“What factors explain unequal access to COVID-19 vaccines among countries?"

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Abstract

Inequity in access to vaccine supply among the countries is a major issue because uneven resource allocation during a crisis affects human rights and delays global recovery. As a result, it is necessary to identify the factors that contribute to disparities in vaccine supply access. This thesis conducts a multiple linear regression on cross-sectional data from 106 nations from 2021 to investigate which factors are related to vaccine accessibility. To develop the hypotheses for this thesis, Dependency theory, World system theory, some ideas from Neo-classical growth theory as well as multiple arguments and discussions in the literature have been explored. The key factors discussed by the previous scholarship are local production, technological and innovation level of a country, patent rights, infrastructure capacity, number of bilateral agreements, early bilateral agreement, wealth, the global influence of countries, and donation. But previous studies have not provided statistical evidence for their claims. So, as per my investigation, my thesis is the first to study the statistical relationship between factors and vaccine accessibility. My findings show that domestic vaccine production ability, the technological and innovation level of a country, the number of bilateral agreements, and the amount of donation received have a statistically significant relationship with vaccine accessibility. I expect that identifying the factors behind vaccine inequity will help governments and international organizations come together to increase vaccine supplies in deprived regions and develop policies to inhibit such inequities in the event of any future recurring global health emergencies.

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I would like to express my gratitude to my supervisor Professor Yusaf Akbar who guided me throughout this thesis. I would also like to thank my parents, my sister and my friends for their support. I, particularly, thank my friend Aisulu Kairberkova, for motivating me to complete this thesis. I also wish to acknowledge the help I have received from CEU academic writing center and Judith Minczinger in improving my thesis. Besides, I want to extend my special thanks to my undergraduate Professor Moinul Islam, for his insightful comments on my methodology. Finally, I thank myself for completing this thesis with perseverance and patience.

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1. Introduction

Historically, the nations of the world are divided by their difference in power, wealth, and capacity. Though today many poor countries have gained noteworthy economic and social development, they still lack behind the rich countries in terms of resources, power, and capacity. This difference became clearer during a recent global crisis when some countries could easily access resources to shield themselves from the crisis, whereas other countries struggled to get any protection. In this thesis, I will be looking into the factors that have caused the discrepancy in the number of vaccines- a particularly important resource to tackle the global crisis- available to different countries. While numerous studies have addressed this question, most of them are qualitative and lack statistical evidence to back up their claims. Thus, to answer this question, for this thesis, I will do regression analysis on cross-sectional data from 106 nations and the data are from December 2021.

In December 2019, a deadly virus was discovered in China and in a short span of a few months, it spread to more than 200 countries. The virus had developed into a serious outbreak by March 2020, according to a WHO warning, and the condition had been dubbed a global pandemic. Based on the name of the virus -coronavirus 2 (SARS-Covid-2) – its syndrome was termed Coronavirus or Covid-19 (Bayati et al., 2022). Globally, the introduction of COVID-19 has been seen as a serious threat to human health. As of September 23, 2022, the virus infected 611,421,786 individuals and caused 6,512,438 deaths according to WHO research. (WHO Coronavirus (Covid-19) Dashboard, n.d.).

Furthermore, its ability to limit mobility instigated an external shock in different areas, including the job and education sectors, the economy, and the socio-political environment. For instance, according to World Bank data, the pandemic brought on a global recession in 2020, resulting in a reduction in GDP growth of -3.3% (GDP growth (annual%), n.d.). In a similar vein, the World Bank reported that in 2020, the unemployment rate increased from 5.4% to a high of 6.6% (Unemployment, total (% of the total labor force), n.d.), deviating from the pre-pandemic falling trend. By mid-2020, a global emergency was established, requiring all governing bodies to mobilize their limited resources to stem the pandemic's impact.

Multiple strategies have been adopted since 2020 to weaken the pandemic and vaccination was one of the most sought approaches by experts. In 2021, eight front-runner vaccines were introduced to the world as an effective shield against the different variants of this rapidly mutating virus (Mallapaty, 2021). Later many other vaccines were introduced, but the eight vaccines are still the most prominent. The WHO endorsed the vaccines' efficacy and claimed that, while immunization cannot provide a guarantee of complete immunity, it can reduce the chance of death brought on by the virus. Thus, vaccinating will make travel safer and reduce the pandemic's overall effects on the world (BBVA, 2021). Scientific studies have also supported the vaccine's efficacy. A study by Bernal et al. (2021) showed that after being infected, the probability of vaccinated people requiring hospitalization is 44% less and passing away is 51% less in comparison to non-vaccinated individuals. Moreover, another study found that the effectiveness of vaccination is 85% within 15-28 days and concluded that the vaccinated individuals receive fewer infections, as well as vaccination, reduces the transmission rate (Mohammad et al., 2022). Due to such effectiveness, almost all the nations around the world developed a high demand for vaccinating their population.

However, not everyone in the world had access to vaccines equally. There has been a noticeable disparity between the number of vaccines that various countries have access to since the beginning. A study has revealed that, in the last 6 weeks of 2021, the number of vaccines received by the European Union, the United Kingdom, and the US is 513 million doses whereas the collective number of doses received by the African countries around the whole year is just 500 million (York, 2021). Of course, the quantity of dosages made available to those nations has grown over time. Nevertheless, the progress is very slow, and the discrepancy is still high. As evidence, figures 1 and 2 below show the quantity of vaccine supply secured by the countries throughout the world in the percentage of the total population, in April 2022 and Sept 2022 respectively:

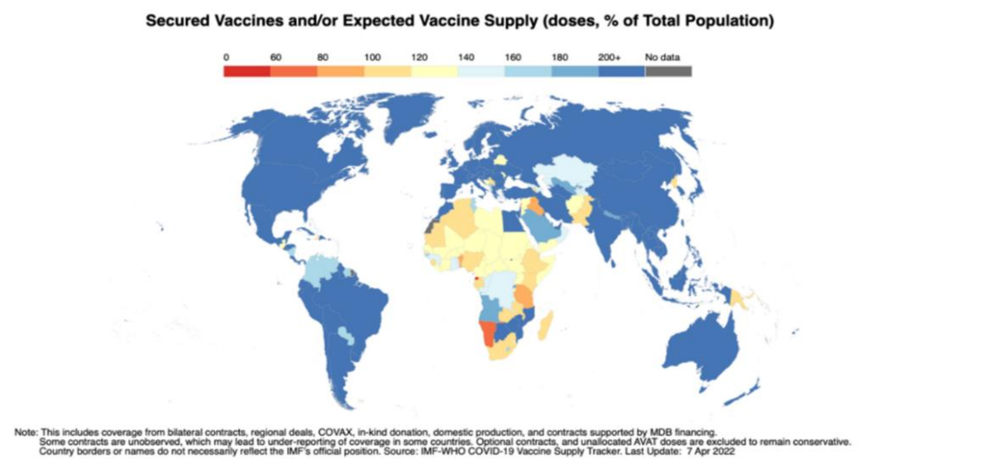

Figure 1: % population that secured/expect to secure vaccine supply worldwide as of April 2022 (IMF-WHO Covid 19 Vaccine Tracker, 2022)

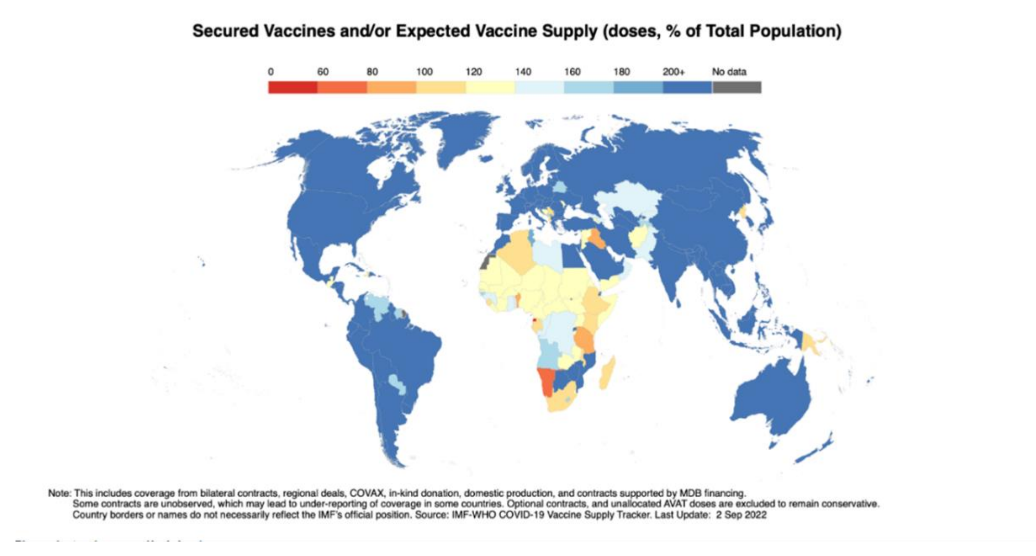

Figure 2: % population that secured/expect to secure vaccine supply worldwide as of Sept 2022 (IMF-WHO Covid 19 Vaccine Tracker, 2022)

Both graphs make it abundantly evident that countries marked in shades of yellow, mostly located in Africa and other parts of the Global South, have a lower vaccine supply than those highlighted in shades of blue. If one looks closely, the figures differ somewhat, and some of the countries from figure 1 marked in yellow, such as Belarus from Eastern Europe and Pakistan from South Asia, have changed to blue in figure 2. However, the difference between the figures is so trivial that it is challenging to tell the two apart. This demonstrates that while there has been a tiny improvement in vaccine access in some regions of the Middle East and Africa between April 2022, and September 2022, the change is small and slow.

This is a serious problem, especially at the time of global crisis. This is because the unequal distribution of resources during the crisis is a human right issue as well as it slows down global recovery. A further explanation for why this is a problem is given below:

1. The discrepancy in the access to vaccine supply can be a human right issue because it reduced the vaccination rate in the deprived regions and left the people vulnerable to infectious diseases. It is stated in the first article of the United Nations Universal Declaration of Human Rights “All human beings are born free and equal in dignity and rights”. Here, the aim of “leaving no one behind” that builds the foundation of human rights is also the core idea of equality (Blanchet, 2021). Yet, the Covid-19 vaccination situation shows a different picture. As of the first quarter of 2022 when the pandemic was still at its peak, Global Dashboard for Vaccine Equity showed that 67.09% of the population of Global North had received at least one dose of vaccine, whereas 10.56% of that from the Global South received one dose (UNDP, n.d.). This inequity in vaccination coverage leaves the country that has lower vaccination rates with a population with a weaker immune system and a high health burden. It is important to mention that low

vaccination rates can be attributed to the low demand for vaccines amongst the public as well. However, lack of access to vaccines thwarts even those who are willing and believe in the efficacy of vaccines, from receiving them. Thus, the inequality in vaccine access could be regarded as a human rights violation, specifically, the right to life and the right to health.

2. At the same time, global recovery gets hampered as unvaccinated people in those regions can increase transmissibility. Describing the importance of a higher vaccination rate, the WHO has mentioned that "No one is safe unless everyone is safe". Higher inequity increases the probability of having new variants with stronger resistance against vaccines in places with lower vaccination coverage. As these variants (with higher power of transmission) transmit and spread very quickly over the globe, a new and more difficult challenge arise for the vaccine and the pandemic again hits the slowly recovering world with severe economic and social consequences as well. For example, at the end of 2021, the low rate of vaccination and vaccine supply turned Africa into the super incubator for the deadly covid variant omicron, prolonging the pandemic all over the world (Smith, 2021).

Overall, the disparity in vaccine supply has led to the discrepancy between countries in terms of controlling and recovering from the pandemic. It also highlighted the global inequity situation once again. Therefore, this problem has become a major global policy issue for the past two years. This motivated my research question for this thesis: What factors explain the unequal access to Covid-19 vaccines across the countries?

To investigate this question, I will conduct Multiple linear regression to check what factors have made a statistically significant contribution to the unequal access to vaccines across different countries. The data for this thesis has been collected from data banks of international bodies such as The World Bank, WHO, IMF, and various related reports. The research is based on data from 2021 or earlier (when data is unavailable for 2021). The reason this thesis only examines data from 2021 is that it is focused on the importance of equal access to preventive resources during an ongoing global crisis- in this case, equal access to vaccine supply during the Covid-19 pandemic. The post-global crisis scenario is different and is beyond the scope of this thesis. Since, as of 2022, experts have already predicted that the pandemic will end soon, the thesis will not further discuss 2022 data (Powell, 2022). Chapter 3 will have a more detailed discussion of the collected data.

To develop the hypotheses for this thesis, Dependency theory, World system theory, some ideas from Neo-classical growth theory as well as multiple arguments and discussions in the literature have been explored. Currently, a lot of factors are discussed and debated on international platforms. For example, Dyer (2020) in his report mentions that rich countries such as Canada[1] have utilized their economic power and position in global politics to hoard more vaccines than needed. Poor countries that cannot afford to spend a huge amount to buy vaccines, thus, have fewer vaccines available to them[2]. To solve this problem, international organizations developed COVAX, a collaboration initiative set up to distribute vaccines by the World Health Organization, UNICEF, the World Bank, and the Bill & Melinda Gates Foundation. However, Dyer (2020) questions the effectiveness of donations because it makes poor countries completely dependent on rich countries. On the other hand, UNICEF (n.d.) has termed donation as an

[1] In 2020, when the Covid-vaccine development process was still ongoing, countries like Canada ordered enough to immunize per person of its population five times (Dyer, 2020).

[2] When it comes to buying, Global Dashboard for Vaccine Equity has shown that the price of covid vaccine dose can range from $2 to $40, with the distribution cost being $3.70 per person who is vaccinated by 2 shots (UNDP, n.d.). Many poor countries cannot afford such expenses, and for those who can afford them- these expenses are a substantial financial burden on them.

“immediate, short-term and urgent solution” to vaccine inequity. Other factors that came up in the discussions are manufacturing location, technological discrepancies, and patent access (Asundi et al.,2021; Iacobucci,2021; Obinna 2022). All these debates and discussions are mostly based on assumptions or logical reasoning. Therefore, in this thesis, I intend to find statistical evidence and provide recommendations accordingly.

The thesis is motivated by the significance of universal vaccine availability and how it affects both human health and the global economy in times of global crisis. Identifying the underlying causes behind vaccine inequity can help governments and international organizations come together to increase vaccine supplies in deprived regions. Besides, it can help them develop policies to prevent such inequities in vaccines and other preventive measures in the event of any future recurring global health emergencies.

Additionally, the more personal motivation to pursue this project stems from the fact that as an individual from a country in the Global South who had the opportunity to study in a wealthy nation after the pandemic, I have seen firsthand the disparity between the regions' access to vaccines. Furthermore, I have witnessed firsthand the severe vaccine shortage that my nation experienced in the early days following the introduction of vaccines. This originally interested me in the issue of inequity in vaccine supply and encouraged me to investigate further the factors that contribute to it.

My findings showed the domestic vaccine production ability, technological and innovation level of a country, number of bilateral agreements a country had for procuring vaccines, and amount of donations received are some of the factors that can be associated with the number of vaccines accessible to a country.

The organization of the thesis is the following: Chapter 2 will cover the literature reviews and the theories, Chapter 3 will discuss the methods used in this research, Chapter 4 will focus on the interpretation and analysis of the result and finally, Chapter 5 will present the policy recommendations towards international bodies as well as different countries, followed by Chapter 6 that will provide the conclusion, limitations of this thesis as well as implications for further studies.

2. Literature Review

Several literatures during the pandemic and even before, have tried to define vaccine equity, discussed the debates surrounding it as well as analyzed varied factors related to it. So far, the literatures have taken a qualitative approach to analyze the factors and debates around vaccine supply inequity. So, as per my investigation, my thesis is the first to study the statistical relationship between factors and vaccine accessibility. Nevertheless, I look at these previous literatures to identify potential factors on which I can conduct my analysis.

Graaf et al. (2022) in their paper discuss the umbrella concepts that explain the underlying mechanisms of vaccine supply inequality. They create a model that describes vaccine equity using a holistic approach, taking all socioeconomic, philosophical, and historical dimensions, rather than the typical normative approach. In the holistic approach, the authors bring in concepts of increasing local production capacity, rethinking patent models, local technical capacity as well as procurement inequity. The paper emphasizes how vaccine equity is comparatively a new term that got prominence due to hashtags in social media as a cry for the government and manufacturers to take fairer steps regarding the Covid-19 vaccine. According to Graaf et al., in a normative approach, its definition could be divided into two components: 1. The responsibility of high-resource countries to share more vaccines with lower-income countries 2. The liability of pharmaceutical companies to guarantee reasonable prices, availability, and equal production for vaccines. However, they point out two faults in this kind of approach. *Firstly,* in the normative approach vaccines are considered the property of companies and countries that invest in them and thus, are donated to third countries only after hoarding heavily for themselves. *Secondly,* the normative approach disregards the large pre-existing patterns of inequity that have led to the current vaccine inequity. So, the authors use the global justice as well as historical approach to restate vaccine inequity as “a consequence of past injustice” linking it to the colonial consequences of the division of power and resource. Under this approach, they view vaccines as a type of public good, and call for equal distribution and local production options, while discouraging the supply of vaccines to underdeveloped countries in the forms of charity. However, they recognize that past trends have led to inequity in the health sectors of various nations, making it challenging to implement their recommendations without synchronized endeavors by the entire globe. To further clarify, the authors acknowledge there are several bottlenecks in achieving vaccine inequity if the holistic definition is followed. Inequity in technological capacity, intellectual property and patent models, and domestic production capacities at market entry are some of them. Therefore, according to Graaf et al., achieving vaccine equity is impossible without concurrent efforts at every level, if the holistic approach is followed. This means, a sincere commitment to solidarity and redressing historical injustices will be needed to combat existing imbalance and stop the gap from widening. In conclusion, Graaf et al. dismiss the normative approach to define vaccine equity because of its faults and use a holistic approach that considered all factors, including the full vaccine life cycle, health systems, local politics and public administration, historical trends, and international cooperation. It is this kind of holistic approach, rather than a narrower one that disregards several factors, which has informed my analysis of the different factors that can be related to vaccine inequality.

The conclusions drawn by Graaf et al. are reflected in Asundi et al. (2021)’s research on the challenges and scope of vaccine supply equity during the Covid-19 pandemic. According to them, the inefficiency of donations and the stockpiling of vaccines by some counties are the greatest challenges to attaining vaccine supply fairness. They further explain that stockpiling of vaccines can be done by high-income countries, who have the international influence and economic power to simply enter early bilateral agreements with vaccine producers to purchase and store all the vaccines manufactured. According to their report, because of this influence, high-income nations have an excess of vaccine supplies that will allow them to immunize their populations for up to five years starting in 2020. The authors further report that a scarcity of vaccines for lower-income countries, particularly in Africa is seen due to this stockpiling by higher-income countries. Though there have been interventions by the UN to secure vaccines for lower-income countries through donation, the authors claim that the inefficiency of donation is another reason behind the vaccine supply inequity during the pandemic. They argue that the donations do not cover the scale of what is needed by the lower-income countries. The authors cite an example of how the G7 promised to provide 870 million vaccine doses to nations who lacked access to them in 2021, whereas the WHO estimated the demand crosses 11 billion doses. This makes the donations by the high-income countries inefficient. Both arguments support the assertions made by Graaf et al. that vaccination equity cannot be explained under a normative approach in which vaccines are seen as private goods and given only after stockpiling. To prevent this, the authors suggest short-term and long-term approaches. These suggestions are on par with the holistic approach introduced by Graaf et al. and consider options that treat vaccines as a global public good that must be distributed equally. The short-term approach is the re-distribution of the global stockpile according to needs around the globe. This recommends that producer and investor countries have bilateral agreements with the lower income countries to sell vaccines at a lower price as well as donate according to need, instead of hoarding the vaccines. The long-term approach is to strengthen regional capacity so that countries do not need to rely on philanthropic contributions. Nevertheless, many countries face countless production barriers that can hamper their local production capacity. The authors mention legal issues with intellectual property transfer, lack of physical infrastructure, limited technical expertise, and absence of opportunities for R&D as production barriers. In short, the arguments of Asundi et al. follow the umbrella framework of Graaf et al. to assert that stockpiling and donation inefficiency are the challenges to vaccine inequity whereas vaccine redistribution and building regional capacity are the solutions. They further claim, again similarly to Graaf et al., that these solutions can be affected by other barriers such as production barriers.

Despite the arguments against the effectiveness of donation by Asundi et al. and Graaf et al., Ye et al. (2022) have considered donation as a beneficial approach that should be taken by countries that have a surplus. Their paper assumes that eventually the production of vaccines will reach its maximum level and will keep growing at that rate by the end of the pandemic. They also assume that this increase in production will help vaccinate more people. Under these circumstances, they explore the consequences of different vaccine allocation strategies through a multi-strain metapopulation model. Ye et al. conclude that donation is the most practical way to attain vaccine equity under the current circumstance. They find that even a small amount of donation reduces cumulative mortality in LMICs greatly. However, the effect is weakened, if the donation is made because of diplomatic ties between neighboring nations rather than based on necessity.

In order to further emphasize the challenges in guaranteeing vaccination fairness, Obinna (2022) adds two more ideas to what has already been addressed in the above literatures. The first one is vaccination nationalism, which refers to the attempts of wealthier countries to secure a surplus of vaccines for their people due to the fear of shortage and this leads the developing countries to have lesser supply. Vaccination nationalism is the explanation of the mechanism behind stockpiling of vaccines mentioned by Asundi et al and it treats vaccines as private goods according to the normative approach. The second concept is intellectual property rights which is related to the production barrier. Obinna reports that, in October 2020, India and South Africa started to demand a TRIPS waiver, which would temporarily remove patent protection required to produce COVID-19 vaccines. The rationale behind this demand, as the author continues, is that possession of IP rights gives companies in high-income countries the liberty to sell vaccines at a higher price that is not affordable for low-income countries. But low-income countries do not have the alternative to produce their vaccines as they face production barriers due to IP. Thus, they either have to be dependent on donations or be forced to buy vaccines at a high cost. Thus, the high cost of vaccinations and the incapacity of developing countries to produce their own are two factors then contribute to the lower access to vaccines in the developing world, leading them to demand Trips waiver. If considered from the perspective of Graaf et al., TRIPS waiver should have a positive effect on vaccine equity as it transforms vaccines into a public good, while IP rights put vaccines under private monopoly power. But Obinna argues that Trips Waiver might not be the complete solution. She digs deeper into the bottlenecks and production barriers mentioned by Graaf et al. and Asundi et al. and focuses on the idea that developing nations also need to strengthen their technology level and infrastructure (roads, electricity, water supply) to produce locally. The author, therefore, calls for vigorous international cooperation, in advancing the technological and infrastructural aspects of developing nations, which we can categorize under the idea of solidarity put forth by Graaf et al., in order to promote vaccine supply equality throughout the world.

The topics of vaccination nationalism, production barriers as well as IP waiver have also been discussed by Katz et al. (2021), where the authors state that the general view of global health and the economy is “flawed”. They assert that, contrary to what Graaf et al. suggest, vaccines are today considered more like a marketable good than a public good. As a result, vaccine manufacturers may set "prohibitively high pricing" for their products which lower-income nations that do not produce vaccinations cannot afford. The authors understand that having a local manufacturing capability may enable these nations to obtain vaccines at a reasonable cost. Here, they raise the matter of patent waiver, agreeing with the demands made of South Africa and India as stated by Obinna. They state that eliminating patent ownership is the groundwork for removing barriers to access to manufacturing for developing countries. However, Katz et al, claim developing capacity for vaccine production to be a more complex process and stressed the significance of the same production hurdles that have been previously highlighted in the discussion of Obinna and Asundi et al.. The authors provide an example of a successful program by the USA called PEPEAR in 2003, which has helped the world combat HIV more furiously than any other program by integrating different stakeholders. They suggest that a similar program for vaccination could "integrate global health needs" with funding priorities, increase financing for vaccine production and delivery, as well as contribute to developing critical infrastructures and technologies for developing countries.

Similar to Katz et al, Iacobucci (2021) also suggests such programs to increase the global supply of the vaccine. But unlike Katz et al., he takes a stronger stand against simply waiving IP. The author's claim against patent waiver is that, instead of removing the production barriers, it might divert supplies to low-quality vaccine manufacturers. Iacobucci's suggestions to increase vaccine supply equity include technology transfers and know-how as well as easing the export of vaccine manufacturing equipment and raw materials to developing nations to boost their production capacity. Iacobucci (2021) also argues that increasing the production capacity of rich countries would do little benefit to the global supply system. The rich countries are already producing to their maximum, so it is better to facilitate the other countries to produce more of their vaccine. In short, in order to expand vaccine accessibility, the author focused on two key prerequisites: enhancing technological competency and optimizing export processes for vaccine manufacturing equipment and raw materials in underdeveloped nations.

In addition to the components discussed above, Woodle (2000) brings up another element that can affect the differences in vaccine accessibility across the globe – differences in the production capacity of countries. Contrary to the claims by Graaf et al. that the concept of "vaccine equity" is a recent one, Woodle had studied vaccine equity long before the Covid-19 pandemic. However, similarly to the recent literature reviewed above, the paper recognizes the need for self-sufficiency in developing countries when donor funds are exhausted. But diverging from the ideas of production barriers, donation, stockpiling, or IP rights, Woodley focuses on increasing procurement capability. Then he stretches the discussion to increasing the self-sufficiency of developing countries through capacity building. He mentions that theoretically, developing countries can procure from producers at high prices or indirectly purchase from UNICEF or PAHO at discounted prices. But purchasing from UNICEF or PAHO, Woodle points out would not only mean that the countries have no control over the type or quality supplied but also there is a risk of stock of vaccines getting exhausted. His paper, therefore, shows an inclination towards direct procurement, which he considers a long-term strategy for ensuring vaccine supply equity for countries that cannot produce for many barriers and have to depend on donations. At the same time, he acknowledges that direct procurement is complex. Monitoring quality, maintaining storage, ensuring funds – all of these requirements to be handled in this process. So, like Obinna and Graaf et al., Woodle call for international collaboration to advance vaccine supply equity, but his emphasis is on enhancing procurement capacities to aid developing nations in becoming self-sufficient in procurement.

Finally, Bayati et al., (2022) in their review study focus on the broader determinants of vaccine inequity rather than the more specific components discussed above. The paper consists of a systematic review of all the original papers published between December 2020 to 30 May 2022 in PubMed, Web of Science, Scopus, and ProQuest databases, that addressed the inequality in vaccine distribution and the underlying causes. They evaluated 4623 papers and selected 22 after screening titles, abstracts, and complete text, and eliminating the duplicates. The study has included studies that have assessed both supply and demand sides to find the factors for vaccine inequity. The result of the systematic review showed that aside from factors such as infrastructure system and health systems, the supply side is also influenced by the economic status and political power of a country, which gives a country control over the global vaccine supply.

In summary, most literatures have concurred on the idea that stakeholders globally need to come together to tackle the inequity issue and manage the key factors behind it. The key factors discussed by existing literatures on vaccine inequity are local production, technological and innovation level of a country, the existence of IP rights, infrastructure capacity, procurement capacity, stockpiling of vaccines, wealth, the global influence of the countries, and donation. My thesis will take their research one step further by checking for statistical support for the relationship between the factors and unequal vaccine accessibility.

2.1.Theoretical Framework

To form my hypotheses for this thesis, I also outline a theoretical framework through Dependency theory, World System theory, and some ideas from Neoclassical Growth theory.

The dependency theory and the world system theory analyze transnational relationships, globalization, and capitalist economy to answer why some countries have higher development levels than others. On the other hand, neoclassical growth theory evaluates the difference in the growth of different countries by looking at the disparity in their level of resources (labor, capital, technology). Through the lens of these theories, I attempt to explain how different factors can result in differences in the number of vaccines accessed by the countries.

Dependency theory

The dependency theory, first introduced by Raúl Prebisch and analyzed by many other prominent scholars such as Fernando Henrique Cardoso and Andre Gunder Frank, gained popularity in the 1960s and 1970s (Munro, 2018). The theory contends that countries in the "core" regions (Western Europe, North America, and Japan) develop by exploiting countries in the "periphery" (Africa, Asia, and Latin America) through expanding capitalism and causing underdevelopment in peripheral countries. Already due to their historical relationship, the peripheral countries lack higher technological advancements, oligopolistic markets, and rapid industrialization than the core countries possess. So, surplus such as primary commodities are transferred from peripheral countries at a cheap price, and this flourishes production industries and markets at the core. This "transfer of surplus" is conducted by "international trade instruments" such as "organization of production, subcontracting, dependent state structure," and the peripheral becomes economically dependent on the core. Hence, the dependency theory describes how a system of unequal relationships between the core and periphery results in the loss of self-sustainability in the periphery countries and increases dependency on the core for economic growth (Yilmaz, 2021)

Despite the widespread claims that dependency theory has lost its relevance, Tausch (2018) in his paper shows that economic penetration of foreign countries and globalization still follow the same pattern of making developed countries wealthier at the cost of underdeveloped countries as well as making underdeveloped countries dependent on developed countries.

Thus, dependency theory is still a suitable tool to analyze existing global inequalities such as the inequality in the case of the Covid-19 vaccine. Yilmaz (2021) in his paper draws a similar conclusion. He refers to the wealthy and influential countries or core countries as the “self-financing” countries. On the other hand, he terms lower-income countries as peripheral countries. The core countries are the countries that can “commit to procuring” as many doses as needed. They also have the ability to make investments in domestic vaccine production, which led most vaccine manufacturing to be in core countries. Therefore, they can enter into agreements and have the power to hoard the surplus of vaccines in their own countries. In contrast, peripheral countries lack the financial means to procure enough vaccines for mass vaccination. Moreover, the influence of core countries that leads them to hoard surplus, creates a greater barrier for them. This makes the peripheral countries dependent on vaccine aid from core countries and international organizations. Yilmaz states that, though dependency theory fails to explain distinctive situations, it provides a decent explanation of how differences in economic and political capacities between core and periphery lead to unequal access to the vaccine.

World System Theory

A modernized adaptation of dependency theory is the world system theory introduced by Immanuel Wallerstein in his book The Modern World System I: Capitalist Agriculture and the Origins of the European World-Economy in the Sixteenth Century. Under this theory, Wallerstein looks at the world system as a "world economy” which is embedded in the capitalist economy and follows the transnational division of labor (Wallerstein, 1976, pp 229-233). Many authors such as Chirot and Hall (1982), Chase-Dunn and Grimes (1995), Martínez-Vela (2001), and Alexanderson and Shen (2021) give a detailed analysis of Wallerstein's world system theory and elements related to it. In world system theory regions are interdependent for supplies such as food, fuel, and protection and follow the transnational division of labor for production. The division of labor creates the following classification: 1) high-skill labor and capital-intensive core countries, 2) low-skill labor-intensive peripheral countries and 3) semi-peripheral countries are a combination of both (Chirot and Hall, 1982; Martínez-Vela, 2001). This setting continuously strengthens the dominance of the core countries, where the high-skill capital is deeply concentrated. This leads the core to have greater ownership of leading industries (Alexanderson and Shen, 2021) Nevertheless, this theory puts high emphasis on technology and states that technological advancement by a country can change its position in the world economy. Therefore, a state can gain or lose its position in the core due to its technological level. Wallerstein brings up two political concepts to describe the relationship between core and periphery: Imperialism and Hegemony. Imperialism means the rule of core states on the periphery. Hegemony, on the other hand, is the term used to describe when one core state temporarily dominates the others. As long as it serves their interests, hegemonic nations maintain a balanced power structure and uphold free commerce (Martínez-Vela, 2001). To summarize, the World System Theory says that the division of labor causes an unequal division of the production process and concentrates power, wealth, and development in the core.

Alexanderson and Shen (2021) apply this theory to "the geography of vaccine production and acquisition, vaccine nationalism, intellectual property, and global health governance" to understand the global unequal vaccine distribution. The paper categorizes core and periphery countries as per the World Bank's definition of High Income and Lower Income countries simultaneously. They consider middle-income countries at the periphery as well. This is because the authors have considered that middle-income countries and lower-income countries would have similar access to vaccines. Next, they have equated the hoarding of vaccines to the accumulation of high-skill capital by the core, pharmaceutical companies to leading industries, and patented vaccines to core-produced commodities. The authors consider production a crucial factor in vaccine access. But the geographical mapping provided in the paper shows that most of the pharmaceutical companies developing and producing vaccines are concentrated in the core countries. This makes the production of vaccines a core process. The paper also explains the role of patents in the vaccine inequality situation using the world system theory. It argues that capital accumulation can only occur through the restriction of competition and a patent is a tool that inhibits the creation of cheaper vaccine alternatives by deprived countries. So, patents can be considered a restriction to competition that reduces vaccine supplies to the core only. Though the paper agrees that some industries need to be protected through patents, it claims that in health markets, particularly during a crisis, it causes underproduction by concentrating production to fewer regions. The paper uses all these factors to show that the failure of capitalist markets to develop affordable vaccines for everyone is created by the conflict between unlimited capital accumulation and the common social interest, aggravating the systemic crisis articulated by World System Theory.

Apart from the above theoretical explanations for inequality between the countries, I also connect the phenomenon of unequal vaccine access to some of the ideas we can find in Neo-classical growth theory. The theory states that the difference in the growth of the countries is determined by differences in their level of capital, labor, and technology. It says that countries with capital and labor level will converge to a higher steady-state for output. Technology is the exogenous factor that induces long-term economic growth (CFI, 2022). I did not find any paper that uses the Neo-Classical Growth Theory to explain vaccine supply inequality. However, I attempt to include the concept of this theory into my thesis by looking at vaccines as the output and claiming that the difference in the level of resources a country possess (technology, capital) can lead to the difference in the level of vaccines available to them. A country with a higher level of resources will have a greater level of vaccines. As seen in the empirical literatures by authors such as Katz et al., Woodles, and Lacobucchi, an argument comes up that a country's technology level or infrastructure level can moderate its access to vaccines by influencing its procurement or production process. Therefore, under neo-classical theory, then it can be assumed that differences in the technology level or infrastructure level of countries explain the differences in their vaccine accessibility.

Nevertheless, it is crucial to mention that under the dependence theory and world system theory, the difference in the level of technology or infrastructure of the countries can be considered the repercussion of the power dynamics between the core countries and peripheral countries. As a result, this thesis primarily applies dependency theory and world-system theory to explain the phenomenon of unequal access to vaccines across the globe.

2.2. Hypotheses

Based on the above theories and taking the key findings of the literature, I have formed the following hypothesis:

H1: Lower economic strength of a country is negatively related to the number of vaccines available to a country. Based on dependency theory and empirical literature, this thesis postulates that countries with greater wealth have the ability to procure and hoard more vaccines, and therefore this increases the accessibility of a country to vaccines. In contrast, a country with lower wealth lacks the ability to procure and stockpile vaccines and thus, decreases vaccine accessibility to the country.

H2: Global Influence of a country has a significant positive relationship with the number of vaccines available to the country. I define global influence as a form of power that lets countries be "considered and consulted" while global strategies, international activities, or foreign policies of other nations are developed (Stevenson 2019, 01). The definition is built on Stevenson (2019)'s model which brings in different kinds of global influence that a country can impose through politics, culture, economic strength, international relationships, provision of incentives, and so on. Based on World System Theory, this thesis assumes countries with more influence at a global level get higher access to vaccines.

H3: Donation has a significant positive relationship with the number of vaccines available to the country. As empirical literatures have mentioned COVAX has been attempting to disrupt the unequal allocation of vaccines between core and periphery through donating vaccines to the periphery, I hypothesize a positive relationship between donation and vaccine accessibility of a country.

H4: Domestic production has a significant positive relationship with the number of vaccines available to the country. Based on the context of dependency theory and world system theory, this thesis assumes that domestic production of vaccines leads countries to have more access to vaccines and depend less on other countries.

H5.1: Bilateral Agreements have a significant positive relationship with the number of vaccines available to the country. Bilateral agreements can facilitate trade by removing taxes and tariffs and are simpler to negotiate compared to multilateral agreements as only two countries get involved (Amadeo, 2022). Based on empirical literatures this thesis hypothesizes that countries with higher bilateral agreements have a higher number of vaccines available to countries.

H5.2. Early Bilateral Agreements have a significant positive relationship with the number of vaccines available to the country. It has been stated in the literature that wealthy nations entered into early bilateral agreements even before Covid vaccines were initially released on the market, in order to stockpile vaccines. Therefore, another hypothesis of the thesis is that countries with bilateral agreements even before vaccines were on the market have higher access to Covid vaccines.

H6: The infrastructure level of a country has a significant positive relationship with the number of vaccines available to the country. Higher infrastructure levels can facilitate vaccine production and import, and thus positively moderates vaccine access to that country.

H7: The technology and innovation level of a country has a significant positive relationship with the number of vaccines available to the country. This thesis assumes that countries with higher technological and innovation levels positively moderates vaccines access to a country by exogenously facilitating vaccine research, development, storage, distribution, and production.

H8: Patent ownership or licensing by the local company has a significant positive relationship with the number of vaccines accessible to the country. The world system theory establishes that patent ownership stimulated domestic production in the core countries. A patent gives access to vaccine manufacturing knowledge to specific companies that own them and prohibits others from using it. Based on that, this thesis hypothesizes that patent ownership or patent licensing by a domestic company is positively associated with vaccine access to that country by making it limited. This implies that if there were no patents, access to vaccines would not be restricted to certain nations and thus, improve vaccine equity.

In summary, I expect vaccine accessibility to be related to the economic strength of a country, the global influence of a country, bilateral agreements, donations, domestic production, infrastructure level, technology level, patents, and procurement capacity.

3. Methodology

3.1 Data Sources and Variable Description

The study uses a balanced cross-section of 106 countries of different income levels and population sizes from all over the world, a choice of which depended on the availability of data.

Description of the Dependent variable and related data

I extracted secured number of vaccines (in millions of doses) data for 106 countries from IMF-WHO Covid-19 Vaccine Supply Tracker (IMF, n.d.). The secured number of vaccines gives a comprehensive overview of how many vaccines have been secured by the countries at a particular time through all possible channels including donations, agreements with manufacturing countries and companies as well as domestic production. The data was collected in December 2021 and thus, it represented the number of vaccines secured till that day by each country. Since the countries in my sample widely vary in population, it is not possible to compare their vaccine accessibility by simply looking at the total number of vaccines they have secured. Therefore, in this thesis, I have divided the secured number of vaccines by population and used "secured number of vaccines per person" as the dependent variable to represent the number of vaccines that were accessible on average in a country by the end of 2021 during Covid-19.

Description of the Explanatory Variables and related data

To assess the relationship between a country's economic strength and its accessibility to vaccines, I have adopted the approach of Alexanderson and Shen (2021) and divided the countries into four categories following the classification of countries done by the World Bank based on income level. World Bank defines countries with GNI per Capita of $1085 or less as lower-income countries (LIC), those with GNI per Capita between $1086 to $4255 as lower-middle-income countries (LMIC), those with GNI per Capita between $4256 to $13205 as upper middle-income countries (UMIC) and countries with GNI per Capita above $13205 as high-income countries (HIC) (World Bank Country and Lending Groups, n.d.). Therefore, the four categories are created applying the World Bank classification namely, LIC, LMIC, UMIC, and HIC. I have used dummy variables to represent these categories, keeping HIC as the reference category and 1) LIC=1 if a country is Lower Income Country and 0 otherwise, 2) LMIC=1 if a country is Lower Middle-Income Country and 0 otherwise, 3) UMIC=1 if a country is Upper Middle-Income Country and 0 otherwise. The data on GNI Per Capita is collected from the World Bank in December 2021(World Bank, n.d.).

Next, to quantify a country's global influence, I have used the World Power Index (WPI) introduced by Daniel Morales Ruvalcavba in his book *Power, Structure, and Hegemony. Volume I: World Power Index* in 2016 WPI is an index created using 18 indexes collected from Data Bank-World Development Indicators[3]. The data is collected from the WPI website and will be used as a proxy for the explanatory variable "global influence." The data is dated back to 2017(Morales Ruvalcaba, 2022). Nevertheless, we use the data under the assumption that the power of the countries has not changed significantly in the last 4 years.

Now, another explanatory variable is "donation per person", which measures the number of vaccines donated by COVAX alliances to a country per person. The data on the number of

[3] **The indicators included in the index:** "National production: gross national income, Atlas method (current US$); total area: territorial area (square kilometers); defense: military expenditure (% of gross domestic product); international commerce: trade (% of gross domestic product); finances: total reserves (including gold, current US$); research & development: research and development expenditure (% of gross domestic product)"; "production per capita: Gross national income per capita; Atlas method (current US$), population: Population, total; consumption: Household final consumption expenditure per capita (US$); energy: Electric power consumption (kilowatt hour per capita); education: Spending on education, total (% of gross domestic product); health: Health expenditure, total (% of gross domestic product)"; "government expenditure: General government final consumption expenditure (current US$); tourism appeal: International tourism; revenues (current US$), international aid: Net official development assistance (ODA) received per capita (current US$); media: Telephone lines; academic influence: Scientific and technical journal articles; cosmopolitism: International migrant stock, total" (Morales Ruvalcaba, 2022).

donations made by COVAX till December 2021 to a country is collected from Covid-19 Market Dashboard by UNICEF (UNICEF, n.d). The total amount of donations is divided by each country's population to determine donations per person so that their access to vaccines can be compared.

Another explanatory variable is "bilateral agreements" which is the number of bilateral agreements for Covid vaccines a country has formed with the companies till December 2021. The data is collected from IMF-WHO Covid Vaccine Supply Tracker (IMF, n.d.). Adding to that, another explanatory variable "early bilateral agreement" is a dummy variable, where early bilateral agreement=1 if a country has had any bilateral agreement with a Covid vaccine company in the year 2020 and 0 otherwise. I have treated the bilateral agreements conducted in 2020 as early bilateral agreements since the first vaccine only began to roll out in December 2020 (The COVID-19 vaccine race, 2022).

Furthermore, the dummy explanatory variable "producing country" is created where producing country=1 if the country produces vaccine and producing country=0 otherwise. The variable will check whether domestic production is related to the number of vaccines accessible on average in a country. This thesis follows the definition of producing countries according to the IMF-WTO Covid Vaccine Trade tracker, which states that a producing country is a country that produces the final vaccines (WTO, n.d.). Data on vaccine-producing countries has been collected from UNICEF Covid -19 Market Dashboard, IMF-WTO Covid Vaccine Trade Tracker as well as Global Commission for Post-Pandemic Policy by December 2021 (UNICEF, n.d; WTO, n.d.; GCPPP, 2021).

Then, to measure the explanatory variable "technology and innovation level" of a country, I used an indicator named Global Innovation Index produced by World Intellectual

Property Organization (WIPO). The indicator is built on 81 indicators to provide an idea of a country's technological and innovative capacity and ecosystem (Global Innovative Index, 2021). Data on the indicator is collected from WIPO's Global Innovative Index 2021 report. For measuring the explanatory "infrastructure level" of a country, the infrastructure score is collected from the Global Competitiveness Report 2019 of the World Economic Forum. The infrastructure score reported by the Global competitiveness report amalgamates 12 different indicators measuring quality, connectivity, efficiency, and accessibility of water supply, electricity, transportation, and roads of the countries. We assume that there has not been a massive shift in the infrastructure level of the countries from 2019 to 2021 (Schwab, 2019). Moreover, data for the binary explanatory variable "patent ownership or licensing by a domestic company" (in which patent=1 when a country is home to companies that own or have licensed patent to Vaccine by December 2021 and patent=0 otherwise) has been collected from WIPO's patent landscape report and Medical Patent Pool's Patent database named VAXPAL (WIPO, n.d., MPP, n.d.)

Finally, I have created a control dummy variable "EU" such that EU=1 if the country is a part of the European Union and "EU" =0 otherwise. The rationale for this control variable is that even when EU members lack resources of their own, they nevertheless benefit from those of one another. In addition, EU members enjoy a single market for a variety of goods and services, which is restricted to non-EU members (J Gabel, n.d.).

3.2. Model

I use the Multivariable Linear Regression (MLR) model to investigate the factors related to vaccine accessibility and test my hypothesis. This is because MLR can predict the outcome of a dependent variable by using more than one explanatory variable. The following is a general MLR model for my thesis:

$Y = \alpha_1 + \Upsilon_1 D_1 + \beta_1 X_1 \ldots. \beta_n X_n + \Upsilon_K D_K + \mu$

where Y denotes the dependent variable, X denotes the explanatory variable, D indicates the dummy explanatory variables, μ represents the error term, β and Υ are the parameters and α denotes the constant or the intercept, that is, it is the mean response value when D and X are 0.

Using this general model, I repetitively add a single explanatory variable at one time into the regression model and evaluate the change in adjusted R-square. So, by adding one explanatory variable each time, I can evaluate the adjusted R-square for examining if the variable is improving the model. It can be claimed that the model has strengthened in its ability to explain variations in the dependent variable if the adjusted R-square increases and that it has weakened if it drops.

Therefore, the following are the models to conduct regression:

1. $SV = \alpha + \Upsilon_1 UMIC + \Upsilon_2 LMIC + \Upsilon_3 LIC + \beta_1 EU + \mu$
2. $SV = \alpha + \Upsilon_1 UMIC + \Upsilon_2 LMIC + \Upsilon_3 LIC + \beta_1 EU + \beta_2 GI + \mu$
3. $SV = \alpha + \Upsilon_1 UMIC + \Upsilon_2 LMIC + \Upsilon_3 LIC + \beta_1 EU + \beta_2 GI + \beta_3 Donate + \mu$
4. $SV = \alpha + \Upsilon_1 UMIC + \Upsilon_2 LMIC + \Upsilon_3 LIC + \beta_1 EU + \beta_2 GI + \beta_3 Donate + \Upsilon_4 PC + \mu$
5. $SV = \alpha + \Upsilon_1 UMIC + \Upsilon_2 LMIC + \Upsilon_3 LIC + \beta_1 EU + \beta_2 GI + \beta_3 Donate + \Upsilon_4 PC + \Upsilon_5 BL + \mu$
6. $SV = \alpha + \Upsilon_1 UMIC + \Upsilon_2 LMIC + \Upsilon_3 LIC + \beta_1 EU + \beta_2 GI + \beta_3 Donate + \Upsilon_4 PC + \beta_4 BL + \mu$
7. $SV = \alpha + \Upsilon_1 UMIC + \Upsilon_2 LMIC + \Upsilon_3 LIC + \beta_1 EU + \beta_2 GI + \beta_3 Donate + \Upsilon_4 PC + \beta_4 BL + \Upsilon_5 E.BL + \beta_5 Infra + \mu$
8. $SV = \alpha + \Upsilon_1 UMIC + \Upsilon_2 LMIC + \Upsilon_3 LIC + \beta_1 EU + \beta_2 GI + \beta_3 Donate + \Upsilon_4 PC + \beta_4 BL + \Upsilon_5 E.BL + \beta_5 Infra + \beta_6 Tech + \mu$

9. $SV= \alpha+ \Upsilon_1 UMIC+ \Upsilon_2 LMIC+ \Upsilon_3 LIC+ \beta_1 EU+ \beta_2 GI+ \beta_3 Donate + \Upsilon_4 PC + \beta_3 BL$
$+\Upsilon_5 EBL+ \beta_4 Infra+\beta_5 Tech+ \Upsilon_6 Patent+ \mu$

The variable short forms denote:

Dependent variable, Y: SV = Secured number of vaccines per person

Explanatory Variable:

- X: GI= Global influence, Donate= Donation per person, Infra= Infrastructure level, Tech= Technology and innovation level, BL= Number of Bilateral Agreement, EU= European Union
- D: UMIC= Upper middle-income country, LMIC= Lower middle-income country LIC=Lower income country, EBL= Early Bilateral Agreement PC= Producing country, Patent= Patent ownership or licensing by domestic company.

Section 3.1 already describes the variables in detail.

It should be noted that there is a possibility that there are additional factors related to access to vaccines in a country. However, they could not be included in the regression analysis due to the limited amount of available data.

3.3. Heteroskedasticity Test and Multicollinearity test

Heteroskedasticity test

To check if the variance of the disturbance is constant, I conducted a heteroskedasticity test on my final model using the Breusch-Pagan method which is constructed to identify heteroskedasticity in the linear regression model. If the p-value of the chi-square is less than 0.05, the null hypothesis of this test is rejected and heteroskedasticity is found in the data (Zach, 2020). The hypothesis tested by the method are:

Null Hypothesis (H_0): Homoscedasticity is present (Residuals are uniformly scattered with equal variance)

Alternative Hypothesis (H_1): Heteroskedasticity is present (Residuals are not uniformly scattered with equal variance).

Multicollinearity test

I also conducted a multicollinearity test to assess if my explanatory variables are correlated. I have used the variance inflation factor or vif to conduct the multicollinearity test. The range of vif can be from 0 to infinity. The general rules follow that:

- if vif=1, then there is no correlation between a given independent variable and the rest of the independent variables in a model.
- if 1<vif<5, then there is a moderate correlation between the independent variable and the rest, but the issue is not required to be corrected
- if vif>5, then there is a higher correlation between the variable and the rest. (Variance Inflation Factor, 2022).

Then, I also created a correlation matrix to specifically identify the magnitude of the correlation between the explanatory variables.

4. Results and Analysis

Table 1 below reports the results of all the regression models and compare their adjusted R squares:

Table 1:Results for Regression model 1-9 with robust error

Dependent Variable: Secured number of vaccines per person (SV)									
Explanatory Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
UMIC	-1.89***	-1.44***	-1.54***	-1.52***	-1.45***	-1.40***	-1.39***	-1.08***	-1.02***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
LMIC	-2.60***	-1.95***	-2.06***	2.12***	-1.88***	-1.88***	-1.85***	-1.48***	1.43***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.004)	(0.001)
LIC	-3.01***	-2.19***	-2.30***	-2.28***	-1.77***	-1.70***	-1.65***	1.40**	1.33**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.007)	(0.016)	(0.023)
GI		2.76***	3.54***	2.97***	2.11**	1.66	1.56	-0.05	0.19
		(0.007)	(0.001)	(0.008)	(0.043)	(0.143)	(0.226)	(0.968)	(0.883)
Donate			1.53**	1.53**	1.73***	1.69***	1.70***	1.73***	1.72***
			(0.03)	(0.029)	(0.008)	(0.01)	(0.01)	(0.006)	(0.006)
PC				0.41	0.34	0.38	0.38	0.39*	0.40*
				(0.108)	(0.144)	(0.113)	(0.113)	(0.08)	(0.07)
BL					0.15***	0.14***	0.145***	0.12***	0.13***
					(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
EBL						0.32	0.329	0.39	0.36
						(0.333)	(0.335)	(0.223)	(0.255)
Infra							0.002	-0.01	-0.015
							(0.871)	(0.278)	(0.308)
Tech								0.06***	0.06***
								(0.001)	(0.000)
Patent									-0.29
									(0.317)
EU	2.15***	2.17***	2.25***	2.24***	1.48***	1.44***	1.42***	1.23***	1.30***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000	(0.000)	(0.000)	(0.001)	(0.001)
Const	4.34***	3.33***	6.27***	1.98**	1.61**	1.73**	1.61	1.43	1.165
	(0.000)	(0.000)	(0.000)	(0.012)	(0.026)	(0.019)	(0.124)	(0.147)	(0.255)
# of Obs	106	106	106	106	106	106	106	106	106
F-test	63.42	55.55	48.87	42.96	46.72	41.61	37.07	39.06	35.9
Prob>F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R^2	0.715	0.73	0.74	0.75	0.793	0.795	0.796	0.82	0.822
Adj R^2	0.70	0.722	0.732	0.736	0.776	0.776	0.774	0.799	0.799

Note: *, **, *** represents significance at 10%, 5% and 1% respectively

To determine which model fits our data the best, the R^2 and the adjusted R^2 for each model can be evaluated from Table 1. The R^2 indicates how well the model explains the fitted data in the regression model and the adjusted R^2 tells us whether an added variable has improved the model. Table 1 shows that the R^2 values for models 1 through 9 are 0.71, 0.73, 0.74, 0.75, 0.793, 0.795, 0.796, 0.82, and 0.822, respectively. The R^2 is the highest for models 8 and 9, and both the R^2 indicate that the models explain 82% of the variation observed in the outcome variable, “secured number of vaccines per person”.

As for the adjusted R^2, for model 1 the value is 0.70. For model 2, it increases to 0.72 showing that the added variable “global influence” has improved the model by more than expected. Moreover, the adjusted R^2 for model 3 increases to 0.732, and for model 4, it further increases to 0.736. Therefore, the addition of variables “donation per person” and “producing country” to models 3 and 4 respectively improved the model by more than expected. But for model 5, the adjusted R^2 significantly exceeds the last one. The value for this model is 0.776, which indicates that the added variable “number of bilateral agreements” has improved the model considerably more than expected. On the other hand, for models 6 and 7, adjusted R^2 showed negligible variation from the prior model. For model 6 its value is 0.776, which is the same as model 5. The lack of change in the adjusted R^2 implies that the added variable “early bilateral agreements” did not improve the model from the prior model. As for model 7, the Table shows that the adjusted R^2 is 0.7745, which is a slight decrease from that of models 5 and 6. It demonstrates that the added variable “infrastructural level” has improved the model by very negligibly less than expected. Since the change is negligible, this thesis disregards the decrease. Nevertheless, for model 8, the adjusted R^2 greatly increases from the last one to 0.7995, showing that the added variable “technology and innovation level” has improved the model by substantially more than expected. Finally, the adj R^2 for model 9 is 0.7995, which did not change from the last one. This means that the added variable "patent" has not brought any substantial change to the model.

From the above Table, it is seen that models 8 and 9 have the best adjusted R^2 and R^2. Since the R^2 of model 9 is slightly better, I selected model 9 for my analysis.

However, I detected evidence of heteroskedasticity in my data. Table 2 below provides the Breusch-Pagan test results for the heteroskedasticity test:

Table 2: Results for Regression model 1-9 with robust error

Breusch-Pagan statistics for Heteroskedasticity	
CHI2 (1) test statistics	10.88
P-value	0.0010***

Note: *, **, *** represents significance at 10%, 5% and 1% respectively

Table 2 test result indicates that the p-value for the Chi-square is 0.0010, which is less than 0.05. Therefore, I reject the null hypothesis discussed in section 3.3 of chapter 3, which means that there is heteroskedasticity in the data. Therefore, I use White's heteroskedasticity corrected standard errors or robust errors to fix the issue of heteroskedasticity with my cross-sectional data. This will still deliver the same OLS estimates but correct the standard errors as per White's method (Hatzinikolaou, 2015).

Table 3 below reports the regression result for model 9 with robust error, corrected for heteroskedasticity:

Table 3: Results for Regression model 9 with robust error

Dependent Variable: Secured number of vaccines per person (SV)	
Explanatory Variables	Model 9
UMIC	-1.02** (0.039)
LMIC	1.43*** (0.007)
LIC	1.33** (0.038)
GI	0.19 (0.895)
Donate	1.72*** (0.000)
PC	0.40** (0.05)
BL	0.13*** (0.002)
EBL	0.36 (0.210)
Infra	-0.015 (0.253)
Tech	0.06*** (0.003)
Patent	-0.29 (0.417)
EU	1.30*** (0.044)
Const	1.165 (0.255)
# of Obs	106
F-test	62.72
Prob>F	0.000
R^2	82.2

Note: *, **, *** represents significance at 10%, 5% and 1% respectively

The results presented in Table 3 show that the estimated coefficient of the dummy explanatory variables "UMIC" (0.039), "LMIC" (0.007), and "LIC" (0.038) are statistically significant at a 5% significance level. The expected negative sign of the coefficient of the dummy variable for "UMIC", "LMIC" and "LIC" shows that upper-middle countries, lower-middle-income countries, and lower-income countries have secured a significantly lower number of vaccines per person for their countries than upper-income countries. These findings support

Hypothesis 1 in chapter 2 and show that economic strength is a factor that can explain the unequal access to vaccines in the countries. The result is in major consensus with the empirical and theoretical literature. Explanations for this association have also been suggested in the earlier-mentioned literature. Countries with greater economic power or core countries have the capability to procure as many vaccines as they want and invest in vaccine development. But lower economic power deprives peripheral countries of the ability to procure enough vaccines. Peripheral countries do not have such financial ability for procurement. The higher capability to procure vaccines can lead core countries to hoard them as well, making the necessary protection from the Covid-19 scare for peripheral countries (Bayati et al., 2022; Obinna, 2022; Asundi et al., 2021; Yilmaz 2021; Alexanderson and Shen, 2021). The above-mentioned argument may be used to support my finding in this thesis, which is, nations with weaker economic power secure a lower number of vaccines controlling for population.

Supporting my hypothesis 4 and the vast theoretical indication the regression results in Table 3 depict vaccine “producing countries” (0.058) secure a significantly greater number of vaccines per person. The estimated coefficient is positively significant at the 5% significance level. This positive significant relationship could be explained by the assertion that domestic production is a long-term approach that makes a country less dependent on external aid and gives the country access to greater home-grown vaccines (Graaf et al., 2022, Asundi et al., 2021, Obinna, 2022, Katz et al., 2021. Iacobucci 2021). But Alexanderson and Shen (2021) have found that geographically, all domestic productions of vaccines are placed in the core countries. Thus, domestic production of vaccines can be a factor explaining the unequal accessibility of vaccines to the countries and contributing to the unequal access.

Table 3 also reveals a statistically significant positive relationship between "secured number of vaccines per person" and "donation per person" (0.000), "technology and innovation level" (0.003), and "number of bilateral agreements" (0.004). The estimated coefficients for these variables are significant at a 1% significance level, representing a robust relationship. The positive sign of these three factors reveals that the higher the degree of donation per person, domestic technological advancement and innovation, or bilateral collaborations with companies, the higher the number of vaccines obtained by a country per person. Based on the significant positive coefficient of donation per capita, this thesis rejects the claim made by Asundi et al. (2021) that contributions from core countries are insufficient to resolve global vaccine supply disparities. The result, however, is consistent with Ye et al (2021) who claim that, regardless of the amount donated, contribution significantly increases access to immunizations in developing countries. However, the result only acknowledges the positive relationship between donation and vaccine access to a country but does not answer the concern regarding the proper allocation of donations raised by Graaf et al (2022). Even Ye et al. (2022) mention that donating to neighboring countries instead of countries in need will not reduce vaccine inequity. Therefore, further study is required to check whether there is an equitable allocation of the donation of vaccines. Again, the positive association between technology and innovation level and vaccine accessibility to a country is supported by multiple literatures (Asundi et al., 2021; Obinna, 2022; Katz et al., 2021; Iacobucci, 2021). The justification provided by the literature is that differences in technology levels influence the variations in vaccine research, development, storage, and production done by countries, which in turn explains the inequity in their access. Moreover, the dependency theory and world system theory predict that high-skilled capital-intensive core nations to have more access to resources, in this case, vaccines. Capital-intensive countries also have higher technological and innovation levels than labor-intensive countries because they depend on plants and equipment for production. Therefore, my observation that there is a positive relationship between the level of technology and innovation and vaccine accessibility is consistent with the dependency theory and the global system theory. Similarly, the significant positive association between bilateral agreements and vaccine access is supported by Asundi et al (2021) since bilateral agreements reduce the trade barriers for the countries. Therefore, the findings for "donation per person", "bilateral agreements", and "technology and innovation level" are consistent with hypotheses 3, 5.1, and 7, and can be viewed as factors that contribute to the unequal access to vaccines across the globe.

On the other hand, there is not enough evidence for the effect of "global influence" (0.895), "early bilateral agreement" (0.210), "infrastructural level" (0.253), and "patent ownership or licensing by a domestic company" (0.417) on "secured number of vaccines per person". The estimated coefficients for the variables are not significant at 10%,5%, or 1% significance levels. Therefore, I reject hypotheses 2, 5.2, 6, and 8 from chapter 2. The lack of statistical evidence for the relationship with patent ownership can be explained by the arguments put forth by Obinna (2022), Katz et al. (2021), and Iacobucci (2021). The authors argue that having access to patents can provide little help in removing production barriers and consequently, in increasing vaccine accessibility to a country. They believe it is the technological support and capacity building that is more required to increase vaccine accessibility. Therefore, I conclude based on my findings and the literature that, if a country's access to patents is not significantly related to its access to vaccines, patent waiver should also not have a relationship with vaccine accessibility and the global vaccine equity situation. On the other hand, there is little theoretical explanation behind the lack of statistical evidence for the relationship between "global influence," "early bilateral agreement", "infrastructural level", and the "secured number of vaccines per person". However, one of the possible explanations behind the insignificant result could be the issue of multicollinearity. As seen in Table 3, the R^2 of the model is quite high, but multiple variables are statistically insignificant. This is a typical sign of multicollinearity (Gujarati, 2004). Table 4 presents the VIF for each explanatory variable:

Table 4:VIF for each explanatory variable

Variables	vif	1/vif
Tech	5.32	0.187
Infra	5.16	0.193
GI	4.45	0.224
LIC	3.42	0.292
LMIC	3.29	0.304
UMIC	2.94	0.340
BL	2.93	0.340
EU	2.65	0.374
EBL	2.65	0.377
Patent	2.08	0.48
Donate	1.56	0.63
PC	1.31	0.762

Table 4 shows that the VIF for the explanatory variables, technology and innovation level, and infrastructural level are greater than 5. So, a multicollinearity issue can be identified for these variables. In Appendix 1, Table 5, I have presented the correlation matrix that shows how the explanatory variables are correlated with each other. It demonstrates that these two variables have a high correlation with global influence, early bilateral agreements, and even with each other.

As a result, the insignificant statistical relationship found for "global influence," "early bilateral agreement," "infrastructural level" and "patent ownership or licensing" can be attributed to the issue of multicollinearity issue. Under these circumstances, this thesis is unable to make strong statistical inferences for these variables.

But it is important that I explain why more action has not been made to address the multicollinearity problem. First, in order to measure some of the key hypotheses put forward in this study, variables with multicollinearity problems have been introduced. Therefore, it would not be logical for this thesis to remove the variables. Secondly, as adj R^2 for model 8 in Table 1 indicates, the addition of the variable "technology and innovation level" substantially improves the model. Hence, it is crucial to put it into the model. Lastly, I have conducted auxiliary regressions[4] for my chosen model 9, and applying Klein's rule of thumb[5], it is seen that R^2 values for the auxiliary regressions do not surpass the overall R^2 value of 82.2 for the regression model presented in Table 3. Table 6 in the Appendix provides the R^2 values for the auxiliary regressions. Therefore, the multicollinearity issue can be expected to be less problematic. For these reasons, I have not taken further steps to address the multicollinearity issue.

Finally, the coefficient of the control variable "EU" is worth noting. The relationship between the variable "EU" (0.044) and "secured number of vaccines per person" is positive and significant. This indicates that countries that are members of the European Union have a higher secured number of vaccines per person. This finding can be a subject of future study to investigate how supranational economic and political alliances contribute to the vaccine accessibility of the countries.

[4] Auxiliary regression refers to the regression of each explanatory variable on the rest of the explanatory variables (Gujarati, 2004).
[5] Klein's rule of thumb states that if the R^2 of the auxiliary regressions surpasses the overall R^2, then the multicollinearity issue is severe (Gujarati, 2004).

5. Policy Recommendations

The findings in this thesis underscore the need for stronger global cooperation and participation of all the stakeholders to address the issue of vaccine access discrepancy in the event of the Covid-19 pandemic and any future recurring global health emergencies. In chapter 2, section 2.1, the theoretical framework outlines the reasons behind the development and capacity differences across the globe. These differences divide the countries into core and periphery and put the peripheral countries at a long-term disadvantage. This has led to the aforementioned factors enabling discrepancies in access to vaccines across the globe. For example, the differences in technology and innovation levels and the domestic production capacity of countries, two significant factors identified by my analysis, can be attributed to their core and peripheral positions. Again, donation, another factor related to the accessibility of vaccines, has become crucial because of the lack of regional capacity of some countries to procure and produce vaccines on their own. Similarly, other factors, such as bilateral agreements, can be connected to the development and capacity difference between the core and periphery countries. Therefore, it is very important that the core countries alongside the international organizations come in support of the periphery and there is a concurrent effort at a global level to make vaccines equally accessible in all countries.

To accomplish that, countries would require to discard the ideology of vaccination nationalism that leads them to stockpile during emergencies and rather focus on need-based procurement of vaccines. In this regard, it needs to be mentioned that in chapter 2, hypothesis 5.2 this thesis assumed based on Asundi et al. (2021) that stockpiling of vaccines is fostered by early bilateral agreement. However, since the variable early bilateral agreement does not have a significant relationship with vaccine access, this thesis does not have concrete evidence for the stockpiling of vaccines. I do not discard the possibility that there has been a stockpiling of vaccines by the core countries. Instead of this practice, I would rather recommend that nation consider that vaccine inequity affects everyone and adopt a need-based procurement approach.

In order to carry out such a need-based vaccine procurement, international agencies like the UN and WTO should evaluate the country's demographics to categorize its population into groups ranging from high risk to low risk, and then determine how many vaccines would be required to immunize each category of population in each country. In addition, rich countries themselves should conduct similar analyses to plan their need-based procurement process more minutely. UN, IMF, WTO, and WHO have launched dashboards to keep track of such information as well as many other data related to vaccine supply and vaccination coverage. However, in case of a future crisis, this analysis could be done during the development period of vaccines (or any other preventive measure) to achieve greater vaccine equity earlier. This would help countries make their need-based procurement plans earlier. In order to encourage wealthy nations to purchase vaccines in batches for one category at a time, rather than the entire population, international organizations need to engage in dialogue with these nations.

Another approach, which could be combined with the one outlined above, is a need-based donation of vaccines. According to my findings, donation increases the number of vaccines accessible to a country. This is in line with Ye et al (2022), who mentions it as a very practical approach to increasing access to vaccines in countries with low production and procurement ability. However, there have been concerns regarding how the donation is distributed (Asundi et al, 2021; Ye et al, 2022). According to Ye et al., giving vaccinations to neighboring countries won't help diminish vaccine inequality; instead, these supplies should go to the nations that most urgently require them. So, organizations such as WHO and UNICEF could conduct a similar analysis as discussed above to map out the donations need by different regions. To understand the needs of the countries, they would need to compare the total and high-risk unimmunized populations of the countries. It is important to keep track of whether these population numbers are changing as donations to various locations expand. They must also regularly assess whether donations are given to the nations that need them the most as per their analysis and track the percentage of vaccination coverage that is supported by donations in each country.

The reports should be shared with the public to maintain transparency. Though many dashboards such as the IMF-WHO Vaccine supply Tracker and UNICEF Vaccine Market Dashboard provide some information on donation, none of the existing dashboards cover the above information regarding the current vaccine donation process in detail. Nevertheless, maintaining transparency with the public will encourage the stakeholders to contribute to and distribute donations more efficiently.

Furthermore, international organizations and rich countries should come forward to increase the domestic production capacity of the countries in the periphery. Both my findings and previous literatures have agreed on the importance of domestic production in increasing vaccine access to a country. However, this thesis has been unable to detect any production barriers faced by the countries, other than the technology level. Further research is required to understand the vaccine production bottlenecks for peripheral countries and to identify what global steps need to be taken accordingly.

However, the findings of this thesis showed that lower technology and innovation level can significantly lower the number of vaccines a country has access to. Vaccines need the support of advanced technology in every aspect, from development, production, and storage to distribution (Manufacturing, safety, and quality control of vaccines, 2020). Many poor countries cannot afford such advanced technological support. Therefore, technology pooling is the most suitable way of increasing their regional capacity to produce, procure and store vaccines. For Covid-19, one such initiative taken by WHO, the Costa Rica government, and other partners was the Covid-19 technology access pool or C-TAP. The idea behind the platform was for developers, therapeutics, and others to share intellectual property, technical know-how, and data, as well as provide support for technology transfer agreements so that potential manufacturers in the periphery get access to them (Covid-19 technology access pool, 2020). However, the refusal of pharmaceutical companies to engage in such a platform has made it difficult for C-TAP to succeed in its motive (H.A.I, 2021). This brings me back to my initial point that the participation of all the stakeholders is the biggest prerequisite to achieving vaccine equity.

An additional way to further increase global cooperation is to increase the number of bilateral trade agreements between companies and peripheral countries, which is also supported by the results of this thesis. WTO could create separate committees that oversee this issue and help peripherals negotiate a higher number of trade agreements under better and cost-effective conditions. Moreover, my results suggest that there should be economic-political supranational organizations that increase the negotiation power for the peripheral countries, similarly to the way the EU does it now for many European countries. Being a member of such an organization may lead to higher access to vaccines. However, the countries in the periphery are not highly integrated and they are heavily dependent on the core countries economically. For these reasons, even the existence of such supranational organizations might not help the peripheral countries have access to a higher number of vaccines. An example of such a failure of a supranational organization is the African Union, which was created to increase Africa's economic and political strength but failed due to coordination issues, financial vulnerability, and a lack of political will (Pinto, 2021). Therefore, this again emphasizes the importance of willingness to cooperate.

Overall, the above-mentioned recommendations will only be successful if there is a willingness to cooperate on the global level. The effectiveness of international cooperation in resolving global crises has been demonstrated in the past through the successful implementation of treaties like the Montreal Protocol, which was an international agreement to gradually stop using and producing ozone-depleting elements and protect the ozone layer (Office of Environmental Quality, n.d.). Similarly, all stakeholders must work together to address the problem of unequal access to vaccines.

6. Conclusion

I set out to study the factors that could explain the unequal access to Covid-19 vaccines across the countries. The motive behind this study was to identify the possible causes of vaccine inequity that would help governments and international organizations take collaborative approaches to increase vaccine supplies to countries with vaccine shortages and create policies that would address such inequities earlier in case of future global crises. The results suggest that donation, technological and innovation level of a country, bilateral agreements, and domestic producing capacity are the factors associated with the number of vaccines accessible to a country. Moreover, my results indicate that economic strength is also a factor associated with the unequal accessibility of vaccines, which once again, reestablishes the historical pattern of inequality. The historical pattern of economic inequality between the countries divides them into core and periphery and puts peripheral countries at a long-term disadvantage in terms of development and production capacity. This disadvantage leads to the above-mentioned factors creating discrepancies in access to vaccines.

Therefore, the results underscore the need for more global cooperation and engagement from all stakeholders in order to address the problem. The countries should focus on creating need-based distribution approaches taking the factors associated with vaccine equity into account, rather than using their economic strength to hoard more for one's own countries. Countries need to take note of the fact that higher vaccine equity during global crises is beneficial to all.

Limitations and Implications for Further Studies

It should be pointed out that, this study is not without limitations and many aspects require further consideration. Firstly, there is an issue of multicollinearity with the data used for this thesis, which made some of the statistical inferences unreliable. Secondly, the model in this thesis is unable to include the price of the vaccines as a variable even though been mentioned by multiple literatures (Asundi et al., 2021; Obinna, 2022; Woodle 2000). Both Obinna and Katz et al., argued that vaccine-producing companies with IP rights create production barriers for other countries, which gives them the monopolistic ability to charge excessive prices. They, along with Asundi et al. and Woodle make the case that the excessive price of vaccines has made them less affordable and hence, less available to the lower income countries. Therefore, statistically examining the relationship between vaccine price and vaccine accessibility to a country would be vital. However, the price of vaccines varies from brand to brand, as seen by the Covid-19 Market Dashboard (UNICEF, n.d.) and the Global Dashboard for Vaccine Equity (UNDP, n.d.). Additionally, there are pricing variations across the locations. Thus, it was difficult to incorporate the price factor as an explanatory variable into my MLR model. Thirdly, due to a lack of data, this thesis had to omit the variable procurement capacity even though this might be a possible factor (Woodle, 2000). Fourthly, this thesis also acknowledges that, despite a rigorous review of theories and literature, some of the factors might have been overlooked. Finally, the thesis assumes that, despite the data on infrastructure score being from 2019, and the world power index being dated back to 2017, the data does not change significantly over the years. With this assumption, any difference that might have been brought by the time component is disregarded, which could contaminate the result.

Therefore, further studies can explore more factors, investigate more robust and up-to-date data as well as experiment with other econometric models. Moreover, in order to comprehend vaccine inequity better, it is also possible to look at each of the factors mentioned in this thesis separately, investigating variables that affect the production of vaccines, efficient ways of distributing donations, vaccine pricing strategies, and the influence of supranational alliances on vaccine inequity.

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Appendix

Table 5: Correlation Matrix for Explanatory Variables

	UMIC	LMIC	LIC	GI	Donate	PC		BL	EBL	Infra	Tech	Patent	EU
UMIC	1.00												
LMIC	-0.35	1.00											
LIC	-0.23	-0.19	1.00										
GI	0.11	-0.33	-0.35	1.00									
Donate	0.16	0.22	0.21	-0.55	1.00								
PC	-0.14	-0.01	-0.21	0.43	-0.24	1.00							
BL	-0.12	-0.27	-0.37	0.57	-0.44	0.29		1.00					
EBL	-0.21	-0.19	-0.36	0.66ƍ	-0.41	0.24		0.68ƍ	1.00				
Infra	-0.068	-0.32	-0.54	0.77ƍ	-0.52	0.31		0.62ƍ	0.63ƍ	1.00			
Tech	-0.18	-0.38	-0.37	-0.53	0.33	0.33		0.67ƍ	0.64ƍ	0.83ƍ	1.00		
Patent	-0.07	-0.25	-0.28	0.60ƍ	-0.40	0.31		0.59	0.48	0.60ƍ	0.65ƍ	1.00	
EU	-0.32	-0.25	-0.20	0.41	-0.39	0.21		0.67ƍ	0.55	0.56	0.62ƍ	0.52	1.00

Note: ƍ represents highly correlated variables

Table 6: R^2 Values for Auxiliary Regressions

Dependent Variable	R^2 Value
UMIC	0.65
LMIC	0.69
LIC	0.70
GI	0.77
Donate	0.36
PC	0.23
BL	0.65
EBL	0.62
Infra	0.80
Tech	0.81
Patent	0.51
EU	0.62