Is Domestic Vaccine Production of COVID-19 Significant for the Vaccination Coverage? Findings from the Major Producing Economies

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Abstract

The effects of COVID-19 have been far-reaching, affecting not just people's health but also the economy and society in profound ways. Despite the rapid progress in vaccine research and institutional innovation efforts like COVAX to address it, vaccine disparity is severe all across the globe. This study analyzed 6 months of consecutive data from 10 of the world's major economies which produce COVID-19 vaccines in order to determine whether or not there is a correlation between the quantity of COVID-19 vaccines manufactured domestically and the rate at which vaccination protocols are followed in the sample countries; through a panel data fixed effect linear regression model. Surprisingly, study results show that bilateral agreements between individual countries and manufacturers, the level of government vaccination policy in each country are more important than the level of domestic production itself in order to achieve a higher vaccination coverage. Factors such as the willingness of its citizens to get vaccinated and their knowledge of COVID-19 are also crucial. Cuba is the only country in the research with a significantly higher vaccination coverage rate than the rest of the world combined, and this is due to the country's advanced biomedical sector and the widespread distribution of vaccines developed in-house. Improved COVAX facilities, funding, affordability, public health infrastructure to deploy, and winning public trust via the dissemination of social awareness and information are all critical if universal vaccination coverage is to be achieved sooner and at a greater rate. The global immunization in defense of COVID-19 outbreak calls for a universal response, as opposed to a regional one that gives preference to countries with higher incomes.

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1. Introduction

1.1. Global Vaccine Inequity: Why is vaccination indispensable?

There is no question that the socio-economic damage produced by the pandemic COVID-19 is enormous and extensive, worsening the uneven socio-economic circumstances throughout the world, and hindering global recovery of health, especially for the developing countries. In January of 2020, the World Health Organization (WHO) issued a global health emergency declaration for the newly emerged COVID-19 virus (a few weeks after the virus was first isolated by Chinese researchers in Wuhan city). Late in March of 2020, the virus was officially classified as a pandemic, the highest level of health emergency. As time has passed, the crisis has grown to affect the world's $90 trillion economy in ways not seen since World War II (Global economic effects of covid-19 2021). The danger of outbreaks and disruption to economic and social life will certainly endure, however, until effective vaccinations are provided to large percentages of the world's population. This is because completing vaccination protocol may help avoiding hospital treatment and serious infections, and herd immunity can be achieved to stop spread of the virus (Wouters et al 2021). After the first COVID-19 cluster was reported in China on December 8th, 2020, researchers at the University of Oxford (UK) developed and administered the first preventative vaccinations against the novel coronavirus, SARS-CoV-2. This was followed by the approval and administration of multiple other vaccine candidates around the world (Ledford 2021 quoted in Asundi et al 2021). With appropriate resources and political commitment, the research and manufacture of this vaccine might depend on current technology and be accelerated far beyond the conventional 5–10 year time frame. By the beginning of June 2021, more than 11% of the global population were vaccinated against coronavirus disease 2019 (COVID-19) with at least one dose. Vaccines that are effective and tolerably safe in preventing COVID-19 and its consequences were developed via a collaboration between researchers, manufacturers, and governments in just 18 months. Since developing a new vaccine typically takes at least 10 years, the fact that many companies have developed effective COVID-19 shots in less than a year is an extraordinary achievement (Wouters et al 2021). Now, the issue becomes whether or not the same level of urgency can be applied to the equally important problem of the uneven distribution of vaccines across the globe. There is a startling and growing gap in COVID-19 vaccine coverage over the world (Asundi et al 2021). To achieve global vaccination immunity, more COVID-19 vaccine doses will be required than for any previous vaccine in human history.

After the first outbreak, there was a pressing need to implement a comprehensive immunization strategy against COVID-19 in an attempt to limit the pandemic's rapid spread. In response to the SARS pandemic, a global arms race in vaccine development efforts was initiated as soon as the genetic sequence of SARS-CoV-2 was made public. The WHO has drafted a landscape of prospective COVID-19 vaccines, and as of 2 March 2021, there were 76 candidate COVID-19 vaccines in clinical development and 182 in the preclinical assessment stages. As of April 3, 2021, seven vaccinations were approved for universal use, and six were licensed for early or limited use, across a range of countries (Wouters et al 2021). Because of the continuous epidemic and the fact that vaccines are scarce, politically fraught, and extensively distributed, they have a major impact on the global economy. While the United States experienced quicker recovery because of its mass vaccination effort, the rest of the globe were left vulnerable to new strains of disease and economic losses due to the time it has taken to procure, manufacture, and ship vaccinations (Uneven vaccination rates are creating a new economic divide, 2021). There is a wide gap in vaccination rates across nations. Public policy, infrastructural limitations, and money shortages are only a few of the factors that limit the reach of immunization programs. Several vaccines have been shown to yield a substantial return on investment (ROI) when assessed via a conventional cost-benefit analysis, supporting the widely-accepted correlation between improved health and economic output (Masia et.al 2018). Immunization is an investment in the health of the population and the ongoing economic recovery of the nation. The vaccinated population benefits from longer life expectancy, higher health and income levels, and brighter employment and academic horizons as a result of vaccination (Center for American progress n.d). The World Bank forecasted that the global economy had recovered at a fast rate of 5.6 percent in 2021. A World Bank expert, however, claims that there are "two recoveries," the social and economic prospects of affluent countries were improving because their inhabitants were vaccinated so quickly. Where vaccination rates were low, especially in emerging nations, local economies showed signs of decline (Uneven vaccination rates are creating a new economic divide, 2021).

Why completing COVID-19 vaccination protocol is economically significant for the countries? A UNDP study found that for every million individuals who get vaccinated, the global GDP increases by around US$7.93 billion. This means that countries with higher vaccination rates might anticipate a quicker economic recovery. Low-income countries with almost no vaccination rate face a long and uncertain path to recovery unless immediate remedial efforts are implemented (UNDP 2021). The new Dashboard uses information from the International Monetary Fund, the World Bank, UNICEF, and Gavi (Global Alliance for Vaccines and Immunization), as well as analysis of per capita GDP growth rates from the World Economic Outlook, to predict that wealthier countries will have faster rate of vaccination and economic recovery from the COVID-19 outbreak. Countries with little income were not able to vaccinate their medical staff and most vulnerable population, and it may be 2024 before they return to their pre-COVID-19 growth rates. In the meanwhile, governments throughout the world were responding to Delta and related viruses by reinstating strict public health social regulations. Consequences in terms of social welfare, economic well-being, and health are becoming more severe, particularly for the most disadvantaged and vulnerable groups. This worldwide problem of vaccine inequality threatens to reverse years of progress toward the Sustainable Development Goals (WHO 2021). According to Centers for Disease Control and Prevention, those who are completely immunized against COVID-19 are at a reduced risk of contracting the disease, hospitalization, and death. Efficacy findings from real-world vaccination studies corroborate data from clinical trials, showing that COVID-19 immunizations safeguard against COVID-19 infections, whether symptomatic or asymptomatic. The efficacy of vaccines against hospitalizations has been generally high throughout time, while it is lower for older persons and those with compromised immune systems. Vaccines against COVID-19 are very effective in preventing life-threatening complications and hospitalizations. Professionals in public health, however, predict that immunity to moderate illness will decline with time, particularly among specific groups. Therefore, booster shots are ideally encouraged to keep up with the COVID-19 vaccinations. Preventing severe illness, hospitalization, and death from COVID-19 have been possible due to vaccinations. Despite receiving all of the recommended vaccinations, some persons will still get COVID-19 because vaccines are not foolproof. A breakthrough infection describes this situation. Vaccinated individuals who get COVID-19 often have milder symptoms than their unvaccinated counterparts.

Besides all the benefits of the vaccination campaigns of COVID-19 and intended outcomes, controversies had arisen regarding the mandatory vaccination policies, restrictions for the unvaccinated people, unintended health outcomes and its impact on human rights and socio-economic consequences. During the COVID-19 pandemic, countries all over the world have implemented mandatory vaccination measures in an effort to reduce the spread of the virus. However, these measures have prompted significant social and political opposition, which suggests they may not be fair, scientifically warranted, or successful. One of the research findings named "The unintended consequences of COVID-19 vaccine policy: why mandates, passports and restrictions may cause more harm than good" concluded that obligatory COVID-19 vaccination policies have negative consequences for society as a whole, including reduced public trust and faith in vaccines as well as increased political division, violations of human rights, and socioeconomic inequality. We raise concerns about the efficacy and repercussions of compulsory vaccination policies in pandemic response and encourage the public health community and policymakers to revert to nondiscriminatory, trust-based public health measures (Bardosh et al 2021).

1.2. Why are there shortages of vaccination in some countries?

Vaccine shortages in certain countries hinder global prevention efforts; why is this so? The inequity in number of vaccines secured by countries and uneven vaccine productions by countries begs the question: why? A successful worldwide immunization plan against COVID-19 requires attention to four areas, as outlined in Lancet's journal: vaccine development and manufacturing, vaccine affordability, vaccine allocation, and vaccine deployment to local populations (Wouters et al 2021). Research and development procedures have significant effect on concerns of cost, distribution, and public trust, and these four dimensions of global vaccine inequities are intertwined in a complex web of interdependences. According to Feinmann (2021) some of the factors to consider when talking about the unequal structure of vaccine manufacturing and vaccine shortages in developing countries are a lack of basic ingredients, a focus on "local supply first" by the manufacturing countries, the structure of the developing countries' factories, the transfer of technology, and the presence of intellectual property rights barriers. The scarcity of crucial equipment used in the production of vaccinations has shown the supply chain's reliance on a small number of countries. For instance, filters, plastic tubing, and, most crucially, massive sterile bags are included in the vaccine cell growth kit, where these bags are used in gigantic containers known as bioreactors to cultivate vaccine cells. The German business MilleporeSigma, a part of Merck, relies on a complex network of tiny suppliers to meet its need for bioreactor bags. For all of 2021, vaccine producers worried that they wouldn't have abundant supply of these bags to meet the demand posing a strong threat to the global vaccination rollout. Another factor with a considerable impact was prioritizing local supply first. The "America first" strategy regarding vaccine distribution continued throughout the Trump administration which led Germany initiate their own factories to produce Pfizer-BioNTech vaccine. Together, AstraZeneca and Covax established licensing agreements with a number of regional manufacturers to fill and finish their vaccine, most notably the Serum Institute in India, one of the largest pharmaceutical companies in the world, with an agreement to be the primary supplier of vaccines to Africa. However, this accord meant little when India was attacked by its second wave of covid-19. Only recently, the export agreement was unblocked by the Indian government so that it could maintain domestically produced supplies for local supply (Wouters et al 2021, Feinmann, 2021). To understand more clearly why the global vaccine manufacturing scenario is uneven and why there are shortages of vaccinations in some countries, we need to shade light on the issues of poor infrastructure and management, barriers that comes with intellectual property rights and vaccine nationalism; which will be discussed in the next section.

1.3. Vaccine Nationalism and Intellectual Property Rights

In 2021, adequate vaccines were produced to cover 70% of the world's 7.8 billion of people, according to studies. Most vaccinations, on the other hand, were preserved for wealthier countries, while other vaccine-producing states were limiting vaccine exports in order to guarantee that their own population get immunized preferentially, a strategy addressed as "vaccine nationalism" (Hafner et al, 2020). Some countries, for example, decided to prioritize providing doses of booster vaccinations to previously immunized individuals above meeting the needs of unvaccinated individuals in developing and poor countries. According to WHO estimates, more than 5.5 billion doses had been delivered worldwide as of September 15; however, the actual number of persons who were vaccinated is likely far lower than this, given most immunizations require two doses (United Nations 2021). It is in the best interests of all countries, economically, epidemiologically, and ethically, to use the most recent information to make potentially life-saving vaccinations affordable to all (WHO 2021).

The low vaccination rate may be attributed to many issues, such as problems with production and processing, surpluses being held by advanced countries, and unequal distribution of additional vaccines. One is that only a few of manufacturers presently produce COVID-19 vaccines, particularly those with emergency use authorization. Moreover, there are circumstances, such as intellectual property rights, that restrict everyone's ability to produce vaccinations. In the midst of the controversy surrounding India and South Africa's request for a waiver of Trade Related aspects of Intellectual Property Rights (TRIPS) via WTO interventions, Jens Spahn, Germany's minister of health, argued that the lack of practical knowledge or expertise required for complicated and sensitive vaccine manufacturing was the main barrier to increasing production, not the patents themselves. The industry lacks enough manufacturing and quality control professionals who are acquainted with and equipped to produce these newer vaccines. Since intellectual property takes the form of trade secrets and expertise, creators' involvement is vital for a rapid transfer developing and underdeveloped countries (Feinmann 2020). Vaccines are simultaneously in great demand around the globe. As a consequence, the pace of vaccine production significantly restricts worldwide availability. In addition, the richer nations acquired the vast majority of the vaccinations made accessible to them as of 2021. The higher income segment has already bought all types of immunizations that may shortly be offered. Even if they have adequate finances, developing nations and humanitarian groups will be unable to obtain vaccinations owing to a lack of availability. Organizations such as the World Bank and the United Nations were negotiating with manufacturers to see if they might get certain immunization supply faster (World Bank Group, Asundi et al, 2021).

1.4. Poor Infrastructure and Management as a Barrier to Domestic Production Capacity

In addition to the standard legal and regulatory obstacles, such as intellectual property transfers, expanding future vaccine manufacturing confronts obstacles such as limited physical equipment, specialized knowledge, and supply chain capacity (Wouters et al., cited in Asundi et al 2021). Production and supply chain problems continue to impede global vaccination equality. Certain nations, like the United States, the European Union, India, and China, have a disproportionately high capacity for developing complex biological goods, such as vaccines. Despite having "finish and fill" capacity, whole areas, such as Africa, lack the ability to produce vaccines. Currently, COVID-19 vaccines made in Africa employ active components manufactured abroad and sent to "finish and fill" facilities; there are no COVID-19 production chains in Africa. Currently, the technical expertise of Africa's vaccine manufacturers to develop new vaccines is likely limited. Technical hurdles to the transfer of technology and administrative capacity, such as the buildup of vaccine production knowledge in Higher Income Countries (HICs) and the scarcity of skilled personnel in Lower Middle Income Countries (LMICs), compound legal and operational barriers to increasing vaccine manufacture (Price et al., 2020; Wouters et al., 2021 quoted in Asundi et al 2021). The lack of research and development facilities and personnel in LMICs is a significant obstacle to the transfer of vaccine technology, emphasizing the need of economic cooperation in research capacity enhancement to meet current and upcoming difficulties. Similarly, the absence of regulatory and monitoring capacity in many LMICs is a technical barrier to producing high-quality, secure, and effective vaccines and evaluating vaccine safety using domestic surveillance technology, as opposed to depending on WHO adverse reaction monitoring (Lurie et al., 2020). According to the WHO, only 30% of local regulators are now capable of effectively supervising vaccine production and deployment, which is a significant barrier to growing the production and deployment of locally-made vaccines (Asundi et al 2021).

1.5. COVAX

Inequitable access to vaccinations is not unusual. During the 2009 H1N1 influenza pandemic, for example, wealthy nations purchased the majority of available pandemic influenza vaccinations, leaving resource-poor nations, among the world's most severely impacted, with insufficient supplies (Wouters et al 2021). Some nations went so far as to prohibit the export of locally made vaccine doses, a measure that EU member states are contemplating for the current epidemic. To prevent a repetition of the H1N1 situation, the WHO announced in April 2020 the establishment of a worldwide allocation mechanism, the COVID-19 Vaccine Global Access (COVAX) Facility, managed jointly by CEPI (Coalition for Epidemic Preparedness Innovations) and Gavi (Global Alliance for Vaccines and Immunization). The WHO described it as a "ground-breaking global partnership to speed the development, manufacture, and equitable access to COVID-19 tests, treatments, and vaccinations". Its goal is to make sure that countries have access to resources based on need rather than purchasing power. COVAX currently has 141 members, but it isn't the only avenue for countries to get vaccines; they can also negotiate bilateral deals with manufacturers (United Nations 2021). COVAX is a pooled procurement strategy that intends to give all nations with access to a wide portfolio of vaccines during the acute stage of the pandemic in 2021, in addition to securing affordable pricing. High-income, self-financing nations may acquire vaccines from COVAX at an anticipated average price of $11 per dose, but 92 developing and underdeveloped countries could obtain them at much cheaper rates ($1.6–2.0 per dose) due to government development support. Prioritizing the protection of older persons, health-care professionals, and other high-risk populations prior to vaccinating broader segments of the population is central to the COVAX strategy for worldwide allocation. According to the COVAX model, all participating nations would initially get adequate stock for 20% of their respective populations, following which distribution would correspond to the WHO framework for dispersing COVID-19 vaccines worldwide based on need. In line with the principles of global equity, COVAX stipulates that no nation shall vaccinate more than 20% of the population until all countries have vaccinated 20% of their populations (Wouters et al 2021). While programs like COVAX have made considerable headway in reducing inequitable vaccination distribution, their efforts appear to be insufficient to meet the worldwide requirement (Asundi et al 2021). Some of the wealthiest nations in the world don't seem interested in joining COVAX because of the widespread practice of vaccine nationalism. Due to their pursuit of bilateral advance purchase agreements with vaccine makers, these nations will be in direct competition with the COVAX Facility for doses whenever they become available. The facility's very existence is in jeopardy as governments hedge their bets, posing a serious danger to its primary function (Eccleston-Turner & Upton 2021).

Therefore, it is really crucial to study and analyze whether domestic production of vaccines is precondition in order to meet the demand and explore if it’s really significant to achieve the desired nationwide vaccination coverage. In this study, we didn’t speculate the quality of the vaccines produced but we looked at the production level of the COVID-19 vaccines manufactured domestically by the major producing economies and examined if domestic production capacity is really significant for achieving higher vaccination coverage, at the same time speculating and taking into account all other essential relevant factors, that may have significant relationship with vaccination coverage achieved by the producing economies. The roadmap of the thesis is as follows: Chapter 1 gives the introduction to the paper, explaining some key concepts and background of the paper such as global vaccine inequity, vaccine nationalism and infrastructural barriers. Chapter 2 is a review of the previous literature that have discussed the efficacy of the domestic vaccine production, importance of agreements in vaccination, public health infrastructure, public trust and other relevant factors. Chapter 3 describes the details of the data collection and discusses the background of some of the indicators included in the study. Chapter 4 explains the empirical strategy for this analysis, the dependent and explanatory variables, and develops the hypothesis. Chapter 5 analyses the results from the parametric and non-parametric regression analysis and discusses the main findings. Chapter 6 presents a case study of Cuba on the effectiveness of domestic vaccine production on their vaccination coverage. Chapter 7 discusses the limitations of this study. Chapter 8 recommends policies based on the literature and the results. The thesis ends with a conclusion in chapter 9.

2. Literature Review

In order to analyze whether domestic vaccine production is significant for vaccination coverage or not, we first review what existing literatures discusses about the success factors of higher vaccination coverage and what are the relevant factors impacting the domestic production of COVID-19.

Meng et al. (2021) discusses some of the causes of the high vaccination rate achievements in China, including technical and nontechnical factors. China has one of the highest domestic vaccine production rates globally, as well as high vaccination coverage per capita. As of September 6, 2021, 77.6 percent of the population of China received at least one dose of the vaccine, and 969.72 million people received all three doses. By the end of the year, all of China's high-risk regions were eliminated, and there were just three medium-risk regions left. As of September 6th, China claimed that 2.113 billion doses of COVID-19 vaccine were delivered nationwide. As a preparation to overcome the pandemic, in their technical side, China has prioritized the development of five different types of vaccinations against COVID-19 with the primary goal to guarantee effective immunization of the populace. All five vaccine types have successfully completed all required clinical studies. The facilities where vaccines are manufactured are open around the clock. The Ministry of Industry and Information Technology, in conjunction with other relevant agencies and municipalities, had sent out service guarantee teams to relevant firms in order to increase vaccine production and supply and ensure that vaccination work demands were satisfied. Each team collaborated with businesses to develop strategies for expanding output and capacity. These strategies often include reversing production schedules, optimizing scientific production scheduling, and allocating resources like labor, machinery, and supplies more effectively. Moreover, local vaccine output were increasing, mostly due to increased manufacturing capacity.

In the non-technical side, China had been using the model of permanent vaccination centers, several cities developed temporary vaccination facilities. Some states considered piloting temporary immunization stations in major stadiums. Similarly, several states and provinces provided a way to schedule appointments online. Key populations in port cities were prioritized for vaccination in several locations where pandemic preventive and control efforts were integrated. The National Health Commission had sent a supervisory team to various cities to assist local authorities in organizing all parts of vaccination in compliance with government standards, guaranteeing the quality and safety of the vaccination procedure. Most importantly, cities in China have a high vaccination rate, a relatively easy mobilization procedure, and a population with a strong knowledge of the dangers to their health (Meng et al 2021).

Confidence in the government and the safety of China's vaccinations is high among the country's population. Market reform in China over the last several decades had established a strong basis for rising living standards. Many citizens have faith in their government and feel optimistic about the future. China's COVID-19 vaccine manufacturing is overseen by the government around the clock, and several Chinese-made vaccines have been given the green light for emergency use by the

WHO. The confidence of the Chinese people in vaccines had grown as a result. This discussion of trust and knowledge have reflected in another study by Toro-Ascuy et al. (2021). According to this study on Chile, acceptance of vaccination, trust in stakeholders, mass communications, influential factors related to history, religious doctrine, gender, socioeconomic background, politics, geographical obstacles, past knowledge with vaccinations, perceived risks, and layout of the vaccination program are some of the most important social factors that heavily impact the vaccination procedures or coverage achieved in a region. According to the research findings of Toro-Ascuy, D. et al. on Chilean vaccination process, a greater degree of faith in the experts, namely scientists and medical professionals, is correlated with a higher level of acceptance of not just SARS-CoV-2 vaccinations but also a booster dosage, an annual vaccination, and the vaccination of children. The importance of putting one's faith in these professionals throughout the COVID-19 vaccination procedure had been highlighted by these strong correlations. In contrast, very little faith was placed in governmental or religious authorities. An increase in vaccination rates might result from cooperation between the religious and medical communities. Results support previous studies' hypotheses that people are more likely to get vaccines if they have faith in the medical community (Toro-Ascuy et al. 2021).

According to Basak et al. (2022), by the end of the year 2021, 56.4% of the world's population was immunized against COVID-19. However, among the world population, roughly 8.3% of persons in low-income nations had ever gotten a single dosage. In low-resource regions, where vaccination coverage was anticipated by experts to reach 20% in 2021, the actual coverage rate was far lower. Despite the importance of research funding, persistent disregard of public health and global delivery tactics has made communities unprepared to put an end to this epidemic. Priority must be devoted to resolving the intricate constraints in the distribution and allocation of recently authorized vaccinations. Vaccines must be manufactured in a safe, efficient, and timely way as part of these efforts. Vaccine uptake has been hampered by skepticism, inaccurate information, and historical legacies. Even affluent nations have met enormous difficulties and made major errors while conducting mass immunization programs. According to the results of "A Global Study on the Correlates of Gross Domestic Product (GDP) and COVID-19 Vaccine Distribution," on general, the greater the vaccination rate in a country, the richer it is. In comparison, the three worst-performing nations are the Democratic Republic of the Congo (DRC), Haiti, and Chad. The gross domestic product of these nations is $1700 or less, and their vaccination rate is less than 1%. Unlike their counterparts in the poor world, developed nations protect their citizens via immunization, where vaccination rates are lower. Countries on the American and European continents made the most headway in vaccinating their populations with minimum single dose. African nations with low incomes are continuously falling behind. The key point is that the deployment of COVID-19 vaccine has been inconsistent and that nations in the Global South are not doing as well as those in the Global North. Consequently, there are large differences in the capacity to create herd immunity among nations, and global efforts to attain herd immunity are greatly hampered. Countries with lower or intermediate incomes have, for a long time, wished they might have easier access to modern medical treatments and pharmaceuticals (Basak et al 2022).

According to Roghani (2021), the policies set by the governments, the structures of national health care systems, and the macro-socioeconomic conditions of individual nations all play crucial roles in determining how quickly vaccines may be introduced on a national scale. When discussing the short- and long-term efficacy of the vaccine for COVID-19 and vaccination campaigns, Freed (2021) focused on two factors that stand out as key variables. An efficient public health infrastructure and a national plan for distributing vaccines are the two parts. The results of the study conducted by Roghani (2022) give more evidence that a positive link exists between per capita GDP and vaccination rates, and that this association strengthens over time. Even while there was initially no linkage between Human Development Index (HDI) and vaccine distribution, we discovered that a higher HDI was associated with higher vaccination rates in August. When other variables were taken into account, however, HDI was shown to have no impact on where vaccines were distributed. Increases in manufacturing, testing, and distribution might be justified by reference to the potential benefits to GDP. A stronger correlation in August suggests a far larger effect after six months, underscoring the significance of GDP in sustained increases in immunization rates. A stronger correlation between GDP, national strategy, and resources means that a country with a greater GDP may expedite vaccination in the early phases of vaccine rollout and guarantee that all high-risk groups, including the sick and the elderly get vaccinated. Long-term improvements in vaccination rates may be supported by the stronger correlation between HDI and public health infrastructure and socioeconomic factors.

According to Lancet, a highly prestigious British health policy journal, COVID-19 domestic vaccine production is constrained by the existing partnerships between lead developers and contract manufacturers, as well as the highly concentrated condition of global vaccine manufacturing capacity16. Transferring technologies widely to increase production capacity is likely necessary for an effective solution to the production bottleneck. Companies should aggressively exchange expertise, technology, and data with domestic manufacturers in the few nations that have the potential to swiftly make COVID-19 vaccines, since these countries currently lack the domestic capacity to do so on their own (Price, W. N., 2nd, Rai, A. K., & Minssen, T. 2020). Several major pharmaceutical companies, including AstraZeneca, Johnson & Johnson, and

Novavax, have entered into partnerships with manufacturers in low- and middle-income countries to expedite the development and distribution of their respective COVID-19 vaccines. These partnerships include the Serum Institute of India, Fiocruz in Brazil, mAbxience in Buenos Aires, Argentina, and Siam Bioscience in Thailand (Wouters et al 2021). This suggests that, bilateral/multilateral agreements are quite significant, especially for the emerging producing economies.

Eccleston-Turner & Upton (2021) states that, although the quick discovery of three effective vaccine candidates is encouraging, the history of prior pandemics shows that availability will be restricted in impoverished nations. Although the COVAX Facility intends to address this critical issue, the widespread practice of vaccine nationalism poses a danger to the facility's capacity to reach its financial goals and its lofty objectives in the area of vaccine procurement. Further limitations on the COVAX Facility might result from a failure to address the underlying lack of infrastructure in poor nations. While bilateral agreements by advanced producing economies to purchase advanced vaccines is beneficial for the high-income countries, it can harm the objective of COVAX. According to the history from the previous pandemics, it is anticipated that vaccine secured through purchase agreements made in advance will be supplied prior to any other agreements, a significant portion of the AstraZeneca/Oxford vaccine supply is reserved through bilateral advance purchase agreement by the Higher Income Countries (HICs). Therefore, it is anticipated that the "200 million doses of the AstraZeneca/Oxford" vaccine from the Serum Institute of India will be given to COVAX at a slower rate than the vaccines obtained by HICs through advance purchase agreements. According to the author, in addition to chronic underfunding, a major obstacle to the success of COVAX is the reemergence of vaccine nationalism during COVID-19, in which rich nations emphasize negotiating bilateral deals with pharmaceutical corporations above the multilateral procurement system. This response is consistent with the pattern of nationalist acts taken by nations during the epidemic, including temporary travel and trade restrictions. The emergence of vaccine nationalism, in which countries prioritize conducting their own bilateral advance purchase agreements with vaccine manufacturers over participation in multilateral initiatives such as the COVAX Facility, poses the greatest threat to the facility's ability to attract sufficient participation. The present pandemic is marked by a trend towards vaccine nationalism. While 69 nations, including the EU trade union, had joined COVAX officially and an additional 86 have shown interest in joining, there were significant exceptions. China and Russia have apparently rejected the COVAX Facility in favor of bilateral deals with vaccine makers. In addition to exploring participation in the facility, a considerable number of developed countries have concluded their own bilateral arrangements (Eccleston-Turner & Upton 2021). Therefore, we can not neglect the impact of bilateral agreements while speculating country's success in achieving high vaccination coverage.

The motivation of this paper is to analyze the pattern of association between vaccination coverage and domestic vaccine production, and find potential indicators crucial to consider in the field of this study. Since no significant literature has been found that directly analyzed the impact of domestic vaccine production of COVID-19 on the attainment of vaccination coverage rate; therefore, this paper aims to analyze the relationship and contribute to existing literature.

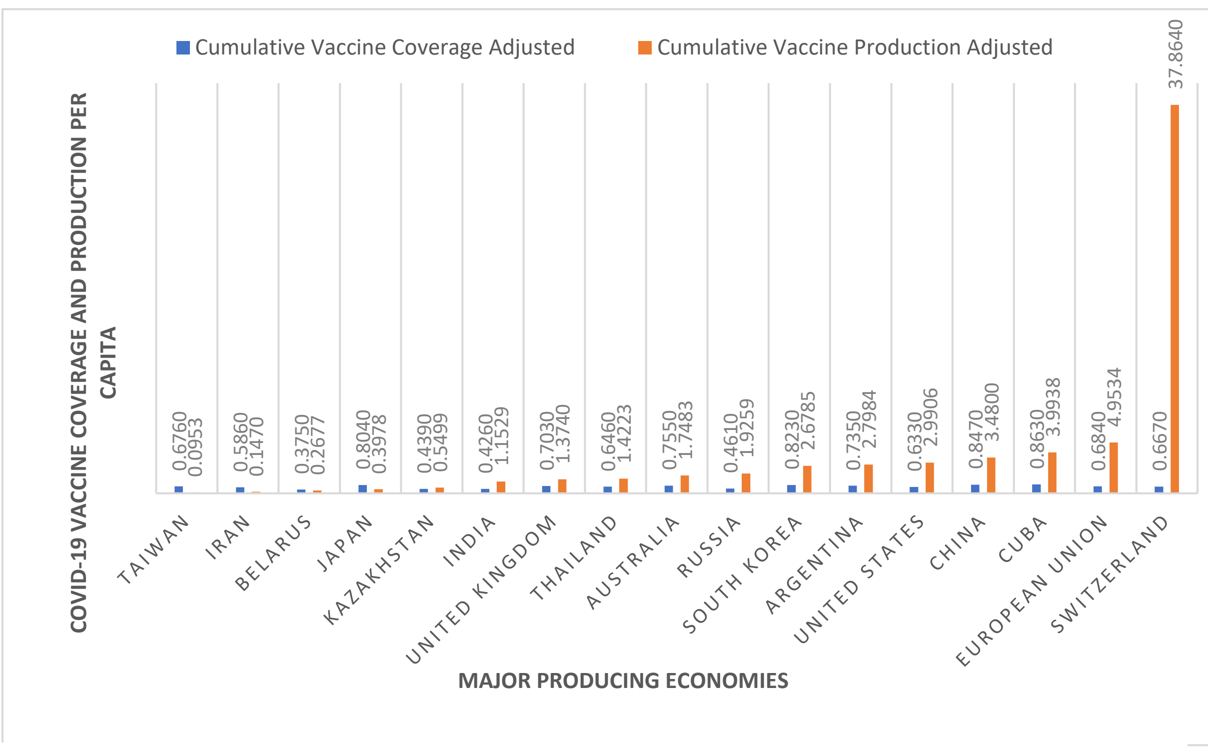
3. Data Collection and Background

To analyze whether the domestic vaccine production of a producing economy has a significant impact on the total vaccination coverage of their population, 10 major producing economies have been chosen, who have the largest export shares according to the WTO- IMF vaccine trade tracker (2022) and monthly data for 6 consecutive months (July 2021-December 2021) have been collected on their end-of-month total domestic vaccine production level, the number of people who received full COVID vaccine protocols (2 doses completed) in that region, and various other essential indicators; based on the literature reviewed. The dataset used in this study is a strongly balanced panel data set with 60 observations (Appendix). According to Torres-Reyna 2007, Panel data, also known as longitudinal or cross-sectional time-series data, is a dataset in which the behaviour of entities is monitored across time. These entities may be governments, corporations, people, or nations. In our dataset, "country" represents the regions or panels (i), whereas "month" indicates the time variable (t). The notation "strongly balanced" refers to the fact that statistics are available for all 6 months for all nations. The producing economies or countries (the European Union which has 27 countries) chosen are: Australia, Argentina, the European Union, India, Russia, South Korea, Cuba, the United States, the United Kingdom, and Switzerland**,** based on the data available on IMF-WTO vaccine trade tracker, WHO-IMF COVID-19 Vaccine Tracker, Our World in Data, Global Commission for Post-Pandemic Policy and World Bank data.

According to World Trade Organization (2022), the European Union, China and the United States hold the largest share of world exports for COVID-19 vaccines with 39.6%, 32.2% and 15.7% shares respectively. Although initially, the major producing economies chosen in the dataset based on the largest world export shares included China, the European Union, India, the United States, Switzerland, Cuba, Argentina, Japan, Thailand, the United Kingdom, South Korea, Russia, Australia, Iran, Kazakhstan, Belarus, and Taiwan (WTO-IMF 2022, IMF-WHO 2022). However, due to the inconsistency in the monthly production data and vaccination coverage data, seven countries have been discarded and the final producing economies have been chosen with consistent and credible data available for each of the indicators. Indicators such as technology level, public health infrastructure, trade barriers and details of intellectual property rights have also been discarded due to the unavailability of consecutive monthly data for the producing economies during July–December 2021.

Data on cumulative vaccine coverage per capita and cumulative domestic vaccine production per capita of the major producing economies have been collected to observe the overall trend from the graph (Figure 1).

Figure 1: Cumulative Vaccine Coverage and Vaccine Production as of December, 2021



Source: Made by author in Excel. Data Collected from Mathieu et al (2022), Our World in Data. Staff, G (2022), Global Commission for Post-Pandemic Policy.

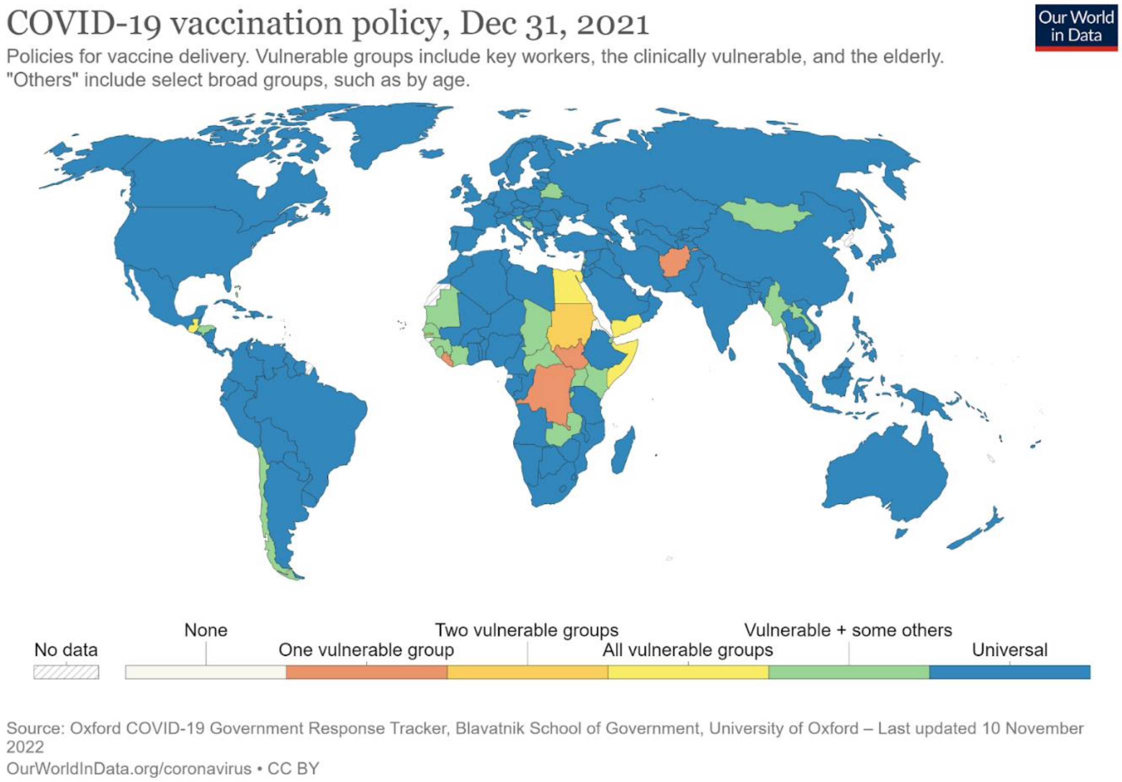
Figure 1 demonstrates one extreme point, although Switzerland has the highest domestic vaccination production per capita, their vaccination coverage per capita is not as high as the production, comparing to other countries. Notably, Cuba has the highest rate of vaccination coverage per capita, as of December 2021, as well as the second highest vaccine production level per capita in the list, being the most sustainably developed country (Mathieu et al, 2022).

Though COVID-19 has reached and impacted most of the countries in the world, the severity of these effects has varied greatly across nations, with some having great success in restricting the disease's spread and reducing fatalities. There are several reasons why certain nations may have been struck worse than others. Differences in government policy responses may account for some variations (Mathieu et al 2020). To determine whether measures could be beneficial in managing the epidemic, particularly as nations moved toward loosening restrictions, the Oxford Coronavirus Government Response Tracker (OxCGRT), a resource produced by scholars from the University of Oxford's Blavatnik School of Government, gathered information on 17 indicators of government actions, including containment and closure policies (such as school closures and mobility restrictions), economic policies, and healthcare system policies. In this study, some statistics and research from the Blavatnik School of Government at the University of Oxford's Coronavirus Government Response Tracker (OxCGRT) has been considered crucial. For instance, country government policy level and stringency index, described in details further.

3.1. Data on Policies for Vaccination Deliveries

From the Blavatnik School of Government at the University of Oxford's Coronavirus Government Response Tracker (OxCGRT), information has been gathered on the country's government policy level, showing how each region's government plans to deliver vaccines varies, based on the availability of the vaccines. To calculate for the European Union, average have been taken of the government policy levels of 27 countries for each month during July–December 2021. There are six broad classifications of the levels for the countries, which takes the value of 0-5 indicating the level. In the dataset, 0 indicates that currently, there are no vacancies available. 1 indicates availability for one of the vital employees, clinically fragile populations, or senior citizens. 2 indicates availability for the key employees, clinically susceptible populations, and the elderly population all have availability requirements of two. 3 indicates access must be ensured for all of the following: critical personnel, clinically fragile populations, and senior people. 4 indicates availability for all three and in some cases even more (for certain age ranges and demographic categories). Finally, 5 indicates universality or availability for everyone, anywhere. Figure 2 demonstrates the worldwide COVID-19 vaccination policy by level (Mathieu et al 2022).

Figure 2: Government Policy Level for Vaccine Deliveries by Region, as of December, 2021

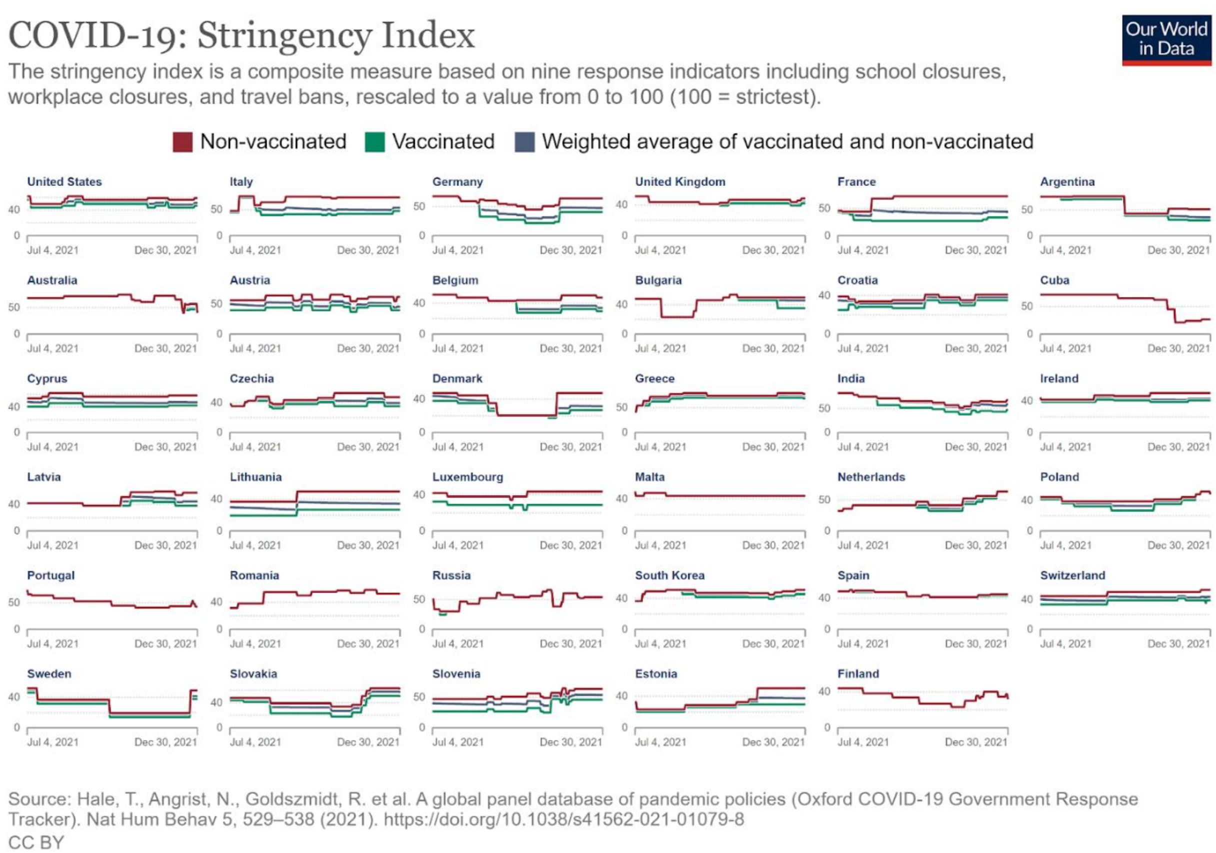


Source: Oxford Covid-19 Government Response Tracker (OxCGRT) (2022) quoted in Mathieu et al (2022).

3.2. Stringency Index

Another significant indicator that has been considered in this study is the Government Stringency Index, a weighted average of nine different response measures calculated by the OxCGRT project. The Government Stringency Index is made up of nine indicators, which include closing schools and workplaces, canceling events, limiting public gatherings, shutting down public transportation, making people stay at home, running public awareness campaigns, limiting travel within the country, and controlling international travel. On any given day, the index is determined by averaging the scores of the nine measures, each of which can range from 0 to 100. More stringent government action is represented by a higher score (the most stringent action is represented by 100). In cases where there is variation in policy from one region to another, the index reflected the response level of the region with the most stringent policies. In Figure 3, we observe that the stringency level across our selected regions fluctuated by month. Since there was no separate data on the stringency index of the European Union in OxCGRT, a monthly average of the stringency level of all 27 European Union countries has been taken to generate monthly data on stringency index for the EU for this study. In this analysis, we only considered the stringency index for unvaccinated people by country, to see its impact on influencing the vaccination coverage per capita.

Figure 3: COVID-19 Stringency Index by Countries (July-December, 2021)



Source: Hale et al (2022), Oxford COVID-19 Government Response Tracker, Mathieu et al (2022), Our World in Data.

3.3. Unwillingness of People to get Vaccinated

According to Toro-Ascuy et al. (2022) and MacDonald (2015), the success of the vaccination process is highly reliant on underlying social factors, specifically "acceptance of the vaccination, trust in stakeholders associated with the vaccination, vaccine-specific factors, communication and media, historical influences, religion, gender, socioeconomic status, politics, geographic barriers, prior experience with vaccinations, risk perception, and programme design." The Chilean study revealed an association between vaccination adoption and trust in science, medical professionals, and the media, such as television. The perceived danger of contracting COVID-19 influences vaccine acceptance, childhood vaccination, and adult booster doses (Toro-Ascuy 2022). Therefore, we may use vaccine hesitancy as a key indicator when examining the vaccination coverage rate in a certain location.

3.4. Accurate Knowledge of COVID-19

The COVID Behaviors dashboard from the Johns Hopkins Center for Communication Programs includes statistics from a worldwide study of COVID-19-related knowledge, attitudes, and behaviours. Together with WHO's Global Outbreak Alert and Response Network (GOARN), academics and specialists in social and behaviour change communication at the Johns Hopkins Center for Communication Programs authored insights and analyses on how to utilize the data. Accurate awareness of COVID-19 impacts the behaviour of individuals to engage in preventative measures, such as immunization. This dashboard's questions gave us an estimate of the number of persons who are misinformed about two crucial aspects of the condition. As this epidemic had progressed, it was incumbent upon governments and health authorities to give timely, accurate, and transparent information about the illness. Assuring that communities or nations have access to reliable information is a defining characteristic of effective public health communication and helps to ensure that people make educated health decisions.

Since any consistent monthly data on the unwillingness or willingness of people to get vaccinated and their behavior for the producing economies couldn't be gathered, nine producing countries were selected (Australia, Denmark, France, Germany, Italy, Japan, Netherlands, Spain, UK) and their monthly data for the period of September-December 2021 from Our World in Data, on vaccination coverage and their reluctancy to get vaccinated were collected to see if this indicator is significant enough for consideration or not. This was dataset 2, a panel data with number of observations equals to 36.

Dataset 3 comprises of the data from Johns Hopkins Center for Communications Programs on the proportion of persons who answered questions concerning COVID-19 transmission accurately and cross-sectional data on vaccination coverage for 32 countries (Australia, Argentina, Austria, Belarus, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, India, Ireland, Italy, Japan, Kazakhstan, Netherlands, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Thailand, United Kingdom, United States). The questions asked in the study were 1) "Children are susceptible to contracting COVID-19," and 2) "COVID-19 may spread in hot and humid settings." True is the right response to both questions.

4. Methodology and Hypotheses Development

In order to analyze the impact of domestic production of COVID-19 on vaccination coverage, both Fixed Effects (FE) model and Random Effects (RE) model are employed on STATA by using the panel data on 10 regions between the timeline July-December 2021 and the Hausman specification test (Hausman 1978) is performed for model selection. First, a model is run with fixed effects and the estimates is stored, then a model is run with random effects and the estimates is stored, and then finally the Hausman test on STATA is run. The Hausman test is conducted using the null hypothesis that the preferred model is random effects as opposed to the alternative, fixed effects (Green 2008, chapter 9). The null hypothesis for this test is that the unique errors (ui) are not linked with the regressors. In other words, the null hypothesis is that Random Effects model is consistent.

Table 1: Hausman (1978) Specification Test

	Coef.
Chi-square test value	12.855
P-value	.025

The specification test result shows that (Table 1), the P-value < 0.05, which suggests that we can reject the null hypothesis and we prefer fixed effects model over random effects model given the dataset. Fixed Effects are used when we are simply interested in assessing the influence of time-varying factors. FE investigate the association between predictor and outcome factors inside an entity (in our study, region). Each entity has unique properties that may or may not affect the predictor variables. When using FE, we consider that something about the subject may influence or bias the predictor or outcome variables, and we must account for this. This is the explanation behind the correlation assumption between the entity's error term and predictor variables. FE eliminates the influence of these time-invariant qualities so that the net effect of the predictors on the outcome variable may be evaluated. Importantly, the FE model assumes that these time-invariant features are unique to each region and should not be associated with other region's characteristics. Since each entity is unique, its error term and constant (which captures individual features) should not be connected with those of other entities (Torres-Reyna 2007).

Therefore, the equation for the fixed effects model we will use in our study is:

$$\mathbf{Y_{it} = \alpha_i + \beta_1 X_{1,\,it} + \ldots + \beta_k X_{k,\,it} + u_{it}} \qquad \textbf{[eq.1]}$$

Where α_i (i=1…. n) is the unknown intercept for each entity (n entity-specific intercepts). Yit is the dependent variable where i = region and t = time. $X_{1,\,it}$ represents one independent variable, β_1 is the coefficient for that explanatory variable, $X_{k,\,it}$ represents another independent variable, β_k is the coefficient for that explanatory variable. u_{it} is the error term.

"The crucial idea is that, if the unobserved variable does not vary over time, any changes in the dependent variable must be attributable to factors other than these fixed characteristics." (Stock and Watson, 2003, p.289-290). In the dataset for our analysis, i is the producing economies, such as the EU, India, the United States, Russia, Australia etc. denoted by unique Regional IDs and t is the months denoted by 7, 8, 9... 12; the number of months between July and December in the year 2021.

In our analysis, dependent variable is the total number of people who received the full COVID vaccine protocol (2 doses) at the end of the month, in the producing economy i during the time t, adjusted for population. Independent Variables are the following: total end-of-the-month domestic vaccine production for each economy i during the time t, adjusted for population; the number of vaccines delivered to the producing economies' population through bilateral/multilateral agreements by month, adjusted for population; government policy level (availability/announcement of vaccination for different groups, with 5 being the universal and 1 most vulnerable group) in each producing economy during month t, adjusted; Stringency Index for the unvaccinated people according to the region i during the month t (strictness level of the government responses/ regulations to the unvaccinated population), adjusted; the number of vaccines delivered to people living in the producing economies through COVAX facility adjusted for population.

According to Roghani (2021), governments are ultimately responsible for the ordering, funding, and distribution of COVID vaccines from manufacturers, a process that necessitates stringent testing to guarantee the vaccines' safety. Due to an insufficient quantity, vaccinations must be given to those who are at the greatest danger first. Due to limited availability of data, studying national vaccination distribution techniques is difficult. GDP, in the absence of other data, may serve as a proxy for a country's capacity to manufacture and deliver vaccinations. Capital investments in countries with strong GDP growth offer exceptional physical and human capital investments, which are essential for boosting immunization rates. Therefore, we plan to use GDP per capita for countries/economies as a control variable. Based on the literatures we have reviewed, specifically Wouters et al (2021), Eccleston-Turner & Upton (2022), Basak et al (2022), Roghani (2021), we develop the following hypotheses:

H1: There's a significant positive correlation between per capita monthly domestic vaccine production and simultaneous monthly COVID-19 vaccination coverage rate. Though no literature directly speculates the correlation between these two variables, however, majority of the studies Asundi et al (2021), Wouters et al (2021), Basak et al (2022) emphasized on the importance advanced manufacturing capacity, public health infrastructure and technology level, which suggest that the domestic vaccine production capacity is significant for vaccination coverage.

H2: There's a significant positive correlation between total number of vaccines delivered through bilateral agreements at the end of the month, adjusted for population and total end of the month COVID-19 vaccination coverage rate in the producing economies. Based on the arguments by Eccleston-Turner & Upton (2021) and Wouters et al (2021), which discusses the vaccine nationalism concept and how countries prioritize conducting their own bilateral advance purchase agreements with vaccine manufacturers over participation in multilateral initiatives such as the COVAX Facility, it can be assumed that bilateral agreements with the manufacturers can be highly significant in terms of vaccination coverage attainment.

H3: There's a significant correlation between monthly stringency index, adjusted for population and total end of the month COVID-19 vaccination coverage rate in the producing economies. According to the studies on government policy responses by Mathieu et al (2022) and the Oxford Coronavirus Government Response Tracker (OxCGRT), a resource produced by scholars from the University of Oxford's Blavatnik School of Government, information gathered on 17 indicators of government actions suggest the significance of government stringency measures on the unvaccinated population.

H4: There's a significant correlation between monthly country government policy level, adjusted for population and total end of the month COVID-19 vaccination coverage rate in the producing economies. Again, based on the studies by Mathieu et al (2022) and the Oxford Coronavirus Government Response Tracker (OxCGRT), we can argue that government policy level for vaccination (the level of availability and the announcement) can be crucial for achieving higher vaccination coverage.

H5: There's a significant negative correlation between total number of vaccines delivered through COVAX facility monthly, adjusted for population and total end of the month COVID-19 vaccination coverage rate in the producing economies. Since COVAX has been a much-discussed topic in the aforementioned literature, and the fact that a considerable number of developed countries have preferred their own bilateral arrangements with the manufacturers and rejected the COVAX facility (for instance, China and Russia), we consider COVAX to have a significant negative relationship with vaccination coverage in the producing countries with higher income.

Through this panel data fixed effects linear regression analysis, this study aims to find the patterns of association between the outcome of interest and explanatory variables, whether the correlation between the chosen variables is significant or not, and in which direction.

For the analysis of the patterns of association between vaccination coverage and unwillingness of people, we will conduct a non-parametric regression analysis using binscatters and lowess regression. Following, for the analysis of the patterns of association between proper knowledge of COVID-19 and vaccination coverage rate by country, we will conduct a non-parametric regression analysis using binscatters and lowess regression. The aim of these two additional analyses with different datasets is to observe the pattern of association of these variables with vaccination coverage, based on the literature Toro-Ascuy et al (2022) and MacDonald (2015) and study on COVID-19 Behaviours by Johns Hopkins Center for Communications Program, so that in future researchers may consider these variables significant for further analysis on the subject matter.

5. Regression Results and Discussion

5.1. Significance of Domestic Vaccine Production, Bilateral Agreements, Vaccination Policy, Stringency Measures and COVAX on Vaccination Coverage

Table 2 shows the descriptive statistics of the sample, with a number of observation N = 60. On average, the monthly vaccination coverage for the chosen countries is approximately 51% and average vaccine production level is 3.31 per capita. The mean value for per capita vaccine delivery through bilateral agreements is 9.435, with a high standard deviation of 25.30, because for two of the countries in the dataset, Cuba and Russia, there's no vaccines delivered through agreements, therefore the values for these two countries are 0, indicating outliers. Similarly, some countries in the dataset didn't secure and deliver any vaccines via COVAX facility, which again, indicates that the minimum value 0 for this variable and outliers. The mean value for stringency index and country government policy level indicates that, on average, countries in the dataset has medium restrictions (approximately 54.8%) for the unvaccinated people and almost universally available supply of vaccines for their population. Since the dataset contains the major producing economies ranging from advanced economies to middle income or developing countries, we observe high standard deviation for the country GDP. The high standard deviation for the variables monthly vaccine production, vaccines delivered through agreements, stringency index and GDP per capita suggests variability in the dataset and indicates that data are more spread out in my sample.

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Monthly Vaccine Coverage	60	.511	.206	.073	.855
Monthly Vaccine Production	60	3.311	6.292	.232	37.864
Vaccines Delivered through Agreements	60	9.435	25.303	0	107.964
Stringency Index	60	54.782	12.49	21.3	77.31
Country Government Policy Level	60	4.86	.388	3	5
Vaccines Delivered through COVAX facility	60	.893	3.118	0	18.51
Country GDP Per Capita	60	39019.006	27737.417	2277.4	93457.4

Before proceeding to the regression analysis, we check if there's Heteroskedascity in the sample dataset for necessary adjustments. To check Heteroskedascity in fixed effects model, we used the Modified Wald test for groupwise Heteroskedascity in fixed effect regression model. The null hypothesis for this test is homoskedasticity or in other words, constant variance. The test result suggests that (Table A1, Appendix), Prob > chi2 = 0.000, which means we reject the null hypothesis and confirm the presence of Heteroskedascity in the dataset (Torres-Reyna 2007). To minimize the biases, the dependent variable has been log-transformed and robust-standard errors has been used in the regression analysis.

First, to look for a pattern in the data and to determine whether the explanatory variables in our dataset is highly correlated with the dependent variable or not, we derive a correlation matrix and observe the correlation coefficients. Table 3 shows that, vaccination coverage rate is strongly and positively correlated with vaccination policies and country GDP per capita, as opposed to, strongly and negatively correlated with Stringency Index. The matrix also demonstrates that vaccination coverage is weakly but positively correlated with vaccine production, bilateral agreements and COVAX.

Table 3: Matrix of Correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Vaccine Coverage	1.000						
(2) Vaccine Production	0.214	1.000					
(3) Bilateral Agreements	0.188	-0.074	1.000				
(4) Stringency Index	-0.520	-0.149	-0.164	1.000			
(5) Policies for Vaccination	0.561	0.152	0.038	-0.416	1.000		
(6) COVAX	0.239	-0.061	0.943	-0.131	0.056	1.000	
(7) Country GDP Per Capita	0.409	0.546	-0.038	-0.208	0.191	-0.047	1.000

The pairwise correlation between the vaccination coverage rate and vaccine production per capita is weak, but the correlation coefficient is positive. The significance level is 0.1, which means that this result is significant at a 10% significance level with a p-value of 0.1004 (Table A2, Appendix). However, we conduct a parametric regression analysis with fixed effect linear regression to find and analyze the pattern of association between the variables in our dataset.

Table 4 demonstrates the parametric regression analysis for our sample with fixed effects linear regression model. From the result, we can interpret the patterns of association between vaccination coverage rate and other explanatory variables. The following linear regression approximates the average slope of the curve, which gives us an idea about the average pattern of association between log-transformed dependent variable y and explanatory variable x. Average slope means the difference in average y that corresponds to different values of x. Therefore, we can approximate the patterns from the slope, which is the best fitting line through the scatterplot (Molnar, 2021).

Table 4: Regression Results (1)

lnMonthly Vaccine Coverage	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Monthly Vaccine Production Per Capita	.006	.002	3.81	.004	.002	.009	***
Deliveries through Bilateral Agreements	.027	.005	5.59	0	.016	.038	***
Country Government Policy Level	.757	.17	4.45	.002	.372	1.142	***
Stringency Index	-.006	.008	-0.74	.481	-.024	.012	
COVAX	-.027	.014	-1.99	.078	-.058	.004	*
Country GDP Per Capita (Omitted)	0	.	.	.	.	.	
Constant	-4.395	1.09	-4.03	.003	-6.861	-1.929	***

Mean dependent var	-0.791	SD dependent var	0.557
R-squared	0.692	Number of obs	60
F-test	283641.728	Prob > F	0.000
Akaike crit. (AIC)	4.538	Bayesian crit. (BIC)	15.010

**** p<.01, ** p<.05, * p<.1*

In Table 4, the R-squared value of this linear regression is 0.69, which means that the overall variation in dependent variable is 69% explained by the linear regression with change in the explanatory variables, but the remaining 31% is left unexplained. The R-squared reflects how accurately the model explains the fitted data in the regression model, whereas the adjusted R-squared indicates if the model has been advanced by the addition of a variable. On the basis of the

R-squared and adjusted R-squared values, we selected the final regression model consisting of all five explanatory variables and the control variable GDP per capita, which had the greatest R-squared value (0.69), as well as the best adjusted R-squared value. Noticeably, the country GDP per capita has been omitted due to the omitted variable bias, which we will discuss further in the limitations of the study.

In Table 4, the slope parameter for monthly vaccine production per capita 0.006 indicates that, keeping everything else constant, the vaccination coverage rate is approximately 0.6% higher on average, for one-unit higher domestic vaccine production per capita. The p-value 0.004 indicates that, this result is significant at 1%, 5% and 10% level. Therefore, the result supports the hypothesis that there's a statistically significant positive correlation between vaccination coverage rate and domestic vaccine production per capita, as suggested by the literatures Asundi et al (2021) Roghani (2021). However, the slope parameter (0.006) indicates that, the average differences in dependent variable for unit change in the production level per capita is not very high. Next, the slope parameter for monthly vaccines delivered through bilateral agreements per capita 0.027 indicates that, keeping everything else constant, the vaccination coverage rate is approximately 2.7% higher on average, for one-unit higher amount of vaccines delivered through agreements per capita. The p-value 0.000 indicates that, this result is highly significant at all the levels. This result support our second hypothesis that, there is statistically positive significant correlation between vaccination coverage rate and vaccines delivered through bilateral agreements per capita, as discussed in Eccleston-Turner & Upton (2021) and Wouters et al (2021). The slope parameter 0.027 suggest that, the average differences in vaccination coverage is quite significant due to a unit change in vaccines acquired through bilateral agreements. Thirdly, the slope parameter for stringency index by country -0.006 indicates that, keeping everything else constant, the vaccination coverage rate is approximately 0.6% lower on average, for one-level stricter government responses to the unvaccinated people (adjusted for population). However, the p-value 0.481 indicates that, this result is not significant according to conventional standard or even at 10% significance level. Therefore, we fail to conclude anything, since the correlation between vaccination coverage rate and stringency measures for unvaccinated people by country (adjusted) are not statistically significant. Following, the slope parameter for vaccination delivery policies by country 0.757 indicates that, keeping everything else constant, the vaccination coverage rate is approximately 75.7% higher on average, for one-level higher vaccination policies (adjusted for population), provided by the government. The p-value 0.002 indicates that, this result is significant at all the levels. Therefore, this result strongly supports the fourth hypothesis that there's statistically significant correlation between vaccination coverage rate and vaccination delivery policies by country (adjusted). The findings of this analysis align with the studies by the OxCGRT and Mathieu et al (2022), indicating that the significance of availability of vaccines and public announcement.

Finally, the slope parameter for monthly vaccines delivered through COVAX per capita -0.027 indicates that, keeping everything else constant, the vaccination coverage rate is approximately 2.7% lower on average, for additional unit of vaccines delivered through COVAX per capita. The p-value 0.078 indicates that, this result is only significant at 10% significance level and not significant according to the conventional level. Therefore, we can not conclude any statistically significant correlation between vaccination coverage rate and number of vaccines delivered through COVAX facilities (adjusted). However, the negative slope parameter (-0.027) at 10% significance level in this analysis supports the arguments by Eccleston-Turner & Upton (2021) and Wouters et al (2021), which discusses how the developed countries are reluctant towards COVAX facilities; explains the negative correlation. This finding supports the aforementioned literature because most of the producing countries in our dataset, did not make sufficient bilateral agreements via COVAX, rather they made advance bilateral agreements directly with the manufacturers, which made the impact of COVAX on vaccination coverage less prominent.

5.2. Significance of Vaccine Hesitancy on Vaccination Coverage

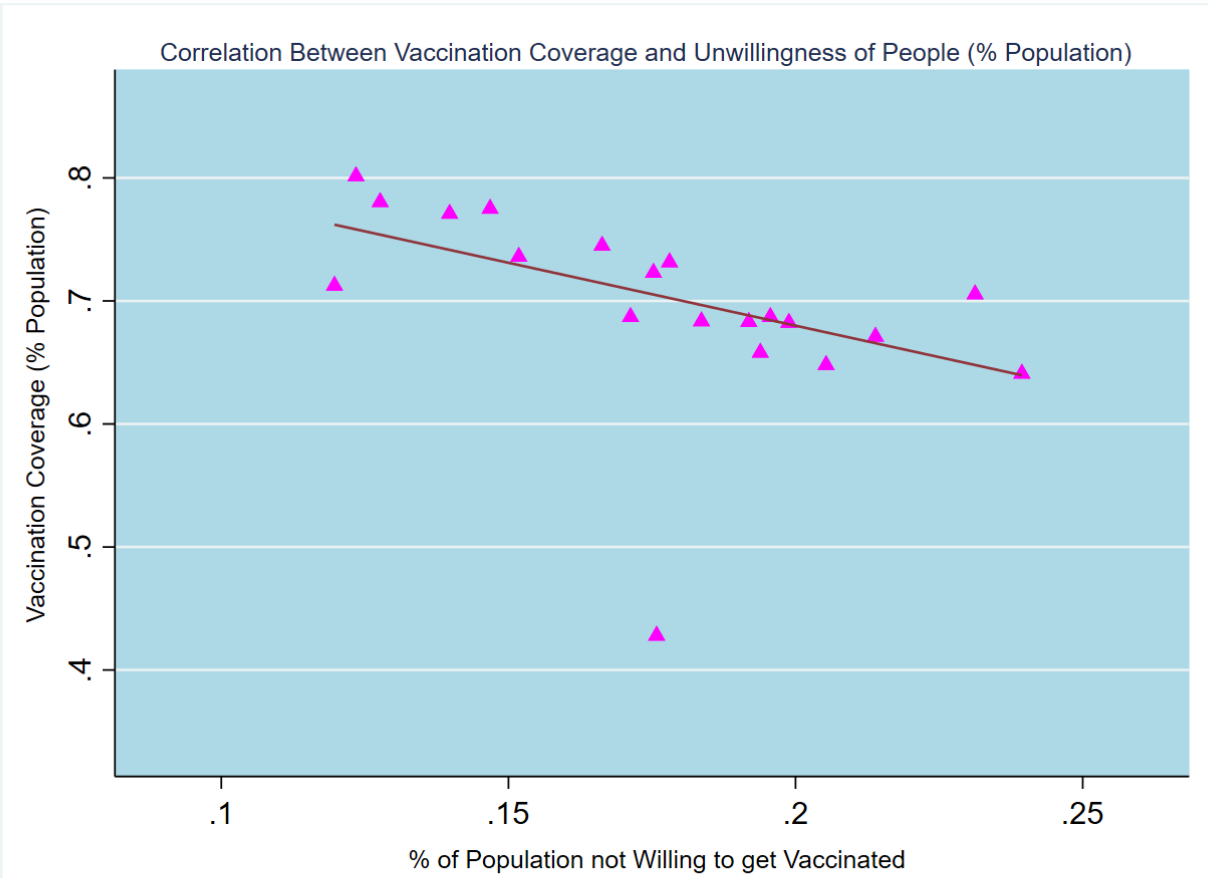
Table 4 shows the descriptive statistics of my sample dataset 2, with a number of observation N = 36. On average, the monthly vaccination coverage for the chosen countries is approximately 70% and average percentage of people who are unwilling to get vaccinated is approximately 17.5%. The low standard deviations 0.071 and 0.033 demonstrate that, overall, there's less variability in the dataset.

Table 5: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Vaccination Coverage	36	.706	.071	.428	.804
Unwilling People pct pop	36	.175	.033	.118	.239

We can analyze the pattern of association between unwillingness of people to get vaccinated and vaccination coverage rate in that country through the findings from non-parametric regression analysis such as pairwise correlation, binscatters and lowess regression. The result of the pairwise correlation between these two variables demonstrates that there is a strong negative correlation between these two indicators, and the correlation is significant at 1%, 5% and 10% significance levels with a p-value of 0.003 and correlation coefficient -0.478 (Table A3, Appendix). Below is the correlation graph between these two variables based on the data:

Figure 4: Correlation Graph (1)



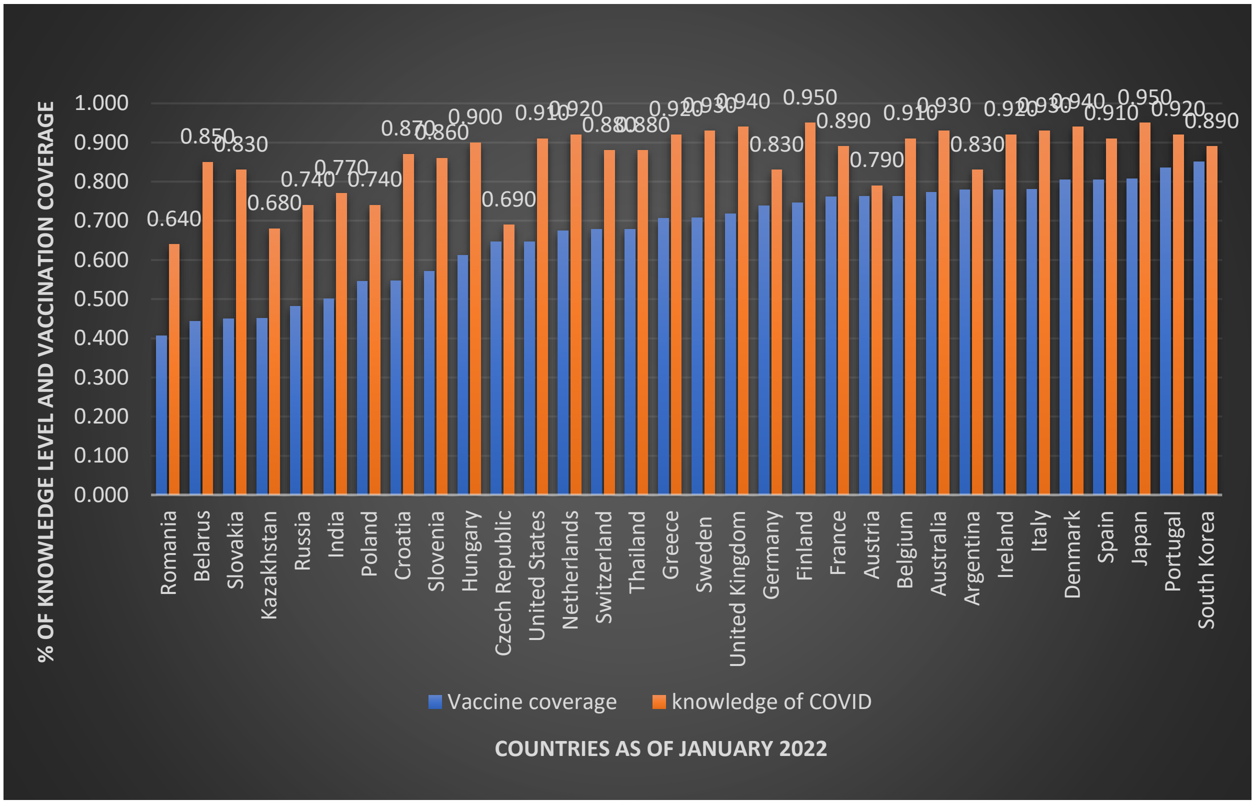
Source: Made by author in Stata. Data collected from Mathieu et al (2022), Our World in Data.

In Figure 4, if we observe the pattern from the binscatters, binscatters plots a best fitting line in the diagram, which has a negative slope. The downward sloping curve indicates that lower the percentage of unwilling people to get vaccinated in a country, higher the vaccination coverage rate in that region and vice versa. In Figure A1 in Appendix, we observe the lowess smoother for vaccination coverage and unwillingness of people, which shows a downward trend. LOWESS (Locally Weighted Scatterplot Smoothing) is a common method used in regression analysis that draws a smooth line across a scatter plot to allow us to understand link between variables and forecast trends. In order to fit a smooth curve to a set of data points, non-parametric methods like LOWESS and least squares fitting are used (Molnar 2020).

5.3. Significance of Accurate Knowledge of Covid on Vaccination Coverage

To analyze whether proper knowledge of COVID-19 is crucial for accelerating vaccination coverage, I collected data on 32 countries for the year 2021 and the level of their accurate knowledge of COVID-19 (Covid Behaviours Dashboard, 2022). Based on the data, a graph has been constructed below which demonstrates a trend that in general, countries with proper knowledge of COVID-19 have a higher vaccination rate as of January 2022 (Figure 5). In the graph, we observe some extreme points such as, Belarus, Slovakia, Hungary, Croatia, United States, where the accurate knowledge level of COVID-19 is above 80% but the vaccination coverage rate is below 65%. The difference in these two indicators in quite visible for Romania, India, Russia, Kazakhstan, Sweden, Netherlands and United Kingdom too. For instance, in the United States, approximately 92% people have accurate knowledge of COVID-19, but only 67% of there are fully vaccinated as of January 2022. On the contrary, in Austria, approximately 79% people have accurate knowledge of COVID-19 and 76% of their population are fully vaccinated (Figure 5).

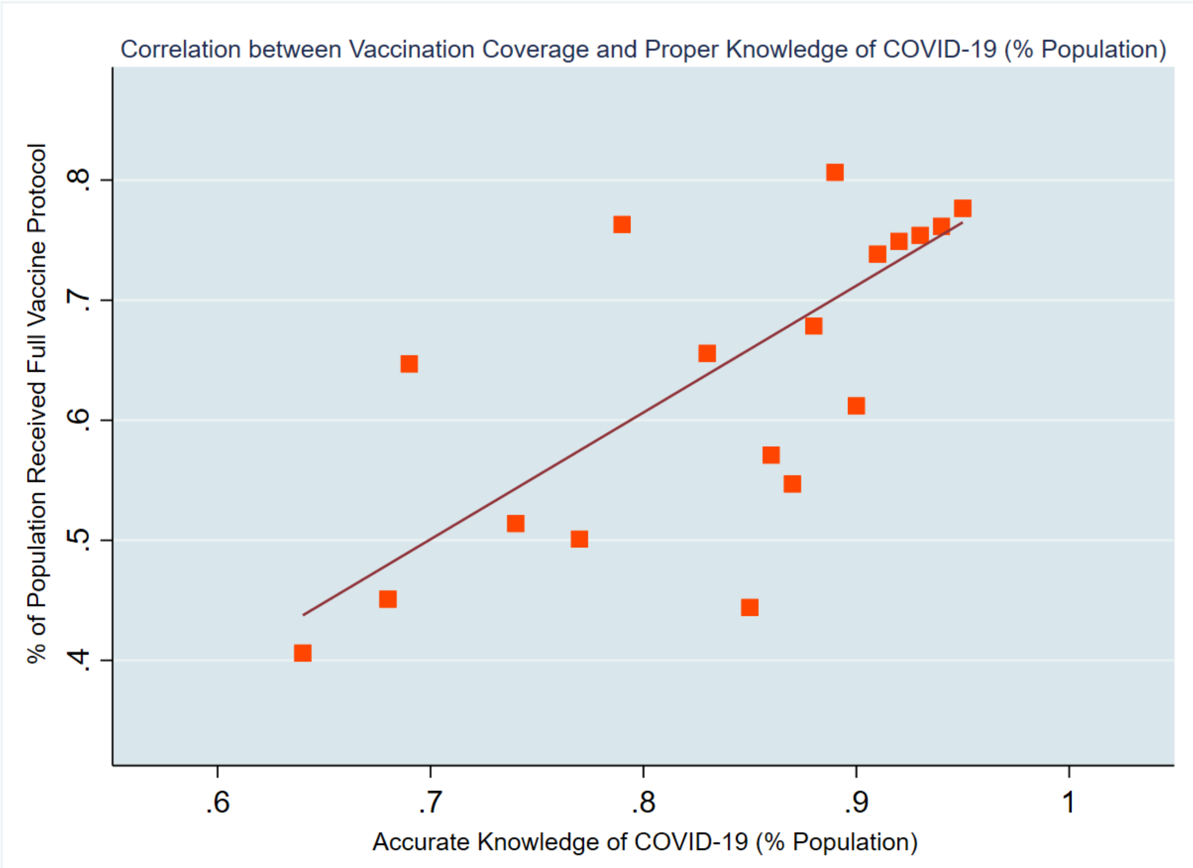
Figure 5: Vaccination Coverage and Knowledge of COVID-19 by Countries



Source: Made by author in Excel. Data Collected from Mathieu et al (2022), Our World in Data, Covid Behaviours Dashboard (2022).

We can analyze the pattern of association between knowledge of COVID-19 and vaccination coverage rate in that country through the findings from non-parametric regression analysis such as pairwise correlation, binscatters and lowess regression. The result of the pairwise correlation between these two variables demonstrates that there is a strong positive correlation between these two indicators, and the correlation is significant at 1%, 5% and 10% significance levels with a p-value of 0.000 and correlation coefficient 0.687 (Table A4, Appendix). Below is the correlation graph between these two variables based on the data:

Figure 6: Correlation Graph (2)



Source: Made by author in Stata. Data collected from Mathieu et al (2022), Our World in Data, Covid Behaviours Dashboard (2022).

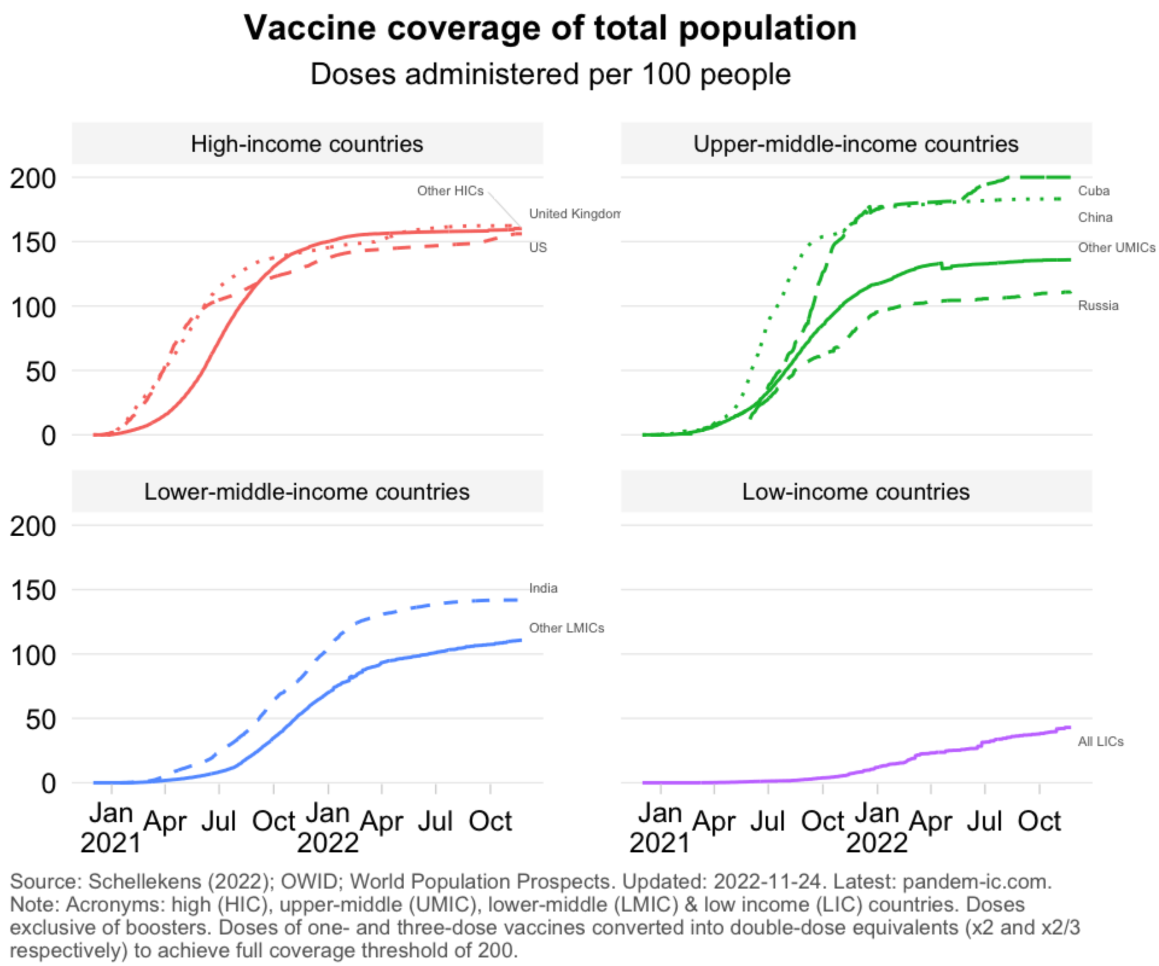
In Figure 6, if we observe the pattern from the binscatters, binscatters plots a best fitting line in the diagram, which has a positive slope. The upward sloping curve indicates that higher the percentage of people with proper knowledge of COVID-19 in a country, higher the vaccination coverage rate in that region. In Figure A2 of Appendix, we observe the lowess smoother for vaccination coverage and knowledge of COVID-19, which demonstrates an upward trend (Molnar 2020).

6. Case Study: Cuba’s Vaccine landscape and what fostered their success in achieving high coverage

According to UNICEF Covid-19 Market Dashboard data (2022), if we analyze the distribution of the COVID vaccines for Cuba via mechanism, we observe that there are no vaccine doses delivered through bilateral/multilateral agreements, donation or COVAX to Cuba. Multiple studies suggest that, Cuba has been impressively successful in achieving vaccination coverage with their domestic production and management capacity. Including Abdala, Soberana 02, and Soberana Plus, Cuba's illustrious biotech industry has created five distinct Covid vaccines to far, all of which, according to Cuba, provide more than 90% immunity against symptomatic Covid if delivered in three doses. When compared to the world's biggest and wealthiest countries, Cuba has immunized a far larger proportion of its people against Covid-19. According to official figures published by Our World in Data (2022), as of January 2022, approximately 86% of the Cuban citizenry has been completely immunized against Covid with three doses, while another 7% have been partially immunized against the infection (Taylor 2021, Meredith 2022).

According to Schellekens (2022), when it comes to producing COVID vaccines domestically, Cuba is an exception. Vaccination in Cuba is offered in both single-dose and multi-dose series. COVID patients have three options for therapy: the 3-dose regimen of Abdala, the 3-dose protocol for children consisting of Soberana 2 and Soberana Plus, or the 1-dose treatment of Soberana Plus on its own. This variety undermines Cuba's comparability to other countries. As an example, country X administers vaccinations in three doses, but country Y administers them in two. Vaccination coverage ratio (doses per 100 persons) would be 300 in X and 200 in Y if both countries immunized their entire populations. Therefore, according to this literature, all doses were converted to double-dose equivalents using the standard 2-dose approach across all countries to eliminate any potential for bias. The 1-dose and 3-dose protocols are converted to 2-dose equivalents using this approach by multiplying by 2 and 2/3, then adding and dividing by the population size.

Figure 7: Cuba's High Vaccination Coverage



Source: Schellekens (2022)

All of Cuba's vaccinations, including the Novavax vaccine, are subunit protein vaccines, as opposed to the mRNA technology used by American pharmaceutical giants Pfizer and Moderna. They don't need to be kept in the freezer, can be made in large quantities, and are inexpensive to create, making them ideal for low-income nations. Because of this, health experts from all around the world have begun praising the vaccines as a possible beacon of light for the "global south," where immunization rates remain dismally low. An "enormous importance" for poor nations would be the World Health Organization's (WHO) possible approval of Cuba's domestically made Covid vaccines, according to John Kirk, professor emeritus in the Latin America department at Dalhousie University in Nova Scotia, Canada. The vaccines don't need the ultra-low temperatures that Pfizer and Moderna demand, so that there are locations, especially in Africa, where we don't have the capacity to keep these global north vaccinations. Unlike other governments or pharmaceutical corporations, Cuba has volunteered to transfer technology in order to share its knowledge of vaccine manufacture with developing nations (Meredith 2022, Head 2022, Schellekens 2022).

7. Limitations of the Study

One key limitation of this study is, the model used to analyze the dataset is impacted by omitted variables bias as the values for GDP per capita for countries are omitted (Table 4). Therefore, the results of my model are likely impacted by omitted variable bias. However, it can be argued that there is always omitted variable bias in observational research. There is omitted variable bias because there are factors that impact the dependent variable for which either we have no data or are unaware. In both instances, we exclude information about these forces from our model, which introduces bias into your coefficient estimations (Orosz 2021). Another possible omitted variable, which is not included in the model and can create bias is Human Development Index (HDI) of the countries. Lastly, due to the inconsistency in the data and lack of credible sources about monthly production level, unavailable information regarding public health infrastructure and management, willingness to accept among the producing countries, a lot of indicators couldn’t be considered in the dataset, which might have been significantly influenced the result. In order to get a strongly balanced panel dataset, we had to decrease the number of observations from 102 to 60. The number of observations in our dataset 2 and 3 were not large as well, due to the inconsistencies and unavailability. Moreover, we could not include the indicators willingness of people to get vaccinated and knowledge of COVID-19 in our fixed effect regression analysis, which might have significantly impacted the regression results. Therefore, we encourage further consistent studies in this field.

8. Policy Recommendations

In order to substantially increase global supply and assure fairness, support for lower middle-income countries is required to facilitate them to ensure and produce vaccinations locally for their people, as well as much more contributions and strong willingness from the developing world to overcome this shortage. To overcome obstacles to global vaccination, sensible and cooperative efforts are highly required by the powerful entities of the world; such as UK, France, Germany Canada, United States and allies (Kavanagh 2021).

8.1. COVAX Facility Improvement

The COVAX Facility should spend extensively in scaling up the essential infrastructure in sponsored nations so that doses can begin to be deployed in all countries, at the same pace, as soon as possible, to prevent disparity of vaccine distribution on the scale seen in the time of 2009 H1N1 pandemic. Keeping mRNA vaccine candidates at -70 degrees Celsius is very important since it will allow for their widespread distribution in impoverished nations when they are approved and made available in the industrialized world. COVAX has not yet placed an order for either licensed mRNA vaccination (i.e., the Moderna and Pfizer vaccines). However, the company has spent money on developing the Moderna candidate as part of the COVAX division's research and development portfolio. This raise concerns regarding COVAX's dual position as a procurement agency for developing nations and as a vehicle to stimulate research and development for COVID-

19 vaccines. The primary objective of the Global Allocation Framework is to ensure a fair distribution of doses, and widespread improvements in vaccination infrastructure in sponsored nations would mitigate the need for such a mechanism. This funding would help developing nations become better prepared for both future pandemics and ordinary vaccination drives. The facility should promote and support risky development in vaccine delivery infrastructure in the same way that it promotes risky manufacture of vaccines. Without this, the substantial resources being spent in the faster research and manufacturing process would only benefit those nations who already have enough infrastructure in place (Eccleston-Turner & Upton 2021).

8.2. Public Health Infrastructure and Social Awareness Campaigns

Immunization in a region must be supported by both a national vaccination policy and a public health infrastructure. As suggested by Meng et al (2021), and Feinmann (2021) public health system should be well-organized and staffed to fulfil its duty to rapidly distribute sufficient vaccination supplies. With the use of cultural determinants, these systems should incorporate preparations for a mass immunization effort against COVID-19. Health care practitioners can also create social media vaccination awareness campaigns and make strong recommendations for the COVID-19 vaccine. These efforts, which include campaigns and education, are crucial to ending vaccination skepticism. Because vaccinations were purchased or created so rapidly, their safety has caused worry in several countries. Also, poor nations, especially religious and ethnic minorities, are more likely to be affected by the ongoing disinformation campaign against COVID-19 vaccinations on social media.

8.3. Production, Funding and Affordability

To have the greatest possible impact, newly produced vaccinations must also be reasonably priced, easily available, widely trusted, and well used. Governments and other buyers of vaccines must now make choices about which vaccines to buy and how to pay for immunization campaigns against COVID-19. The availability, price, effectiveness, and dosing storage need of vaccinations, among other factors, must be evaluated by government authorities and partners in international organizations before these choices can be made. The substantial involvement of the public in supporting vaccine research may provide possibilities. Funders might urge vaccine inventors receiving public money to routinely and broadly share their inventions and expertise in order to boost global manufacturing. Funders might also collaborate with developers to reduce supply chain limitations and expedite production scale. Insofar as international control of COVID-19 is a priority for particular nations, governments may have an incentive to use these levers (Eccleston-Turner & Upton 2021), (Wouters et al 2021).

8.4. Public Trust and Evaluation

During the introduction of a vaccine, trust must be strengthened by post market monitoring. Understanding the contextual and historical impacts on vaccination hesitation and rejection is necessary for developing effective, locally-tailored solutions. Simultaneously, vaccine producers should strive for maximal openness and examination of their clinical trial data to increase public confidence. By determining whether the advantages of medications exceed their hazards, regulatory authorities defend public health. In order to ensure the public that authorized goods are safe and effective, regulatory judgments and their justifications must be effectively conveyed. Vaccine developers have an incentive to seek approval or emergency use authorization from a stringent regulatory body or the World Health Organization (WHO): only vaccines that have passed through one of these mechanisms that regulate will be qualified for buying through COVAX or via financing from major development banks (Wouters et al 2021).

8.5. Global Approach and Technology Transfers

Undoubtedly. In order to hasten global vaccine distribution and vaccination campaigns, it is necessary to build a mindset, strategy, and set of activities that reflect global justice, solidarity, and equality. Dr. Tedros Adhanom Ghebreyesus noted in his opening comments at a meeting of the WHO's executive board "This self-centered attitude not only endangers the world's poorest and most vulnerable people, but it is also self-defeating. These actions will simply contribute to prolong the pandemic, our suffering, the required restraints to manage it, and the resulting human and economic suffering." This strategy is also compatible with the principle that no one is safe until everyone is safe. Some present practices may worsen disparities in COVID-19 infection and mortality rates. In addition, the immunization deployment requires local, national, regional, and international cooperation. There is already a method in place to do this. The Access to COVID-19 Tools (ACT) Accelerator is a collaboration formed by the World Health Organization and its partners to assist this coordinated and global endeavor (Eccleston-Turner & Upton 2021). Initiatives to promote the sharing of intellectual property rights for vaccines and their essential components might be linked with initiatives to encourage technology transfers. Establishing a system in which established vaccine researchers license their vaccines to new vaccine manufacturers in exchange for production know-how would enable them to benefit from the use of their technology while expanding the global vaccine manufacturing capacity. These measures may be coupled with vaccination programme pledges to purchase vaccinations locally wherever possible so as to support regional producers (Asundi et al 2021).

9. Conclusion

Without a shadow of a doubt, the destructive effects of COVID-19 on economic growth and societal advancement extend far beyond its influence on human health. The fight against the pandemic and the protection of human life came at a heavy cost to medical experts, biomedical specialists, and allied pandemic prevention units (Meng et al 2021). Vaccine disparity is widespread and extremely discriminatory despite the fact that biomedical research has been very successful in creating vaccinations in far shorter trial period time than is typical. Our research on the world's key producing economies led us to conclude that bilateral agreements with the world's leading vaccine producers are more vital than local vaccine production capability when it comes to reaching greater and speedier immunization procedure. This again lends credence to the claims made in the aforementioned literatures, namely, that countries with high per capita incomes (or economies that generate high per capita incomes) have a higher overall vaccination rate because of their greater access to vaccines, higher HDIs, and more developed health care systems (Roghani 2021) (Basak et al 2021). Initiatives like COVAX are struggling to have their intended effect because of the strategic tactics and vaccine nationalist attitude of rich nations. The results also suggested that the vaccination coverage rate was significantly related with the policy level of individual countries, with greater coverage rates being shown in countries where vaccines were made accessible to the general public more quickly. Surprisingly, there is no significant link between the vaccination rate and the stringency index for the unvaccinated population across areas. This suggests that the willingness to accept vaccination and public trust are more important, rather than stringencies. The research based on the Chinese population (Meng et al 2021) also suggests that health awareness, a thorough knowledge of COVID-19 and infrastructure management are crucial. Cuba's performance shows the necessity of a solid biomedical research foundation, a robust desire to battle, and ongoing initiatives to expand production capacity, even though we didn't uncover a substantial association with domestic output. To reduce the disparities across the major producing economies and countries, it’s extremely crucial to rearrange the COVAX facility and there’s no alternative to invest in public health infrastructure, advanced research, spreading awareness in order to gain public trust and acceptance. Above everything, we need both a top-down strategy from our scientific, industrial, and political leaders, as well as a bottom-up one from the members of our communities, in order to solve the global inequity in vaccination coverage. The primary argument behind these suggestions is that the worldwide scope of the COVID-19 epidemic necessitates a global response, as opposed to a regional approach that prioritizes high-income nations. If the poorer countries aren't vaccinated properly, the richer countries won't be safe. Therefore, international efforts should be made to hasten the COVID-19 immunization campaign in all nations, regardless of their economic status.

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11. Appendix

Dataset 1:

Panel variable: Region ID (strongly balanced)

Time variable: month, 7 to 12

Delta: 1 unit

Table A1: Heteroskedascity Test for Fixed Effects Regression Model

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (10)  =    1093.46
Prob>chi2 =      0.0000
```

Source: Stata Analysis copied as picture

Table A2: Pairwise Correlation between monthly vaccination coverage and monthly vaccination production per capita

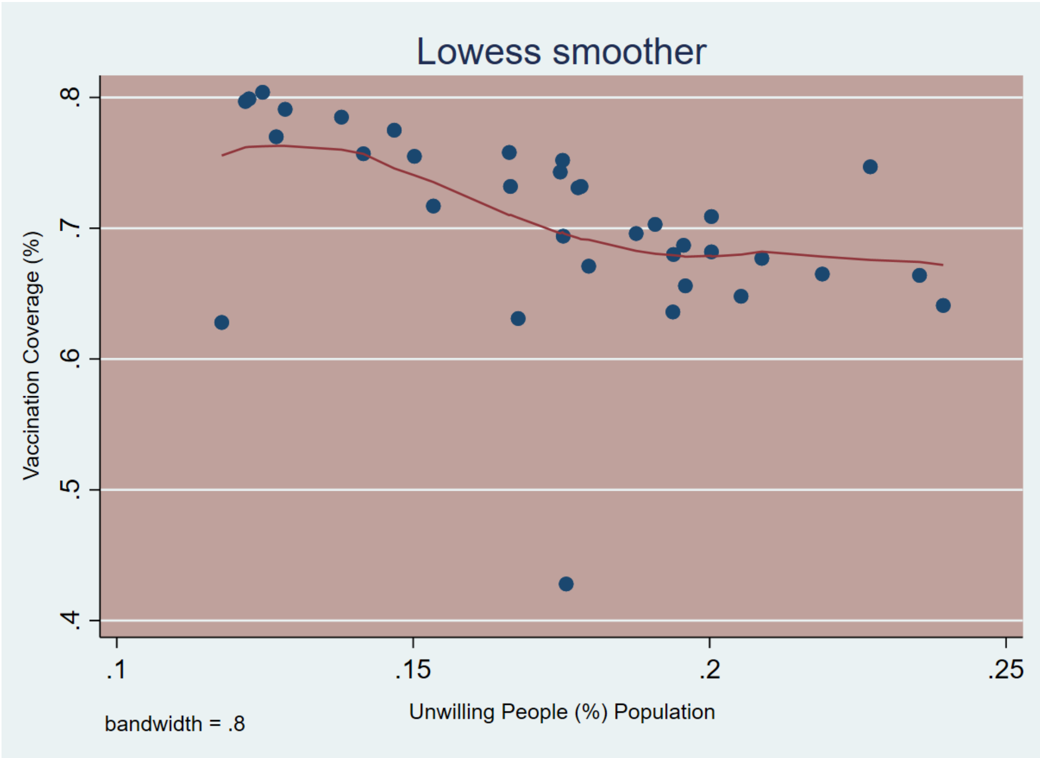
```
. pwcorr mvaccine_coverageadjusted mvaccine_productionadjusted, sig

             | m~cove~d m~prod~d
-------------+------------------
mvaccine_c~d |   1.0000
             |
             |
mvaccine_p~d |   0.2141   1.0000
             |   0.1004
             |
```

Source: Stata Analysis result copied as picture

Table A3: Pairwise correlations

Variables	(1)	(2)
(1) Vaccination Coverage	1.000	
(2) Unwilling People pct pop	-0.478	1.000

Figure A1: Lowess Smoother (1)



Source: Made by author in Stata, Data collected from Mathieu et al (2022), Our World in Data

Table A4: Pairwise correlations

Variables	(1)	(2)
(1) Vaccination Coverage	1.000	
(2) Knowledge of COVID-19	0.687	1.000

Figure A2: Lowess Smoother (2)

Source: Made by author in Stata, Data collected from Mathieu et al (2022), Our World in Data and Covid Behaviours Dashboard (2022), Johns Hopkins Center for Communications Program.