1N1 Virus) OR (Highly Pathogenic Avian Influenza) OR (HPAI)
S6	MERS	(Middle East respiratory syndrome-related coronavirus) OR (MERS-CoV) OR (MERS Virus)
S7	Mad Cow	(Mad Cow Disease) OR (bovine spongiform encephalopathy) OR (BSE)
S8	Zika Virus	(Zika) or (Zika Virus) or (ZikV)
S9	Ebola	(Ebolavirus) or (Ebola virus) or (Hemorrhagic Fever) or (haemorrhagic fever)
S10	Nipah Virus	(Nipah Virus)
S11	Plague	(Plague) or (yersinia pestis infection) or (septicemic plague) or (black plague) or (bubonic plague)
S12	Chikungunya	(chikungunya)
S13	Japanese Encephalitis	(Japanese Encephalitis) or (Japanese B Encephalitis) or (Japanese B Viral Encephalitis)
S14	Combined Search	(S1) **AND** (S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13)