Charting the Global Economic Recovery from COVID-19 Vaccinations

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I. Introduction

1.1 COVID-19 and its global impacts on economic consequences

Since the COVID-19 outbreak in early 2020, the growth of the global economy declined approximately by 4%, with the highest drop in Argentina (9.9%), Italy (8.9%), India (8.0%), Columbia (6.8), Thailand (6.1%), and the USA (3.5), while China and Vietnam experienced a slight increase of 2.3% and 2.91%, respectively. These two economies registered positive economic growth because they took early actions, classifying from border closures and face coverings, massive testing and lockdowns, contact tracing, and compulsory quarantines based on possible exposure, rather than symptoms only, which minimized asymptomatic and presymptomatic transmission. Table 1 shows the real GDP rank of countries studied in our model.

Millions of jobs and businesses have been impacted by the economic catastrophe that followed the health crisis across the world. According to the latest report of the International Labor Organization (2021), in comparison to the fourth quarter of 2019, 8.8% of worldwide working hours were lost in 2020, equating to 255 million full-time jobs. Working-hour losses were especially significant in Latin America, the Caribbean, Southern Europe, and Asia. Working-hour losses in 2020 were almost four times higher than they were in 2009 during the global financial crisis. Consequently, worldwide labor income (before considering income support measures) was expected to have decreased by 8.3%, amounting to US$3.7 trillion, or 4.4 percent of global gross domestic product (GDP). Workers in the Americas lost the most money (10.3 percent), while those in Asia and the Pacific lost the least (6.6 percent).

Table 1: GDP rank of countries in the model, 2020

Country	Real GDP at constant 2015 US$ billion
USA	19294.5
China	14631.8
Japan	4380.8
Germany	3434.4
UK	2891.6
India	2500.1
France	2410.3
Brazil	1749.1
Italy	1744.7
Republic of Korea	1623.9
Canada	1607.4
Russia	1416.1
Mexico	1148.7
Indonesia	1027.6
Argentina	514.8
UAE	370.9
Singapore	330.1
Colombia	299.8

Vietnam	258.5
Peru	191.0

Source: World Bank (2022)

According to Baldwin and di Munro (2020), the pandemic outbreak has influenced a majority of economies involving the Group of Seven (G7) nations, including Canada, France, Germany, Italy, Japan, the United Kingdom, and the United State, who contribute about 60% of the world supply and demand (GDP), 65% of the world producing, and 41% world exports. Hence, since these economics are presently seriously influenced by the pandemic, the rest of the world will follow suit in the similar pattern. McKibbin and Fernando (2020) employed dynamic Stochastic General Equilibrium and Computable General Equilibrium modeling to demonstrate seven pandemic scenarios, assuming only China was affected by the COVID-19 in different levels in the first three scenarios while the rest focused on the global economies. Their findings showed a decline in GDP development across economies worldwide under all scenarios. It was determined that if the consequences of COVID-19 were likely to the Spanish flu, the global GDP would drop between -4.8 and -6.7 percent (McKibbin & Fernando, 2020; McKibbin & Sidorenko, 2006). Also, Fernandes (2020) determined the drop in GDP growth is about 3-5% in a mild scenario depending on the conation, with an increase of around 2-2.5% of worldwide GDP development for each additional month of lockdown. It is clear that border closures led by the widespread pandemic crash numerous economies detrimentally. A study completed by Baldwin and Tomiura (2020) discussed the COVID-19 widespread effect of a demand shock and a supply shock that can significantly down aggregate trade streams. Beck (2020) centered on finance and banking risks created by the widespread debate; the impact would depend on three elements: the extent of the pandemic's financial impacts worldwide, the financial and monetary policy reactions to the shocks, and regulatory reactions addressing possible bank fragility. Also, Wren-Lewis (2020) indicated the COVID-19 gauge decreased economic development, resulting from the declined labor force, higher manufacturing cost, higher temporary inflation, and decreased social consumption.

1.2 COVID-19 vaccines development

Since COVID-19 was initially discovered in December 2019, vaccines for the COVID-19 have offered hope for better limiting the pandemic, which had infected over 300 million people and killed over 5 million as of January 13, 2022. Much appreciated to modern science and technology, government support, and people who volunteered to participate in vaccine trials, the development of vaccines has been remarkable. **Table 2** represents 36 authorized COVID-19 vaccines utilized by at least one country. Vaccinations developed by Pfizer/BioNTech, Oxford/AstraZeneca, and Moderna have been approved for early or emergency use in about 85–141 countries. In contrast, other approved vaccines are only available in a small number of nations. Currently, 19 economies in the area have approved at least one of these vaccinations, but the number of national approvals for accessible vaccines is projected to rise. To assure global equitable access to COVID-19 vaccines, COVAX, the vaccine's pillar under the Access to COVID-19 Tools Accelerator, the worldwide collaboration platform developed by the World Health Organization (WHO) and partners to resolve the pandemic, was introduced. Through the COVAX platform, the global economy saves a monthly loss of US$ 375 billion to the world economy. As of January 14, 59.6% of the world population has got at least one done of a COVID-19 vaccine, and 9.6 billion doses have been delivered, with 34.5 million doses are presently managed every day worldwide.

A few countries are attempting to produce their vaccines. China has manufactured two vaccines approved outside of its original country. India is developing its vaccine, called Covaxin, which is approved for limited emergency usage in the country and might help the country meet its own vaccine need. Vietnam's vaccine, Nanocovax, is presently in Phase ½ trial results, another one is set to begin Phase 1 testing in February, and the other two vaccines are in the development stage (Thuy and Tuan, 2021)

Table 2: 36 authorized COVID-19 Vaccines

No.	Developer	Vaccine name	Types of vaccine	Countries approved
1	Pfizer/BioNTech (US/GER)	BNT162b2 (Comirnaty)	RNA	141
2	Moderna (US)	mRNA-1273 (Spikevax)	RNA	85
3	Gamaleya (RUS)	Sputnik V	Non Replicating Viral Vector	74
4	Gamaleya (RUS)	Sputnik Light	Non Replicating Viral Vector	26
5	Takeda	TAK-919 (Moderna formulation)	RNA	1
6	Oxford/AstraZeneca (UK)	AZD1222 (Vaxzevria)	Non Replicating Viral Vector	138
7	Serum Institute of India (India)	Covishield (Oxford/AstraZeneca formulation)	Non Replicating Viral Vector	47
8	Bharat Biotech (India)	Covaxin	Inactivated	14
9	Sinopharm (Beijing)	BBIBP-CorV (Covilo)	Inactivated	90
10	Sinovac (China)	CoronaVac	Inactivated	54
11	Anhaui Zhifei Longcom	Zifivax	Protein Subunit	4
12	CanSino (China)	Convidecia	Non Replicating Viral Vector	10
13	Bagheiat-allah University of Medical Sciences	Noora vaccine	Protein Subunit	1
14	Biological E Limited	Corbevax	Protein Subunit	2
15	Center for Genetic Engineering and Biotechnology (CIGB)	Abdala	Protein Subunit	6
16	Chumakov Center	KoviVac	Inactivated	3
17	Health Institutes of Turkey	Turkovac	Inactivated	1
18	Instituto Finlay de Vacunas Cuba	Soberana 02	Protein Subunit	4
19	Instituto Finlay de Vacunas Cuba	Soberana Plus	Protein Subunit	1
20	Johnson & Johnson	Ad26.COV2.S	Non Replicating Viral Vector	108
21	Medicago	Covifenz	VLP	1
22	Medigen	MVC-COV1901	Protein Subunit	3
23	National Vaccine and Serum Institute	CHO Cell	Protein Subunit	1
24	Novavax	Nuvaxovid	Protein Subunit	36

25	Organization of Defensive Innovation and Research	MIVAC	Inactivated	1
26	Razi Vaccine and Serum Institute	Razi Cov Pars	Protein Subunit	1
27	Research Institute for Biological Safety Problems (RIBSP)	QazVac	Inactivated	2
28	Serum Institute of India (India)	COVOVAX (Novavax formulation)	Protein Subunit	3
29	Shenzhen Kangtai Biological Products Co	KCONVAC	Inactivated	2
30	Shifa Pharmed Industrial Co	COVIran Barekat	Inactivated	1
31	Sinopharm (Wuhan)	Vero Cells	Inactivated	2
32	Valneva	VLA2001	Inactivated	1
33	Vaxine/CinnaGen Co	SpikoGen	Protein Subunit	1
34	Vector State Research Center of Virology and Biotechnology	Aurora-CoV	Protein Subunit	1
35	Vector State Research Center of Virology and Biotechnology	EpiVacCorona	Protein Subunit	4
36	Zydus Cadila	ZyCoV-D	DNA	1

Source: COVID-19 Vaccine Tracker, retrieved on April 9, 2022.

Since the pandemic hit the global economy in 2020, almost 495 million confirmed cases and approximately 6 million deaths of COVID-19 had been reported across all regions. The number of cases in selected nations are shown in **Table 3**. Vaccines have been developing to stop the pandemic and are currently being slowly rolled out. As of August 1,2021, 28.3% of the world population had gotten at least one dose of a COVID-19 vaccine, and 14.6% were fully vaccinated. 4.14 billion doses have been delivered, with 37.72 million doses presently managed worldwide. However, the global equitable access to COVID-19 vaccines has not been addressed. Even in the leading region, North America, only around 15 doses were administered per 100 individuals (Our World in data, 2021). At the same time, Asia and the Pacific stand behind in administering vaccines, with less than two doses administered per 100 individuals, driven by India, Indonesia, China, and Singapore. Besides, about 1.1% of individuals have received at least one dose in low-income economies. Vaccination coverage in Indonesia (5.5%), Thailand (4.74%), and Vietnam (0.29%) is behind schedule. COVAX has increased vaccine attainment for low and low- to middle-income nations, whereas high-income have gained enough doses to incorporate 185% of their populations. COVAX program is expected to provide 2.3 billion vaccine doses in 2021 (Gavi 2021). The rollout of vaccinations is notably challenging in Asia and the Pacific's developing economies, with the first reason involving the vaccine’s storage and distribution requirement in ultra-low temperature freezers. In addition, existing immunization systems in developing regions are not prepared for new vaccines, necessitating new guidance involving allocating massive vaccination programs for adults and the elderly. Next, limited vaccine supply, transportation, logistics infrastructure, adequate medical professional, and public vaccine hesitancy are the factors that affect the successful vaccination strategy implementation. As a result, effective national vaccination policies and strategies have been challenging in these countries.

Table 3: The numbers of COVID-19 cases in selected countries

	No. of confirmed cases	No. of deaths	Mortality rate	Population (2020)	Infection rate
USA	79,544,396	976,516	1.2%	331,002,651	24.0%
Republic of Korea	14,983,694	18,754	0.1%	51,269,185	29.2%
Japan	6,887,421	28,528	0.4%	126,476,461	5.4%
China	935,640	14,048	1.5%	1,439,323,776	0.1%
India	43,033,067	521,573	1.2%	1,380,004,385	3.1%
Vietnam	10,070,692	42,733	0.4%	97,338,579	10.3%
Germany	22,441,051	131,370	0.6%	83,783,942	26.8%
Italy	15,106,066	160,402	1.1%	60,461,826	25.0%
UK	21,508,550	169,412	0.8%	67,886,011	31.7%
Brazil	30,067,249	660,723	2.2%	212,559,417	14.1%
Colombia	6,086,811	139,687	2.3%	50,882,891	12.0%
Russia	17,969,431	371,169	2.1%	145,934,462	12.3%
Mexico	5,683,288	323,403	5.7%	128,932,753	4.41%
Peru	3,549,511	212,396	6.0%	32,971,854	10.8%
France	25,781,400	139,811	0.5%	65,273,511	39.5%
Argentina	9,047,408	128,144	1.4%	45,195,774	20.0%
Indonesia	6,030,168	155,556	2.6%	273,523,615	2.2%
Canada	3,535,095	37,850	1.1%	37,742,154	9.4%
Singapore	1,128,155	1,290	0.1%	5,850,342	19.3%
UAE	892,929	2,302	0.3%	9,890,402	9.0%
ROW	170,305,616	788,107	0.5%	3,153,696,009	5.4%
World	494,587,638	6,170,283	1.2%	7,800,000,000	6.3%

Source: World Health Organization (2022), retrieved on April 9, 2022.

1.3 Vaccine inequity

Mathieu et al. (2021) stated that approximately 85% of worldwide vaccine doses were administered in high and upper-middle-income countries, with 755 in only ten countries, including the US, the UK, Germany, and France. As of February 21, 2022, most of the estimated 10.57 billion COVID-19 vaccine doses had been administered in a small number of nations. COVID-19 vaccines remain out of reach for much of the world, particularly those living in low- and middle-income countries. Only 11.4% of people in low-income nations have received at least one dose (Our World in data, 2022). While international initiatives like COVAX and other vaccine donation programs aim to advance global vaccine access, it is predicted that some countries and regions will not achieve significant levels of vaccination until 2023. Globally, inequity in vaccine access can be explained by rich countries' accumulation of vaccines, resulting in the poorest countries suffering considerable damage from the pandemic due to lack of vaccine access (Asundi et al., 2021). The economic cost of vaccine inequity has also affected the global economy. According to a RAND EURO report, if the vulnerable nations do not utilize the vaccine, the world would lose $153 billion in GDP per year (Hafner et al., 2020).

The need for global vaccine coverage is becoming more pressing since new transmissible variants can cause increasing cases in almost all countries, even countries with a young population. In the case of Brazil and India, where new variants have appeared, the infection rate was higher in younger generations compared to the initial virus (The Wall Street journal, 2021), emphasizing the critical need for vaccinations.

This paper endeavors to quantify COVID-19's potential global economy under four different vaccination scenarios. The objective of the paper is to analyze the economywide impact of the COVID-19 pandemic on the global economy, evaluate the effectiveness of COVID-19 vaccinations towards economic recovery, and address vaccine inequity among the developing countries with high COVID-19 infection rates by utilizing a Computable General Equilibrium (CGE) model based on the Global Trade Analysis Project (GTAP) database. The model comprehends the economic interactions due to COVID-19 infection as well as vaccination rates based on the inter-regional and inter-industry relationships. This paper outlines the global economic model and scenarios in Section 3, with section 4 presenting the results and discussion of scenarios simulated in the model. Section 5 concludes the research by summarizing the essential findings and limitations.

II. Methodology

Global computable general equilibrium (CGE) models have been broadly utilized in health policy analyses involving pandemic applications, such as influenza (Smith et al., 2011; Keogh-Brown, 2020). CGE models are adaptable and can be employed to evaluate both direct and indirect effects of health on labor supply and consumption impacts on industries (WHO, 2009).

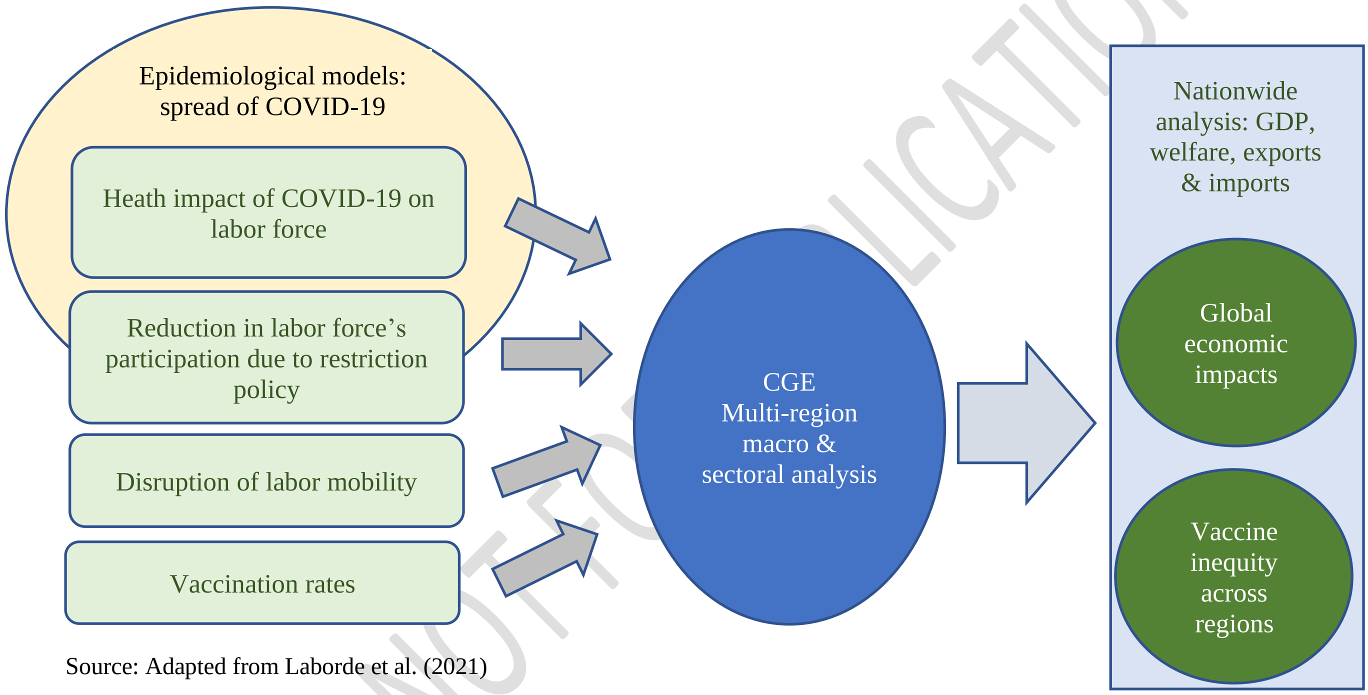
CGE models produce results by apprehending the interactions of various economic agents in the economy. Firms, consumers (private households), governments, and foreign companies are the four main economic agents. A producer firm maximizes profits in each sector in each region and pays income to the regional household. The firm sells the final products by incorporating the endowments with the intermediates to the private households, government, and trade commodities in an open economy. Consumers budget their income between household consumption and savings. The government collects taxes and subsidies from the firms. Foreign companies collaborate with domestic agents on imports and exports. The model considers equilibrium in all markets simultaneously, taking into account the interdependence of various sectors in the economy. The interaction of the different agents depends on economic theory. CGE models are top-down models that can seize inter-industry and inter-regional linkages through input-output tables and macro-economic flows.

In the current exercise, we adapt the GTAP database and evaluate the global impacts of COVID-19 and the impact of vaccinations on economic recovery from the incessant pandemic. We developed a framework with an aggregated GTAP database comprising of 22 regions and 14 sectors, and assumed perfect competition in all sectors. Health impacts, disruption of labor mobility due to restriction policy, and reduction in labor force's participation, which are elements underlying the socioeconomic impacts of COVID-19, are incorporated into the CGE model to simulate endogenously the impacts on the development of economy, consumption, international trade, and welfare. Moreover, the health consequences of the pandemic on labor productivity and supply are associated with the results of epidemiological models. As presented in **Figure 1**, the overall study approach includes utilizing epidemiological models based on COVID-19 infection rates and translating into economic shocks to the globe.

For the present analysis, working day loss is assumed as 15 days (3 weeks absence from work). We assumed further that labor loss is the same as machinery loss, a capital loss is the same as productivity loss since it is assumed that one labor uses one machine, and manufacturers have minimal capacity to transform the use of capital and labor relations in one year. Governments have also taken numerous critical economic responses regarding fiscal measures, monetary instruments, and foreign exchange operations. One of the critical government policy responses is employing macroeconomic stabilization policies. Primarily, they categorize from payroll support to maintain jobs, cash transfer and distribution of essential goods, reduction in the advance payment of the corporate tax and deferment or installment payments of tax debts without generating late payment interest for businesses, and market liquidity support through numerous market instruments.

Since this study aims to determine the impacts of COVID-19 on the global economy during 2020 and 2021, we first update the database from the base year 2014 to 2019. For this purpose, we use historical data on macroeconomic variables, such as growth rates in GDP, population, and labor force across all the regions in the model.

Figure 1: Implementation of the COVID-19 & Vaccination Scenarios



Source: Adapted from Laborde et al. (2021)

III. Modelling scenarios

The impacts of COVID-19 on the global economy have been considered from different perspectives, such as health costs (Keogh-Brown et al., 2020), food security (Laborde et al., 2021), global trade (Vidya and Prabheesh, 2020), and unemployment (Bauer and Weber, 2020), in the relevant literature. The influence of the virus on labor supply and productivity has received little consideration in the literature to date. Therefore, all the shocks are designed for these two factors. The model comprehends the economic interactions due to COVID-19 infection and vaccination rates based on the inter-regional and inter-industry relationships. We formulated four scenarios as listed below.

3.1 Scenario 1: Global impact of COVID-19 pandemic in 2020

The high infection and mortality rate in the population have resulted in a decline in labor supply and productivity. Hence, this scenario introduced adverse shocks in labor supply and productivity. Labor supply loss was determined by total workforce before COVID-19 minus total human resources loss due to mortality. We model the supply-side shock from 0.2% to 2% reduction in labor productivity, depending on the mortality rate, for each country and region.

3.2 Scenario 2: Global economy effects with actual vaccination rate

This scenario was based on the actual vaccination rates in each country and region until December 2021. According to an International Labor Organization report on the COVID-19 and the world of work (2021), a comparable full-time job was included in the worldwide labor market for every 14 completely vaccinated person. In the equitable distribution of vaccines worldwide, working hours would increment by 2.0 and 1.2 percentage points in low-income and low- to middle-income, respectively. We calculated an increase in working hours, which is followed by productivity gain after being vaccinated.

3.3 Scenario 3: Increase in vaccination rates in 2021 on the global economy

Various vaccination rates reflect labor participation and productivity at different levels. 75% and 100% of the population covered by vaccination were proposed to evaluate their impacts on the economy. From the real vaccination rate in scenario 2, we enumerated differences in rates and labor supply, and productivity gain as a 1% additional vaccination rate.

3.4 Scenario 4: Varied vaccination rates across developing (up to 30%) and developed (up to 75%) countries

Nations with high vaccination rates are deliberately reopening, whereas countries with low vaccination rates maintain lockdown policies while suffering from reopening their economies. This is specifically tough for laborers whose prolonged lockdowns equate to job losses. Inequities in vaccine coverage have direct and indirect consequences for both developing and developed countries. Each country's population-weighted labor supply and productivity in the full vaccination rate scenario. In this scenario, we include up to 30% vaccination rates in developing countries with higher COVID-19 infection rates compared with 75% infection in developed economies and delineate the vaccination inequity on their economic recovery.

IV. Results and Discussion

The pandemic economically hurt almost all countries across the world except for China. All modeled regions showed a dramatic drop in their GDP, the output of commodities, imports/exports, and welfare. The model predicted a contraction in GDP in the USA and the EU by $0.49 trillion (or 3%) and $0.42 trillion (or 2.4%), respectively. It is interesting to note that China was barely affected by the pandemic, and the model predicted a marginal growth of $0.01 trillion (0.08%) in overall GDP. The projected increase of the volume of exports is most prominent for the US, which is about $ 0.14 trillion, whereas the EU suffers a significant loss of $0.1 trillion in exports. Other countries in the model undergo the uniform pattern of mild contraction in the volume of exports in 2021. For imports, the USA and the EU undergo a notable negative decrease of $0.15 trillion (6.5%) and $0.14 trillion (2.25%). The reduction in consumer demand in the US and EU would stall imports from developing countries, who have also experienced trade disruption and production downsizing. Furthermore, the US imports more products more than it exports; therefore, the recession is more significant than their trading partners. In other words, the pandemic's recessionary phase has been more significant on US imports than on exports.

Some Asian economies such as Japan, the Republic of Korea, India, China, and Indonesia showed a slight increase of $0.001 trillion (0.18%) to $0.03 trillion (1.56%) in GDP.

It could be possible that once these countries gradually reopened after lengthy shutdowns, and a decline in coronavirus cases had occurred, it ultimately allowed the country to ease travel restrictions. Their massive monetary and fiscal stimulus measures have been released to support the economy. Light and heavy manufacturing are the most severely affected sectors due to the disruption of the supply chain. Canada, Argentina, and Peru experienced a severe drop in both heavy and light manufacturing with numbers consisting of 4.6%, 4.55%, and 5% in heavy manufacturing. In light manufacturing specifically, the numbers were 3.9%, 3.7%, and 4%. The disruption is primarily the result of the nation's lockdown measures, which lead to production halts, restrictions on people/product movement, and border closures. Therefore, the flow of raw materials and finished goods have temporarily stopped. Another disruption is the labor shortage due to these countries' high infection and mortality rates. A 14-day home quarantine is indicated and is assumed to consume at least two weeks' absence from work for infected cases. Social distancing may lower labor participation in factories as well. It is noteworthy to note that the vaccine was not available until December 2020.

Our simulations show that an increase in vaccination rates is associated with a substantial increase in GDP growth rates, as shown in **Table 4.** The level of disparity in GDP and vaccination rate has been observed in studied regions. The total direct economic growth from the current vaccine coverage status, which is captured by changes in real GDP, is ranked from $0.003 trillion (Vietnam) to $3.3 trillion (the US). With 75% of the population getting vaccinated, the model indicated an increase in GDP in these economies. For instance, the USA and the EU gained the most real GDP increase with $2.45 trillion (15%) and $ 2.3 trillion (13%). If 100% of the population gets vaccinated, these numbers would increase further. It is noted that there is a rise in the change in GDP in all model countries. Significantly, the USA and the EU observed an increase of $3.2 trillion (19.8%) and $3 trillion (17.2%). Decomposition of these issues demonstrates that consumer spending is a principal component of these economies, accounting for almost 60% to 70% of the country's GDP. The increase in demand levels and the rise in both consumption and purchasing have occurred as the economy has recovered since travel restrictions were lifted.

These activities were satisfied by companies who had sold out their entire inventory. Moreover, vaccinations had advanced work mobility since the labor force is back to work or they are currently working from home, which leads to overall growth in the size of the workforce and growth in the productivity of that workforce. Our results align with two studies completed by Dongarwar et al. (2021) and Basak et al. (2022), which concluded a relationship between GDP and vaccination rates. While certain developed countries make solid economic recoveries, developing countries encounter slow economic growth due to vaccine inequity. For example, in Peru, their GDP growth is estimated at 0.48% ($1,032 million). Peru is one of the countries most affected by the inequalities, whereas the US counterpart currently sits at 0.64% ($103,566 million). These findings highlight a global equity gap in access to COVID-19 vaccinations, especially for low-income countries. Vaccination protects populations in developed countries, while developing countries have struggled with the pandemic since vaccination rates are lower It can be concluded that the COVID-19 vaccine rollout is unbalanced. Wealthy countries request the vaccine at an alarming rate, while other countries are having a hard time to access it. It must be noted that developing countries deal with a number of challenges when it comes to developing and implementing an effective vaccination program. A vaccination program's successful implementation desires transportation, storage, adequate medical human resources, safety monitoring, and strong public awareness (Park et al.,2021). On top of that, there is a limitation to the financial stability of the country so that those developing countries have hardly been able to access the COVID-19 vaccine. Therefore, people who are more vulnerable to COVID in these countries, should be supported to fairly join the COVID-19 vaccine rollout. In addition, if the ineffective vaccine allocation strategies continue, these gaps may widen, and many developing nations will not reach the global targets of vaccinating at least 40% of their population.

The COVAX facility was introduced to fairly distribute the COVID-19 vaccines for all countries, regardless of income level. However, this program has been behind in its work. For instance, Vietnam, Colombia, Peru, and Mexico are on the COVAX list however, the supply is just enough for about 9 percent of Vietnam's population (8.7 million doses until August 2021), and around 2 percent of Colombia's population (1 million doses until April 2021). These numbers are far behind the needed amount to achieve community immunity.

In addition to that, the balance of trade under different rates of vaccinations on the path of global economic recovery is presented in **Table 5.** The USA, Japan, India, Russia, and Vietnam are predicted to undergo a trade surplus when the vaccination rates vary from 75% to 100%. These countries' volume of exports lay mainly on Heavy and Light Manufacturing and the Energy Mining sectors. China is the largest destination for Heavy manufacturing exports from the US ($233,678 million – 22.7%), Japan ($79,906 million – 34%), and Vietnam ($31,744 – 35%). This sector includes motor vehicles and parts, machinery, and equipment. While the US and China continue to impose tariffs on each other's goods, China's tariff exclusion process, which was ineffective in March 2020, did in fact permit the flowing of goods from the US normally. These exclusions were implemented to support China's commitments to purchase large quantities of US energy, manufacturing, and agricultural products. Since China did not reach its goal, its imports of goods increased significantly. Other economies in the model have been predicted to suffer a trade deficit. The businesses in these countries try to meet the demand for products by selling out their inventories. However, they are not increasing their overall output production of goods at the rate they have to grow to address the supply chain problem; hence, they import more goods to meet that demand.

Table 4: GDP impacts- different vaccination rates

Countries/ Regions	Change in Real GDP ($2021 trillion & % Change)							
	Actual vaccination rate		75% vaccination rate		100% vaccination rate		Vaccine inequity	
	$ trillion	% Change	$ trillion	% Change	$ trillion	% Change	$ trillion	% Change
USA	3.28	20.10%	2.45	15.05%	3.24	19.87%	0.10	0.64%
Japan	0.05	1.15%	0.03	0.86%	0.05	1.14%	0.03	0.63%
India	0.09	3.08%	0.07	2.34%	0.09	3.08%	0.01	0.47%
Vietnam	0.003	1.18%	0.002	0.90%	0.003	1.18%	0.001	0.45%
Canada	0.17	7.64%	0.13	5.71%	0.17	7.57%	0.01	0.65%
Mexico	0.29	20.25%	0.22	15.36%	0.29	20.26%	0.01	0.50%
Argentina	0.16	25.01%	0.12	18.82%	0.16	24.82%	0.004	0.63%
Brazil	0.82	28.20%	0.62	21.33%	0.82	28.21%	0.02	0.64%
Colombia	0.12	25.21%	0.09	19.03%	0.12	25.19%	0.002	0.51%
Peru	0.12	57.08%	0.09	43.48%	0.12	51.07%	0.001	0.48%
EU	3.04	17.33%	2.28	13.00%	3.01	17.16%	0.11	0.63%
Germany	0.01	11.05%	0.01	8.34%	0.01	11.01%	0.001	0.62%
UK	0.005	20.32%	0.004	15.16%	0.005	20.06%	0.0002	0.64%
Russia	0.26	12.55%	0.20	9.56%	0.26	12.56%	0.01	0.61%

Source: Authors' model simulation

Table 5: Imports and Exports impacts – different vaccination rates

Countries/ Regions	Imports						Exports					
	Actual vaccination rate		75% vaccination rate		100% vaccination rate		Actual vaccination rate		75% vaccination rate		100% vaccination rate	
	$ billion	% Change	$ billion	% Change	$ billion	% Change	$ billion	% Change	$ billion	% Change	$ billion	% Change
USA	333.6	14.75%	253.6	11.21%	324.2	14.33%	451.2	19.35%	341.0	14.63%	468.7	20.10%
Japan	4.2	0.51%	4.7	0.57%	5.6	0.68%	53.1	5.29%	39.4	3.93%	51.8	5.16%
India	17.0	3.22%	13.9	2.63%	18.4	3.49%	24.3	7.69%	18.6	5.89%	24.0	7.61%
Vietnam	5.9	1.09%	5.2	0.94%	6.5	1.16%	19.6	0.51%	14.9	0.35%	19.5	0.37%
Canada	9.8	14.59%	7.8	10.91%	10.4	14.97%	7.0	-1.84%	5.4	-1.39%	-6.4	-2.57%
Mexico	5.8	20.01%	5.1	15.17%	6.7	20.11%	3.3	16.98%	3.0	12.80%	3.9	16.61%
Argentina	2.2	18.04%	1.9	14.09%	2.4	18.38%	0.8	21.63%	0.6	16.17%	0.6	21.22%
Brazil	22.4	24.18%	23.5	18.68%	31.4	24.78%	8.0	19.46%	9.5	15.32%	4.2	19.41%
Colombia	93.7	30.82%	70.1	23.53%	96.2	31.62%	-4.6	19.36%	-3.4	15.16%	-6.4	19.11%
Peru	79.8	32.57%	60.5	25.09%	80.2	32.75%	48.3	47.69%	36.4	35.41%	47.2	47.52%
EU	14.2	16.30%	11.1	12.32%	14.5	16.22%	11.2	17.54%	8.4	13.12%	11.0	17.45%
UK	18.8	18.56%	14.3	13.95%	19.3	18.47%	6.7	19.28%	5.3	14.44%	6.6	19.04%
Russia	15.9	15.61%	12.3	12.11%	16.0	16.30%	18.5	6.80%	13.7	5.42%	18.5	6.75%

Source: Authors' model simulation

Table 6 summarizes the regional welfare changes that result from our simulations. Before the vaccine was developed, almost all countries were affected by welfare loss in different degrees such as the US ($504 billion), the EU ($408 billion), and Brazil ($63 billion). Thanks to the invention of the vaccine, countries in the model experience a huge increase in welfare because labor get back to work, except for China. Welfare increased by 1290% (Canada), 1285% (Mexico), 1100% (Brazil), 676% (ROW), 445% (the US), and 503% (the EU). In dollar terms, the equivalent variation measures of these welfare changes are $180 billion (Canada), $250 billion (Mexico), $703 billion (Brazil), $420 billion (ROW), $2245 billion (the US), and $2057 billion (the EU). These countries had high infection rates; therefore, when the people are vaccinated, welfare is affected positively. Total welfare rates impact a collection of components which consist of changes in allocative efficiency as resources move to more or less efficient uses, changes in terms of trade, as a country's export prices change relative to import prices, changes in returns to owners of capital, and also development in endowments, technological change, and efficiency improvements. In actual vaccination rates, the endowment component dominates for the US ($1877 billion), the EU ($1323 billion), Brazil ($527 billion), and Mexico ($201 billion), respectively. It can be explained that when the labor gets vaccinated, they are able to get back to work; hence, the number of labor increases. In the scenario of 100% of population vaccinated, welfare changes are small in the US (1.5%, $41 billion), Canada (0.3%, $0.7 billion), and the EU (1.1%, $27.8 billion) since their vaccination rates were already high, there is no difference in welfare when their vaccination rates achieve 100%. In comparison with ROW, where the vaccination rates are still not high, if all people get full vaccinated, their welfares change can reach at 76.5%, equivalent to $369 billion. The exception is China, which reverse the development trend and experience a decline of $35.8 billion and $20.4 billion, respectively. China is the least affected country with the infection rate is 0.1%. That means its domestic economy is not affected; hence, no matter how much the vaccination rate is, welfare is not influenced. The similar pattern happens for Japan, where the infection rate is about 5%. It can be concluded that vaccine is productive in economic recovery, especially in the growth of GDP due to an increase in consumption.

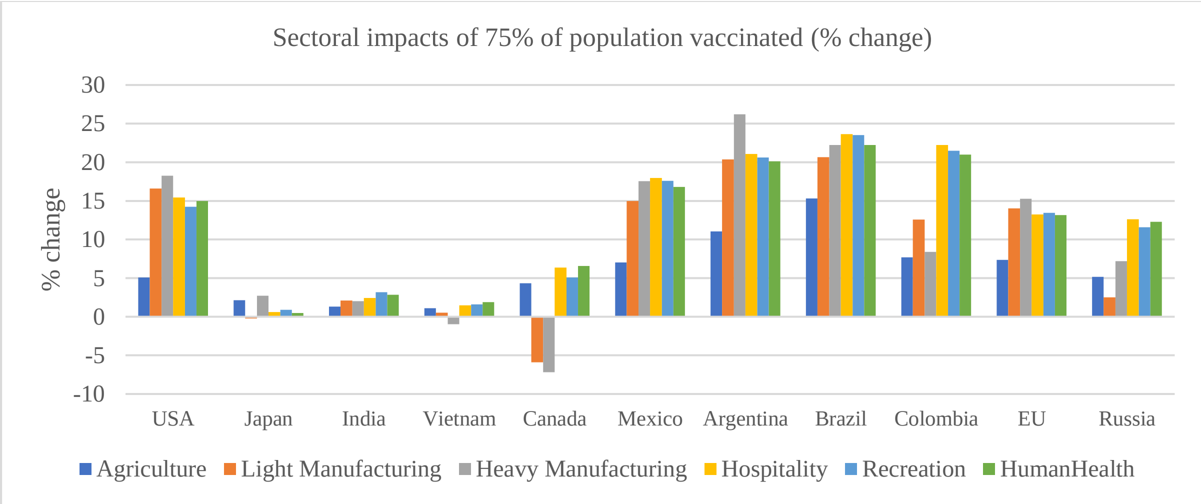
Table 6: Welfare change in different vaccination rates ($ million)

	Actual vaccination rates		100% of population get vaccinated	
	% Change	$ Billion	% Change	$ Billion
USA	445.2%	2245.9	-1.5%	-41.1
Japan	674.8%	3.6	-20.2%	-0.8
India	556.5%	53.3	0.1%	0.1
Vietnam	159.2%	1.9	5.8%	0.2
China	-152.6%	-35.8	-34.5%	-20.4
Canada	1290.1%	180.9	0.3%	0.7
Mexico	1285.8%	250.8	0.2%	0.6
Argentina	758.0%	128.1	-0.6%	-0.9
Brazil	1100.2%	703.1	0.2%	1.2
Colombia	1055.0%	103.7	0.2%	0.2
EU	503.9%	2057.5	-1.1%	-27.8
Russia	723.1%	262.3	0.9%	2.7
ROW	676.1%	420.8	76.5%	369.3

Source: Authors' model simulation

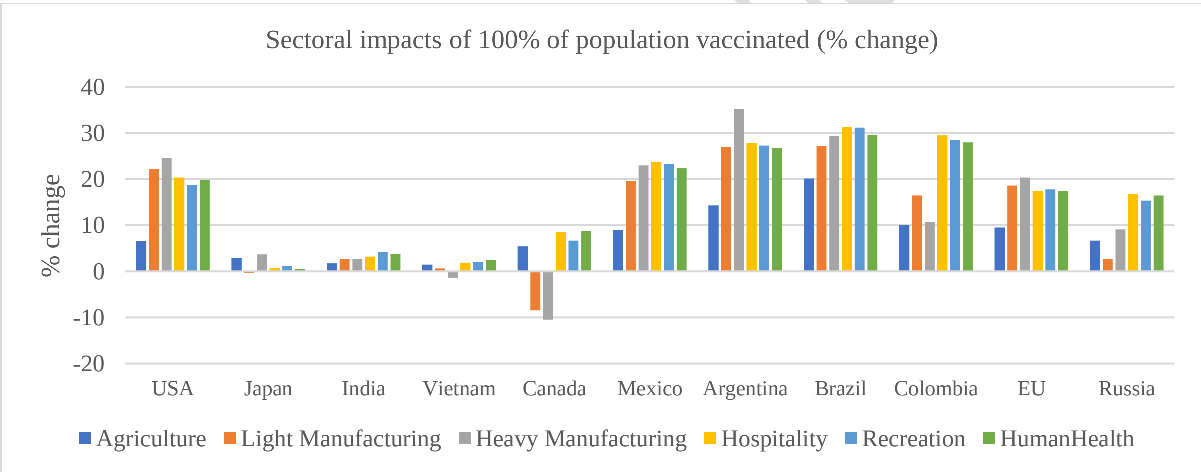
Our simulations indicate the sectoral activity results in **Figures 2 and 3**, and they highlight the considerable expansion in sector-level production changes. Most industries registered a noticeable boost in output due to the rise in vaccination rates across all the modeled global regions. When the vaccination rate reaches at least 75%, Heavy and Light manufacturing (up to 35%) are affected the most across countries. For example, the US's output mainly serves as a domestic purpose with the change of 12%, which is equivalent to $3517 billion in Heavy manufacturing and 8%, equivalent to $2390 billion in Light manufacturing. The exception is Light and Heavy manufacturing in Canada (-5.9% and -7.2%) and Japan (-0.2%). It is important to note that all the countries in the model experience the growth of air transport sectors from 4% (Canada) to 28% (Brazil), except for Vietnam. The vaccine can enhance sectoral demand and supply conditions in vaccinated nations. As a result, the economic costs of COVID-19 from negative sectoral demand and supply, cease globally as soon as the vaccine is available.

Figure 2: Sectoral Production impacts of 75% vaccination rate



Source: Authors' model simulation

Figure 3: Sectoral Production impacts of 100% vaccination rate



Source: Authors' model simulation

V. Conclusions

The CGE model has been utilized to simulate four COVID-19-related scenarios, particularly the vaccine rollout. The simulation experiments were designed to apprehend an increase in labor supply and productivity generated from the growth of vaccine coverage. This study showed the impact of the unprecedented COVID-19 pandemic on the global economy. Most of the impacts on their GDP were driven by the economic consequences of reduced labor supply and productivity in various economies. The Light and Heavy manufacturing sectors are the most affected sectors due to the disruption of the global supply chain. International trade plays a critical role in the global economic recovery, especially in the case of trade in intermediate goods alongside travel and tourism sectors.

Moreover, our results propose that the COVID-19 vaccine strongly affects economic activity. When the vaccination rates hit much higher levels, people will be more comfortable returning to the new normal with substantial labor productivity gain across all industries. Labor participation and productivity are projected to increase significantly with higher vaccination rates. Relatively lower vaccination rates in some developing countries had shown a slowdown in overall global economic recovery.

The present study reveals critical findings; nevertheless, this study has inherent limitations that must be addressed. First, the CGE simulation experiments are not explicit predictions but rather experiments about what the world would be like when the particular event or policy had been in operation in the assumed circumstances and year. Secondly, although CGE models are quantitative, they are not empirical in the sense of econometric modeling since they are essentially hypothetical with constrained conceivable outcomes for thorough testing against experience. Thirdly, this is a static analysis in which it was assumed that almost all consumers and manufacturers purchase and produce the same goods day in and day out without any time lag. Their preferences and purposes are in uniform, and their economic choices are in an ideal congruity with one another. In practice, consumers and manufacturers act and think differently. Changes continuously occur in preferences, and production costs vary from producer to producer. Because the given conditions are constantly changing, the movement towards a general equilibrium is ever obstructed, and its achievement has ever stayed an impractical ideal. Fourthly, the CGE model is employed mainly to predict medium-term periods (three to five years) rather than short- or long-term purposes due to the absence of a time factor and the integrated annual data in the model.

The findings of this study were interpreted with our choice of macroeconomic closures, which represented vital indicators of the global economy. Another significant limitation is that this model was developed for 22 countries with 14 sectors aggregated only. The picture of the COVID-19 impact worldwide is still incomplete.

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