Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13006
e-ISSN : 2541-2019
p-ISSN : 2541-044X

Analysis of Factors that Affects COVID-19 Vaccination on Countries Worldwide with the Spearman Rank Correlation Method

Ferawaty[1)], Melvin Lee[2)], Elisabeth Marlina Sari Lintong[3)], Daniel Cassa Augustinus[4)]
[1,2,3,4)]Universitas Pelita Harapan
[1)]Ferawaty.fik@uph.edu, [2)]Ml80024@student.uph.edu, [3)]elisabeth.simanjuntak@uph.edu, [4)]daniel.augustinus@uph.edu

Submitted : Sep 13, 2023 | **Accepted** : Nov 13, 2023 | **Published** : Jan 1, 2024

Abstract: Despite the urgency of vaccination against COVID-19 worldwide, each country has different levels of vaccination rate which lead to different success rates. While several past studies have shown what factors affect a country's vaccination rating from past epidemics, there are no correlation studies done on factors to COVID vaccination rates, with several media and institutes forming theories, with New York Times stating it's GDP per Capita, and National Health Institute postulating literacy and other various factors, while none those two showing correlation studies of the factors as the proof. With values ranging from -1 to 1, results showed among six factors ranging from 0.51 to 0.64 for four factors showing that of six factors listed in this study, meaning they are moderately strongly related with the vaccination rate, with one having a value of 0.14, meaning it's weakly related, another with value of -0.58, indicating strongly unrelated with vaccination rate.

Keywords: COVID, Correlation, Vaccination Rates, Factors, Values

INTRODUCTION

In today's era, COVID or scientifically known as SARS-CoV-2, is the pandemic that had caused major disruption economically and politically worldwide. With symptoms such as sneezing, coughing at early stages, with respiratory failure at severe stages, and spreads through the air contaminated with the virus, or touching contaminated surfaces, COVID is considered a top priority for all countries worldwide to focus on. The issue of COVID for countries worldwide is the high infection rate brought on by the disease, which had caused hospitals throughout each nation to be suddenly overloaded with patients suffering from COVID numbering from hundreds to even thousands, with chances some of them will not survive the disease. Furthermore, COVID can mutate into a more infectious and deadlier offshoots, as demonstrated with past variants such as Delta, Lambda, Mu, with the most recent one being Omicron. While the solution to this plague would be COVID vaccination, the process still faced challenges, with many countries unable to reach 100% vaccination nationwide, and there are several theories and explanation formulated as to why the target had been met with such difficulties, without any empirical studies and conclusions made as a guide for governments worldwide to achieve the 100% vaccination goal.

In the Myanmar case study (Nozaki et al., 2019), it is determined that economic status, mother's age, tetanus vaccination of the mother, and number of mother's care visits can have an influence on a country's vaccination rating. Other studies found out that cellphones can increase the delivery of

*name of corresponding author

vaccinations to ordinary people (Gavi, 2018), the Gross Domestic Product or GDP levels of a country (Basak et al., 2022), literacy level (both health and science literacy, basic reading aside) in a country(Lorini et al., 2018) the types of work a person does (Solis-Moreira, 2021), and other elements that can influence the rating, such as the country's population and country size. However, there are other unexpected possibilities which affects a country's vaccination rate, such as politics (Albrecht, 2022), and the perspective of vaccination in cultures of a country (The College Of Physicians Of Philadelphia, 2022).

To understand what influences the vaccination rates within a country, studying the past successes of mass vaccination in history, and exploring previous studies done on the factors that affect the vaccination rating will be the first important step in this research. To simplify this research, the quantitative elements of factors that affect vaccination rate, which is GDP per Capita values, literacy ratings, and the economic sector composition of a country will be selected. While politics and culture of a country can affect the vaccination rating, it will be difficult to measure quantitively due to the variation and subjectivity for it to be included in the dataset. With the selection done, a detailed exploration is required to understand how such factors influences the vaccination rating.

Since the use of mobile phones in this current year is ubiquitous, it can be used as a tool to influence people to vaccinate, or it could be a coercive tool as shown in a Reuters article, where the governor of Pakistan said that the population must be vaccinated against COVID or the cell phones will be blocked (Shahzad, 2021), or it could also be a tool for monitoring health, COVID, individual tracking, and checking vaccination status as suggested in an article by Michigan Health (Gavin, 2021). From another case study in Nigeria, the use of cellphones as notifications and reminders to vaccinate has yield positive effects, with people who receive the notifications having a three lever higher vaccination doses than those who do not receive it (Yunusa et al., 2022). The use of cellphones as a tool to educate people to increase vaccination rates also proves to be successful (Sun et al., 2022). From these case studies, it can be inferred how cellphones can influence people to vaccinate, and how it can be regarded as one factor that influences a country's vaccination rating, as a reminder, to increase awareness of the importance of vaccination, and as an educating tool against COVID.

Gross Domestic Product, or GDP for short, is the total value of goods produced and services provided annually within a country. While the GDP is usually used as an economic indicator, it can also be used in predicting how much a country's vaccination rate will reach. According to a research conducted by Nature, vaccination against COVID has differences between countries that are classified as "Low-Income" such as Burkina Faso, "Lower-Middle" such as India, and "High-Income" countries such as the United States: from a survey of 13 countries in the study, Burkina Faso has the lowest score among all in vaccination rating, while the United States has the highest in vaccination rating (Solís Arce et al., 2021) Another article from National Library of Medicine stated that GDP has a positive correlation with vaccine distribution levels, although there are countries with higher vaccine distribution rate despite low GDP value (Roghani, 2021) The figure below is a bubble graph published in New York Times illustrating the strong relationship with GDP and the doses of vaccination received by the country's' populace:

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13006
e-ISSN : 2541-2019
p-ISSN : 2541-044X

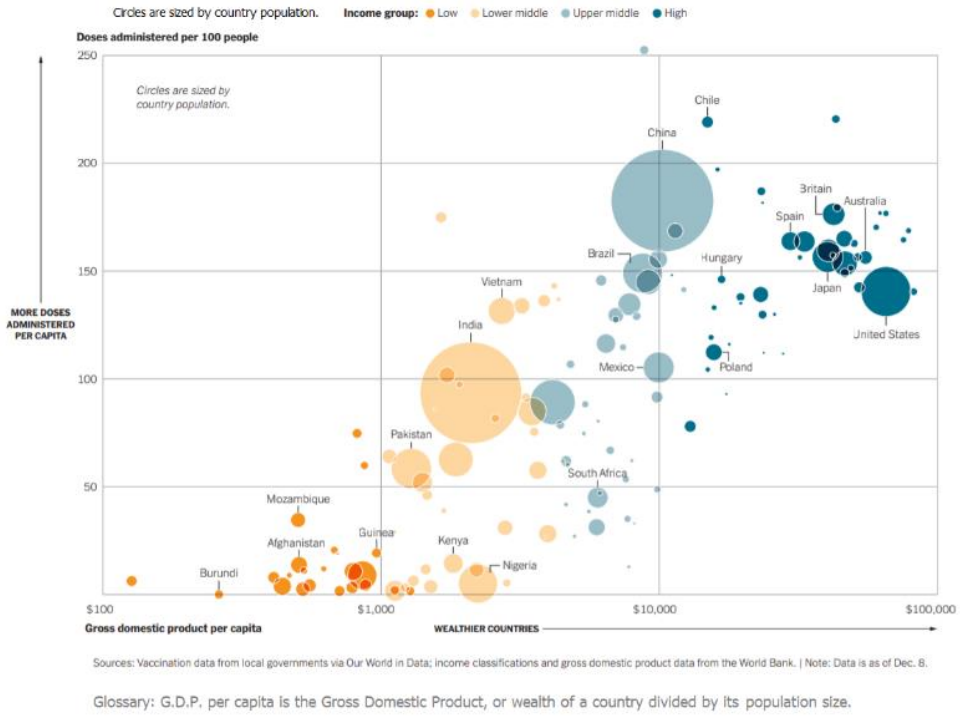

Fig. 1. Bubble Graph showing the COVID vaccines received per 100 people on each country. Source: (THE LEARNING NETWORK, 2022)

From the previous studies conducted, it can be concluded that there is a very strong relation between vaccination rates and a country's GDP levels, which can be explained that the higher a country's GDP is, the easier for it to obtain vaccines and create an effective distribution network to manage and promote vaccination efforts in several communities.

It is important to note that in terms of "literacy" in this study, the definition is a broad one, which can mean the literacy level regarding reading, health, and science. Most people will assume "literacy" only means a person's ability to read, but in matters related to health and vaccinations, "literacy" means how literate a person is regarding health and knowledge on how diseases and vaccinations work, such as COVID. Health literacy is the link between literacy and a person's ability in health sciences, while scientific literacy is the knowledge in science, with its framework used in decisions based on facts, researching, and gathering knowledge on a subject. Although both have different meanings, both are yet tied to the level of literacy, because without it, people cannot read and understand scientific and health facts and information which influences a person's decision-making process to undergo the COVID vaccination. Thus, within this study, it will be assumed that "literacy" means a person has sufficient ability to read and understand health and scientific importance of vaccination and COVID. From a study done in India, literacy levels have a positive correlation with the willingness to receive the first dose of COVID vaccination (Das & Bansal, 2021), and another one from the National Library of Medicine, people with higher health literacy are more accepting of the COVID vaccination than those who don't (Montagni et al., 2021). High health literacy can also help people to detect fake news and disinformation on vaccinations, and avoiding such sources to prevent second thoughts to it (Dib et al., 2022). Low health literates will avoid the vaccinations, which according to an articule from Patient Engagement Hit, is due to the inability to understand the seriousness of COVID, and therefore ignorant on the importance of preventive measures during the pandemic (Bailey, 2021). An article from Frontiers in Communication showed that literacy in science has a high correlation in positive views of COVID vaccination (Motoki et al., 2021), as shown in the figure below:

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13006
e-ISSN : 2541-2019
p-ISSN : 2541-044X

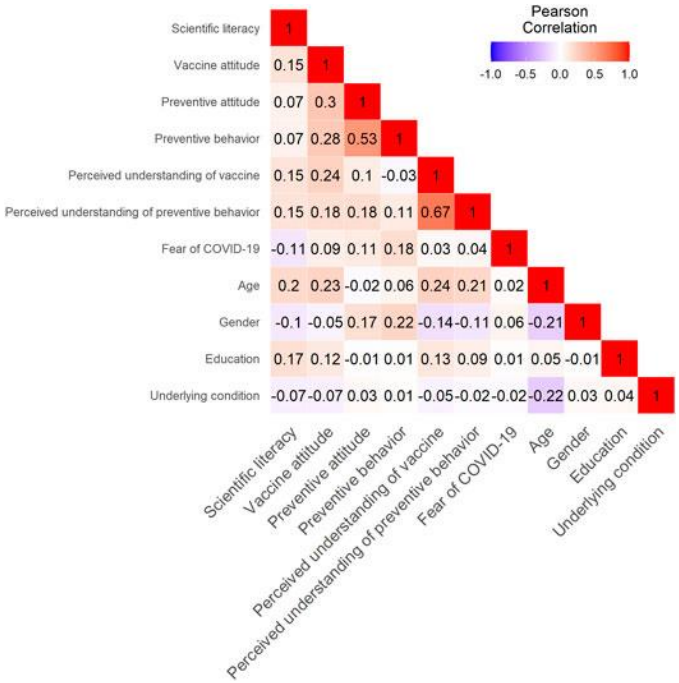

Fig. 2. correlation matrix showing the relationship between scientific literacy and various aspects relating to COVID and vaccination.
Source: (Motoki et al., 2021)

In each country, industrial sectors are divided into three types: primary, secondary, and tertiary. Primary industries are agricultural related, secondary industries are manufacturing/factory related, and tertiary industries are services related, such as retailing and restaurant waiters and waitresses. Compared with jobs from primary and secondary industries, jobs from tertiary industries, such as office work and administrative support, are high-contact jobs, which can assist with vaccination, and lowering and delaying peak COVID infection rates (Nunner et al., 2022). From a poll conducted by Forbes, agricultural workers have the lowest vaccination rate, with 49% of workers being vaccinated and also the most resistant to it, with 26% rejecting COVID vaccination. Conversely, workers in the financial sector are the highest in the poll, with 78% of the workers being vaccinated (Durkee, 2021) From the points noted, it appears that vaccination in tertiary sectors are a top priority compared to others due to the proximity to the people as part of the job requirement, which increases chances of COVID transmission, while in agricultural sector, it is the opposite, caused by a shortage of stable housing, food insecurity, access to information about the importance of vaccination, and being vulnerable to disinformation from word of mouth and social media (SOHRABJI, 2021)

METHOD

The dataset that will be used for this exploration will be sourced from various websites. Dataset number of mobile users, level literacy, and the economic sector of a country will be sourced from the WorldBank, while the country's GDP will come from World Population Review, with a five-year span from 2017 – 2022, as not all. Data is available within one year for use because inconsistencies in data recording, and state vaccination rate data worldwide, from 2021, when COVID vaccinations began, will take from the Our World in Data website. The picture below is a source of statistical data on mobile phone user countries, literacy, GDP, and Economic sectors:

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13006
e-ISSN : 2541-2019
p-ISSN : 2541-044X

	Unnamed: 0	Gross domestic product	Unnamed: 2	Agriculture	Unnamed: 4	Industry	Unnamed: 6	Manufacturing	Un
0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	
1	NaN	$ billions	NaN	% of GDP	NaN	% of GDP	NaN	% of GDP	
2	NaN	2010	2020	2010	2020	2010	2020	2010	
3	Afghanistan	15.9	20.1	26.2	26.8	21.2	14	12.5	
4	Albania	11.9	14.9	18	19.1	24.9	20.1	5.5	

Fig. 3. Datasets for economic sectors in countries around the world (*Our World in Data*, n.d.)

	ranking	country	gdppc	pop2022
0	1	Luxembourg	118001	642.371
1	2	Singapore	97057	5943.546
2	3	Ireland	94392	5020.199
3	4	Qatar	93508	2979.915
4	5	Switzerland	72874	8773.637

Fig. 4. Dataset for GDP per Capita in countries around the world (*Our World in Data*, n.d.)

	Series Name	Series Code	Country Name	Country Code	2017 [YR2017]	2018 [YR2018]	2019 [YR2019]	
0	Mobile cellular subscriptions (per 100 people)	IT.CEL.SETS.P2	Afghanistan	AFG	65.92913406	59.12084823	59.3560197	58
1	Mobile cellular subscriptions (per 100 people)	IT.CEL.SETS.P2	Albania	ALB	125.7103519	94.17699827	91.29301538	91.
2	Mobile cellular subscriptions (per 100 people)	IT.CEL.SETS.P2	Algeria	DZA	110.7672465	111.6647921	105.510594	10:
3	Mobile cellular subscriptions (per 100 people)	IT.CEL.SETS.P2	American Samoa	ASM	..	..	..	
4	Mobile cellular subscriptions (per 100 people)	IT.CEL.SETS.P2	Andorra	AND	104.3324113	107.2825494	113.9573773	12

Fig. 5. Dataset for the number of mobile users in countries worldwide(*Our World in Data*, n.d.)

The dataset is then the data on vaccination rates in percentage of COVID in countries worldwide "COVID-19 World Vaccination Progress", which is a dataset taken from the site statistics "Our World in Data" and compiled into the dataset, through extracting data from the site directly and inserted into Microsoft Excel. Below is the cover of the raw vaccination percentage dataset in these countries around the world:

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13006
e-ISSN : 2541-2019
p-ISSN : 2541-044X

	A	B	C	D	E
1	Country	Share of people with a complete initial protocol			
2	Country	13-Dec-20	1-May-22	Absolute Change	Relative Change
3	Afghanistan	May 11, 2021 0.14%	Apr 27, 2022 11.64%	11.5	'+8,214%
4	Africa	Feb 3, 2021 0.00%	16.56%	16.56	
5	Albania	Feb 2, 2021 0.00%	Apr 26, 2022 42.84%	42.84	
6	Algeria	Aug 20, 2021 1.62%	Apr 24, 2022 14.53%	12.91	'+797%
7	Andorra	Mar 8, 2021 1.52%	Apr 10, 2022 69.04%	67.52	'+4,442%
8	Angola	May 12, 2021 0.12%	Apr 26, 2022 18.65%	18.53	'+15,442%
9	Anguilla	Apr 22, 2021 5.18%	Apr 8, 2022 65.28%	60.1	'+1,160%
10	Antigua and Barbuda	May 17, 2021 2.61%	Mar 31, 2022 62.48%	59.87	'+2,294%
11	Argentina	Dec 29, 2020 0.00%	Apr 30, 2022 81.64%	81.64	
12	Armenia	Jun 20, 2021 0.40%	Apr 10, 2022 33.18%	32.78	'+8,195%
13	Aruba	Mar 29, 2021 9.48%	Apr 29, 2022 76.44%	66.96	'+706%
14	Asia	Dec 19, 2020 0.00%	68.78%	68.78	
15	Australia	Feb 23, 2021 0.00%	83.48%	83.48	
16	Austria	Jan 15, 2021 0.00%	Apr 29, 2022 73.06%	73.06	
17	Azerbaijan	Apr 1, 2021 2.91%	Apr 30, 2022 47.34%	44.43	'+1,527%
18	Bahamas	May 21, 2021 1.52%	Apr 29, 2022 39.80%	38.28	'+2,518%
19	Bahrain	Mar 6, 2021 11.40%	Apr 27, 2022 69.70%	58.3	'+511%
20	Bangladesh	Apr 8, 2021 0.05%	Apr 25, 2022 69.84%	69.79	'+139,580%
21	Barbados	May 1, 2021 5.75%	Apr 30, 2022 52.83%	47.08	'+819%
22	Belarus	Mar 12, 2021 0.11%	Apr 17, 2022 60.01%	59.9	'+54,455%
23	Belgium	Dec 29, 2020 0.00%	Apr 26, 2022 78.56%	78.56	
24	Belize	May 18, 2021 2.35%	Apr 29, 2022 52.09%	49.74	'+2,117%
25	Benin	May 21, 2021 0.00%	Apr 26, 2022 21.04%	21.04	
26	Bermuda	Feb 6, 2021 2.56%	Apr 22, 2022 76.44%	73.88	'+2,886%
27	Bhutan	Jul 5, 2021 0.17%	Apr 24, 2022 85.95%	85.78	'+50,459%
28	Bolivia	Feb 20, 2021 0.00%	Apr 26, 2022 49.90%	49.9	
29	Bonaire Sint Eustatius and Saba	Apr 9, 2021 6.30%	Sep 1, 2021 63.29%	56.99	'+905%
30	Bosnia and Herzegovina	Apr 14, 2021 0.31%	Jan 29, 2022 25.93%	25.62	'+8,265%
31	Botswana	Jun 14, 2021 0.96%	Apr 26, 2022 55.62%	54.66	'+5,694%
32	Brazil	Feb 5, 2021 0.00%	76.63%	76.63	
33	British Virgin Islands	May 21, 2021 12.41%	Apr 22, 2022 58.56%	46.15	'+372%
34	Brunei	Apr 26, 2021 0.02%	Apr 8, 2022 91.82%	91.8	'+459,000%
35	Bulgaria	Jan 18, 2021 0.02%	29.81%	29.79	'+148,950%
36	Burkina Faso	Aug 31, 2021 0.06%	Apr 8, 2022 5.78%	5.72	'+9,533%

Fig. 6. Raw Data samples after being extracted from Our World in Data website (*Our World in Data*, n.d.)

DATASET CLEANUP

There is also another problem with some datasets is that entries data intended to set an empty data value, such as "..", makes it difficult to convert every record in each column into a data type that exactly, because trying to convert it to a number will result in syntax error. The solution here is to convert the column with Such a value becomes a string, removes "..", and then Change it back to the right data type value. Below the image provided, are the results after cleaning is done:

	Country Name	Literacy Rate 2017 - 2022
0	Afghanistan	37.266041
1	Albania	98.141151
2	Algeria	81.407837
3	American Samoa	NaN
4	Andorra	NaN
...	...	...
212	Virgin Islands (U.S.)	NaN
213	West Bank and Gaza	97.514458
214	Yemen, Rep.	NaN
215	Zambia	86.747963
216	Zimbabwe	NaN

Fig. 7. Results of dataset cleaning for literacy rates in countries

The GDP Per Capita dataset is the most complete, and the data cleanest among all datasets available for use here, with little zero data, very few columns are unused for is removed, and the data type is mostly correct. Pictured below are the results of dataset cleanup :

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13006
e-ISSN : 2541-2019
p-ISSN : 2541-044X

	Country Name	GDP Per Capita 2022
0	Luxembourg	118001
1	Singapore	97057
2	Ireland	94392
3	Qatar	93508
4	Switzerland	72874
...	...	...
180	Malawi	993
181	Central African Republic	979
182	Somalia	925
183	South Sudan	791
184	Burundi	760

Fig. 8. Results of dataset cleaning for GDP per Capita levels in countries

Picture below are the results of cleaning the dataset for the number of mobile phone users:

	Country Name	Cellphone Users Per 100 People 2017 - 2022
0	Afghanistan	58.255812
1	Albania	91.002944
2	Algeria	103.887317
3	American Samoa	NaN
4	Andorra	121.659225
...	...	...
212	Virgin Islands (U.S.)	76.610007
213	West Bank and Gaza	83.783026
214	Yemen, Rep.	50.888548
215	Zambia	103.917835
216	Zimbabwe	88.755806

Fig. 9. Results of cleaning the dataset for the number of mobile phone users per 100 people in the country.

DATASET MERGE

After all data is cleaned and has the corresponding values for each column, the next step is to combine each separate data sets into a single file, using functions deep join by country name column. Image in below are the results after merging multiple datasets into one:

	Country Name	Literacy Rate 2017 - 2022	Cellphone Users Per 100 People 2017 - 2022	GDP Per Capita 2022	Agricultural Sector 2017 - 2022	Industrial Sector 2017 - 2022	Tertiary Sector 2017 - 2022	Vaccination Percentage (1 Dec 2020 - 3 May 2022)
0	Afghanistan	37.266041	58.255812	2390.0	26.820600	14.031699	54.688342	11.64
1	Albania	98.141151	91.002944	14218.0	19.121963	20.062647	48.358342	42.84
2	Algeria	81.407837	103.887317	11112.0	14.134793	20.282297	48.741457	14.53
7	Argentina	99.003868	121.170400	20751.0	5.932404	23.311218	54.612674	81.64
8	Armenia	99.788612	117.735771	13261.0	11.213424	27.055226	53.155996	33.18
...	...	...	...	...	...	...	...	...
207	Uruguay	98.770348	131.019855	22459.0	7.481413	17.951096	63.011059	82.14
208	Uzbekistan	99.999947	99.754392	7449.0	25.101749	31.568516	35.965687	42.55
209	Vanuatu	87.506310	80.167999	2586.0	21.219398	10.029671	59.793988	37.57
211	Vietnam	95.753868	142.733362	10869.0	14.853162	33.724108	41.625276	79.20
215	Zambia	86.747963	103.917835	3342.0	2.977086	40.257899	53.616377	12.79

Fig. 10. Data cover for "merged" dataframe

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13006
e-ISSN : 2541-2019
p-ISSN : 2541-044X

RESULT

The goal of this study is to find the correlation between the given factors related to vaccination rates on each country, and to do a detailed analysis on each of those factors as to why and how do they affect it. The Spearman Ranking Correlation equation will be used in this study for its suitability for this study's non-linear datasets and having no constraints in relating to other factors. While there exist two types of Spearman Correlation equations, with one being bounded to a ranking system and another being suitable for unranked dataset, the latter will be chosen for this study since the datasets used do not have any rank assigned to it. Thus, the equation used for this calculation will be:

$$\rho = \frac{1 - 6\Sigma d_i^2}{n(n^2 - 1)}$$

A sample of 9 values from the datasets used in this study will be randomly taken, extracted from the datasets of vaccination rates, and cellphone users per 100 people, and used to illustrate how the equation works as shown in the picture below:

	Country Name	Cellphone Users Per 100 People 2017 - 2022	Vaccination Percentage (1 Dec 2020 - 3 May 2022)
154	Peru	133.447152	80.72
30	Burkina Faso	105.807440	5.78
22	Bhutan	96.569372	85.95
185	Sudan	80.264084	8.04
204	United Arab Emirates	185.779425	96.71
100	Kazakhstan	129.383177	48.67
40	Chile	131.136145	90.87
160	Romania	117.436131	42.33
148	Oman	133.846960	57.97

Figure 11. Sample of 9 random data to be used to explain the Spearman Correlation equation used for this study.

The value X will be the values for vaccination rates, and the value Y will be used for the cellphone users per 100 people. The next step will be classifying the numbers into ranks, from 1 being the largest, to 9 being the smallest in the sample dataset, as shown below:

X = [133.45 105.81 96.57 80.26 185.78 129.38 131.34 117.44 133.84]

Y = [80.72 5.78 85.95 8.04 96.71 48.67 90.87 42.33 57.97]

X_r = [3 7 8 9 1 5 4 6 2]

Y_r = [4 8 3 9 1 6 2 7 5]

With the ranking of values done, the next step would then be to find the differences between the X_r and Y_r and then square each of the value of the differentiation, and then sum it all up, like the calculation shown below:

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13006
e-ISSN : 2541-2019
p-ISSN : 2541-044X

d = [1 1 5 0 0 1 2 1 3]

d^2 = [1 1 25 0 0 1 4 1 9]

d^2 SUM = 1+1+25+0+0+1+4+1+9 = 42

Returning to the given equation, the calculation and the correlation, the result will be thus:

$$\rho = 1 - \frac{6(42)}{9(81-1)} = 0.65$$

From the result above, the correlation value is 0.65, denoting a fairly strong positive correlation from the sample of 9 data from the 2 datasets picked at random. From this it can be inferred that there exists a connection, if fairly related, between vaccination rate and the number of cellphone users. This method of calculation will be reused on comparison of vaccination rate datasets with the other datasets chosen for this study, with each correlation values displayed and compared in the form of a matrix graph.

While there are other types of graphs that will be used in this study, which are bar graphs and scatterplot graphs, such graph types do not need a calculation to provide the final result, so this section will only discuss the correlation calculation used for the Spearman Correlation Matrix.

The results of the correlation map made can be seen in the figure below:

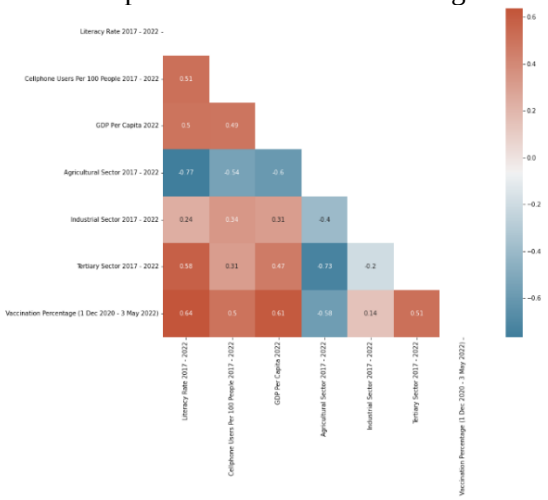

Fig. 12. Correlation Matrix of every factor listed in this study, with the percentage of the population vaccinated of each country worldwide.

From the correlation matrix and heatmap on Fig. 12. shown above, it can be seen that a country's vaccination rate has a fairly strong positive correlation with literacy levels, mobile phone users per 100 people, the tertiary economic sector, and GDP per capita, with values of 0.64, 0.5, 0.51, and 0.61 respectively. Conversely, the vaccination rate has a medium negative correlation value with the agricultural sector, with a score of -0.58. While the industrial sector has a positive correlation with vaccination rates, it only has a weak score of 0.14. It is also interesting to note that the level of literacy has a moderate positive correlation with the number of cell phone users per 100 people, tertiary industrial sector, and GDP per Capita, with values of 0.51, 0.58, and 0.5 respectively, and a strong negative correlation with agricultural sector, with a value of -0.77. Further exploration of other correlation matrix results via scatterplot graphs on literacy, mobile phone users per 100 people, literacy rates, GDP per Capita, and economic sectors reveals more details which will be explored one by one in this section, the first of which will be getting into a deeper study on the literacy rate and cellphone users per 100 people of countries in this scatterplot chart below:

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13006
e-ISSN : 2541-2019
p-ISSN : 2541-044X

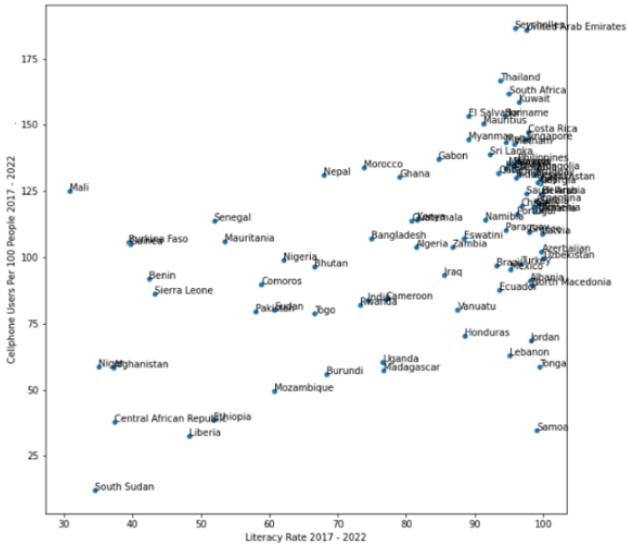

Fig. 13. Scatterplot Graph of countries, compared with literacy rate and cellphone users per 100 people of each countries.

As shown in the graph, countries with 100% literacy rate or at least close to it often have high number of mobile phone users, with some outlier countries like Mali having the lowest literacy rate in this study, yet having a high number of mobile phone users per 100 people. Samoa meanwhile, is the reverse, having a very high literacy rate and yet low number of mobile phone users per 100 people. Note that most countries with close to or are at 100% literacy rate are belonged to high-income groups, such as Kuwait and Singapore, or upper-middle-income groups like Thailand and Costa Rica, which on average have higher number of mobile phone users compared to low-income countries such as South Sudan and Central African Republic, which have fewer mobile phone users per 100 people and low literacy levels. The next figure below shows another scatterplot graph of the countries compared with literacy levels and GDP per Capita:

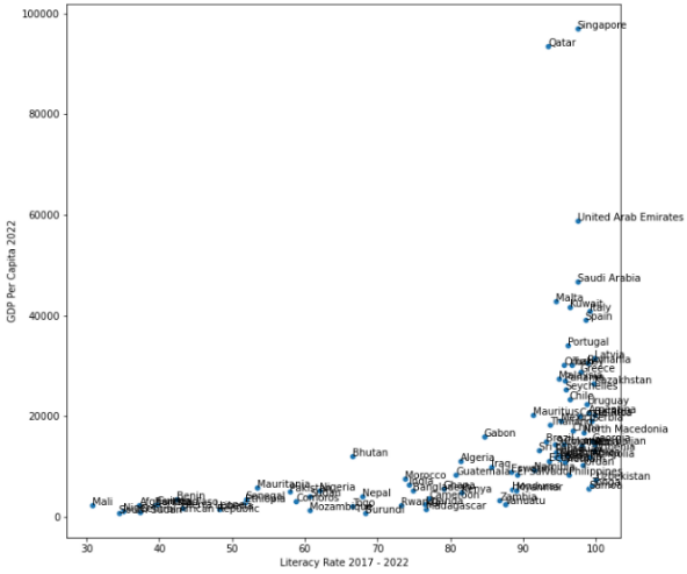

Fig. 14. Scatterplot Graph of countries, compared with literacy rate and GDP per Capita of each country.

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13006
e-ISSN : 2541-2019
p-ISSN : 2541-044X

As seen here on this scatterplot graph, countries with high levels of literacy are often grouped on the rightmost side of the graph, indicating high GDP per Capita, such as Singapore and Kuwait, or upper middle-income countries like Samoa and Thailand. Meanwhile, countries with low-income groups like Mali and Benin have both low literacy rate and GDP per Capita. Finally, comparing the literacy levels by secondary and tertiary industrial sectors by country:

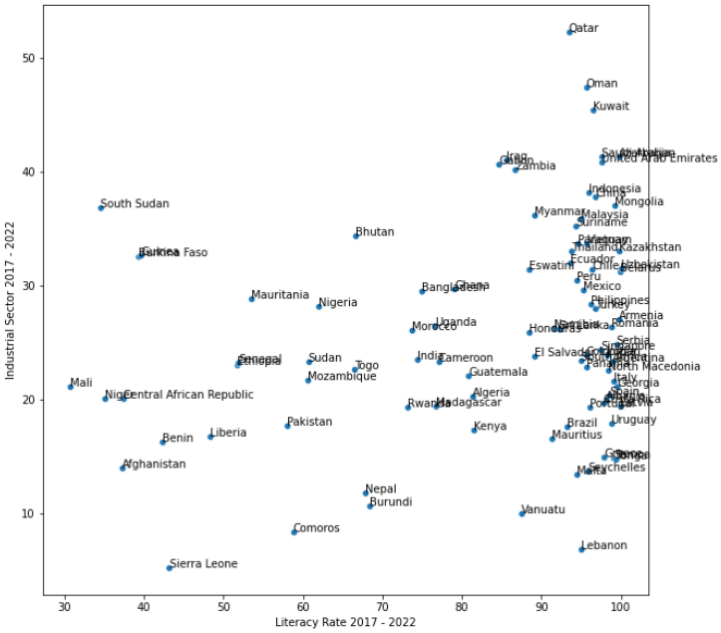

Fig. 15. Scatterplot Graph of countries, compared with literacy rate and secondary industrial sector of each country.

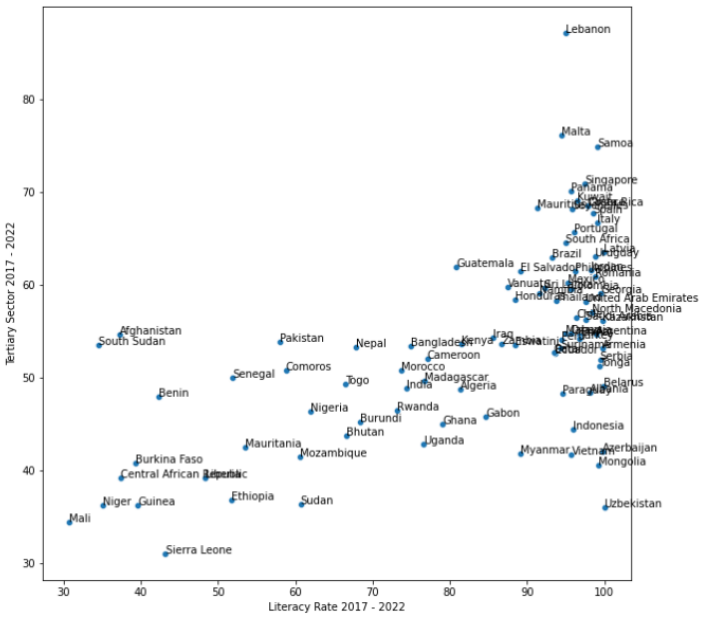

Fig. 16. Scatterplot Graph of countries, compared with literacy rate and tertiary industrial sector of each country.

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13006
e-ISSN : 2541-2019
p-ISSN : 2541-044X

Both scatterplot graphs showed that the level of literacy also influences the industrial sector composition of a country, with high literacy rate of 100% or close countries having a high level of secondary and tertiary economic sectors, whether high-income countries such as Qatar and Kuwait, or lower-middle-income countries like Indonesia and Mongolia. On the other hand, low-income countries such as Niger and Mali have lower levels of secondary and tertiary economic sectors compared with others, although South Sudan is an outlier case, having quite high levels of secondary and tertiary industries despite low literacy rating.

Next up, analysis of GDP per Capita and economic/industrial sector composition within each countries of the study will be done, to understand the stark differences of the vaccination rates of all countries within the study. First, the output of GDP per Capita of every country in this study in a bar chart is done on the image below:

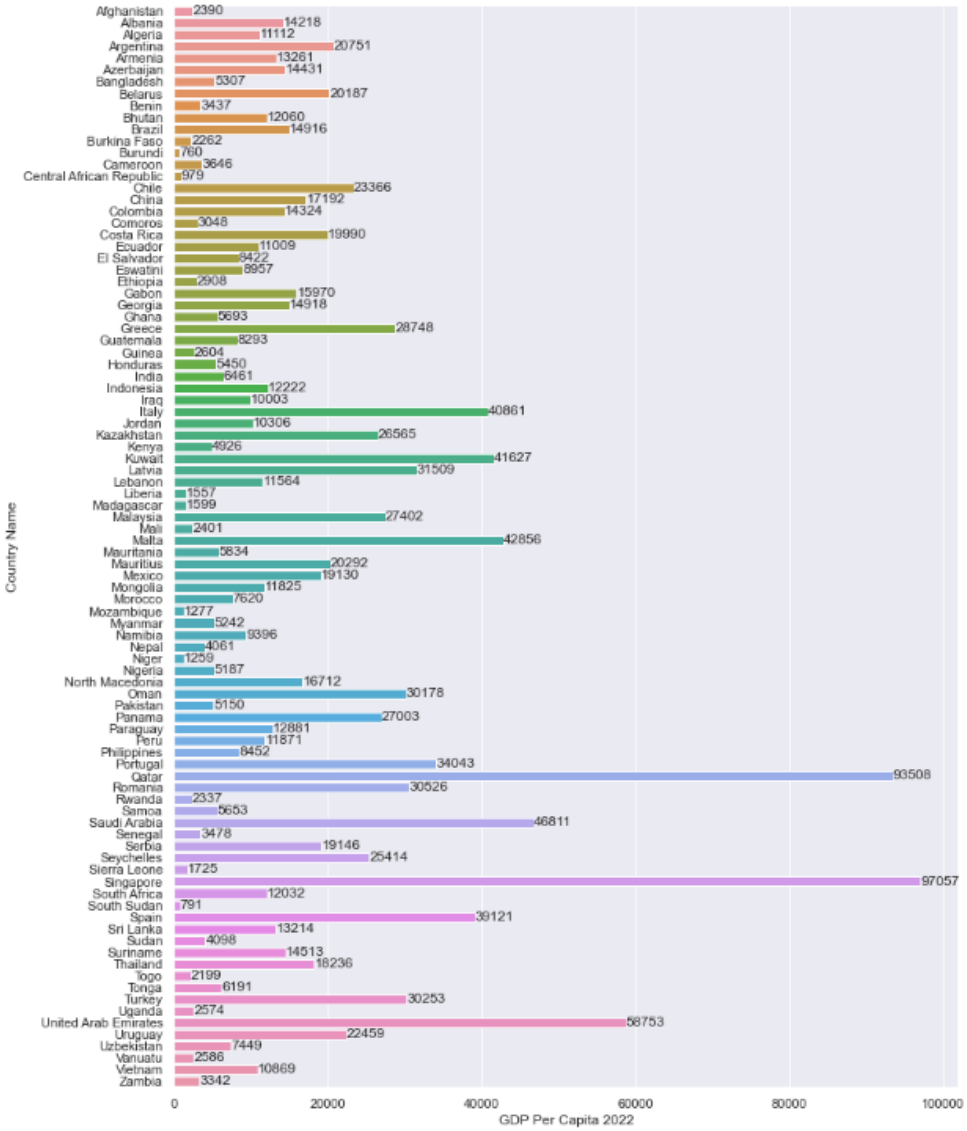

Fig. 17. Bar Graph showing the GDP per Capita of each country within the dataset.

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13006
e-ISSN : 2541-2019
p-ISSN : 2541-044X

Note that countries with high vaccination rate, such as Singapore (91.32% fully vaccinated), and Qatar (88.00% fully vaccinated), are countries with very high GDP per Capita levels which would classify both countries in the "high-income" group. In contrast, countries with low vaccination rates, such as Afghanistan (11.64% fully vaccinated), and Burundi (0.09% fully vaccinated), are countries with low GDP per Capita which will put both in the "low-income" group. Finally, in the comparison of economic sectors of every country within this study:

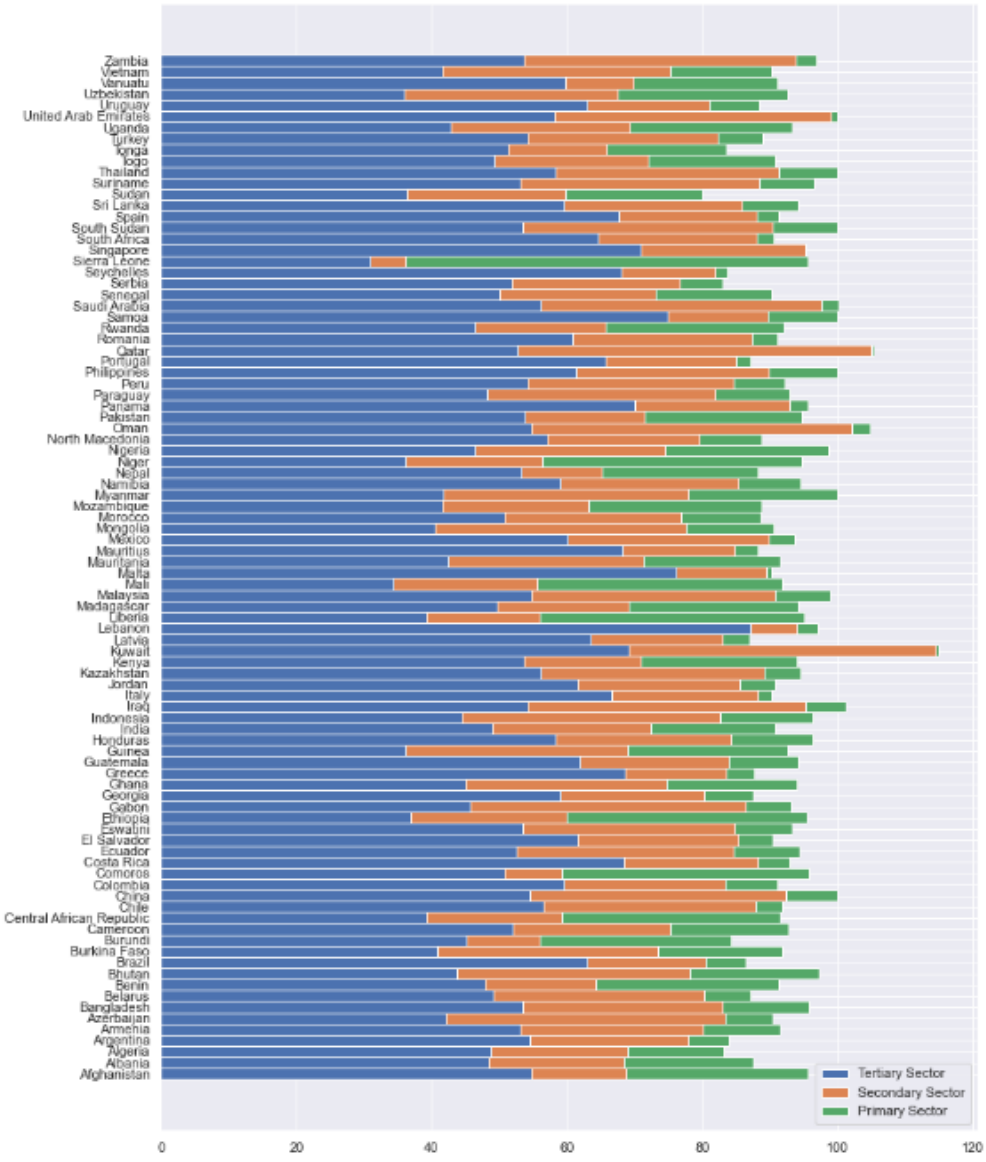

Fig. 18. Bar Graph showing the industrial/economic sectors of each country within the dataset.

The graph showed that all countries in this chart have a strong tertiary economic sector, compared to the primary and secondary sectors, with Kuwait and Singapore having zero Agriculture sector with few industrial sectors in their industrial composition, with Sierra Leone being an outlier in this result, being the only country with very strong agricultural sector while possessing a moderate level of tertiary sector and a weak level of industrial sector.

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024 e-ISSN : 2541-2019
DOI : https://doi.org/10.33395/sinkron.v9i1.13006 p-ISSN : 2541-044X

DISCUSSION

Overall results have shown that previous studies for the most part on the factors chosen for this study that affects the vaccination rates of a country, are largely accurate. The correlation matrix and heatmap with overall values from all countries mirrored the result from the past studies showing that high literacy rate, GDP per Capita, with a strong secondary sector of industry has a strong influence on vaccination ratings within a country, with primary sector of industry having the smallest chance of it being seriously considered to be one of the influencing factors of vaccination ratings within a country. After getting each of its correlation values with vaccination rates, any correlation value considered strong to very strong deserves a more in-depth study to find out why, and this will be the focus of this section.

Further exploration on the relationship between literacy rates and factors affecting vaccination rate, such as the GDP per Capita, economic sector divisions, and the total number of cellphone users per 100 people by country had provided more insight on this research, which previous studies had shown that literacy rates do not only affect vaccination rates, but also other important aspects of a country. The scatterplot graph showed the relationship between cellphone users per 100 people and literacy levels, showed that countries with a low GDP per capita will have lower literacy levels, which in turn affects the number of cellphone users per capita. Another scatterplot shows the link between GDP per Capita and literacy rate showing that the income group of a country affects its literacy level, which in turn affects the vaccination rate since as shown in chapter 2 regarding literacy and vaccination rates, low literacy means low health and scientific literacy, which influences the decision of individuals who will undergo a COVID vaccination. Another scatterplot graph detailing the relationship between tertiary and secondary industries further showed the level of literacy relative to the division of economic sectors within a country, however this is too simplified as a detailed explanation on why it is so, since there can be various economic conditions, policies, external elements, and other reasons that affect how industrial sectors are structured that way. Then again, it does illustrate how higher literacy rates meant the bigger dominance of tertiary sectors in a country, which in turn increases the vaccination rates because such industry has more contact with people compared with other industrial sectors, based on a previous study.

As recalled on the previous studies, countries with higher GDP per Capita have high vaccination rates, not only due to both having higher bargaining and purchasing power to buy and stockpile vaccines, but also higher health and scientific literacy rates, which teaches its citizens the importance of vaccination, with the results in this study confirming it.

Coincidentally, Singapore and Kuwait have the highest vaccination rates among all listed countries, while countries like Sierra Leone have the lowest vaccination rate. However, vaccination rates in countries like Afghanistan and Burundi are very low, yet having strong tertiary sectors compared with other industrial sectors, are the outliers in this study. Overall, while other previous studies suggest that vaccination rates may differ between countries based on the composition of its economic sectors, this study had shown that this is unlikely to be the cause, as the countries in the graph show having strong tertiary industrial sectors, which goes against the study which postulated that higher tertiary sector within a country means better vaccination rating, due to the nature of the industry making it a priority in vaccination, and yet this study had shown otherwise.

CONCLUSION

From the results shown, this study concludes that there exists a strong correlation between vaccination rates with the chosen factors in this study; vaccination rate and cellphone users per 100 people with a value of 0.5 out of 1, vaccination rate and GDP per Capita with a value of 0.65 out of 1, vaccination rate and tertiary sector job with a value of 0.51 out of 1, and vaccination rate and literacy rate with a value of 0.64 out of 1.

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13006
e-ISSN : 2541-2019
p-ISSN : 2541-044X

REFERENCES

Albrecht, D. (2022). *Vaccination, politics and COVID-19 impacts*. https://doi.org/https://doi.org/10.1186/s12889-021-12432-x

Bailey, V. (2021). *Low Health Literacy Hinders Access to COVID-19 Information*. Patient Engagement Hit. https://patientengagementhit.com/news/low-health-literacy-hinders-access-to-covid-19-information#:~:text=Individuals with low literacy levels,protect themselves during the pandemic.

Basak, P., Abir, T., Al Mamun, A., Zainol, N. R., Khanam, M., Haque, M. R., Milton, A. H., & Agho, K. E. (2022). A Global Study on the Correlates of Gross Domestic Product (GDP) and COVID-19 Vaccine Distribution. *Vaccines*, *10*(2), 1–13. https://doi.org/10.3390/vaccines10020266

Das, A., & Bansal, T. (2021). *Literacy and Response to COVID-19*. *56*(34), 1–12. https://www.epw.in/engage/article/literacy-and-response-covid-19

Dib, F., Mayaud, P., Chauvin, P., & Launay, O. (2022). Online mis/disinformation and vaccine hesitancy in the era of COVID-19: Why we need an eHealth literacy revolution. *Human Vaccines and Immunotherapeutics*, *18*(1), 1–3. https://doi.org/10.1080/21645515.2021.1874218

Durkee, A. (2021). Here Are The Industries With The Highest — And Lowest — Covid Vaccination Rates, Poll Finds. *November*. https://www.forbes.com/sites/alisondurkee/2021/11/12/here-are-the-industries-with-the-highest---and-lowest---covid-vaccination-rates-poll-finds/?sh=56e7a2c6383f

Gavi. (2018). *Mobile phones and digital technology to boost vaccine delivery in Uganda*. https://www.gavi.org/news/media-room/mobile-phones-and-digital-technology-boost-vaccine-delivery-uganda

Gavin, K. (2021). *Your Smartphone Can Help Fight COVID. Here's How.*

Lorini, C., Santomauro, F., Donzellini, M., Capecchi, L., Bechini, A., Boccalini, S., Bonanni, P., & Bonaccorsi, G. (2018). Health literacy and vaccination: A systematic review. *Human Vaccines and Immunotherapeutics*, *14*(2), 478–488. https://doi.org/10.1080/21645515.2017.1392423

Montagni, I., Ouazzani-Touhami, K., Mebarki, A., Texier, N., Schück, S., Tzourio, C., & CONFINS group. (2021). Acceptance of a Covid-19 vaccine is associated with ability to detect fake news and health literacy. *J Public Health (Oxf)*. https://doi.org/10.1093/pubmed/fdab028

Motoki, K., Saito, T., & Takano, Y. (2021). Scientific Literacy Linked to Attitudes Toward COVID-19 Vaccinations: A Pre-Registered Study. *Frontiers in Communication*, *6*(July), 1–7. https://doi.org/10.3389/fcomm.2021.707391

Nozaki, I., Hachiya, M., & Kitamura, T. (2019). Factors Influencing Basic Vaccination Coverage in Myanmar : Secondary Analysis of 2015 Myanmar Demographic and Health Survey Data. *International Journal of Environmental Research and Public Health*. https://doi.org/10.1186/s12889-019-6548-0

Nunner, H., van de Rijt, A., & Buskens, V. (2022). Prioritizing high-contact occupations raises effectiveness of vaccination campaigns. *Scientific Reports*, *12*(1), 1–13. https://doi.org/10.1038/s41598-021-04428-9

*name of corresponding author

Our World in Data. (n.d.). https://ourworldindata.org/grapher/share-people-vaccinated-covid

Roghani, A. (2021). The relationship between macro-socioeconomics determinants and COVID-19 vaccine distribution. *AIMS Public Health*, *8*(4), 655–664. https://doi.org/10.3934/PUBLICHEALTH.2021052

Shahzad, A. (2021). *Threats of cellphone blocks, work bans boost Pakistan's vaccination rate.* Reuters. https://www.reuters.com/world/asia-pacific/threats-cellphone-blocks-work-bans-boost-pakistans-vaccination-rate-2021-08-05/

SOHRABJI, S. (2021). COVID-19 Farmworker Study. *Http://Covid19Farmworkerstudy.Org/*. https://calexicochronicle.com/2021/11/01/ag-workers-lag-furthest-behind-in-vaccinations/

Solís Arce, J. S., Warren, S. S., Meriggi, N. F., Scacco, A., McMurry, N., Voors, M., Syunyaev, G., Malik, A. A., Aboutajdine, S., Adeojo, O., Anigo, D., Armand, A., Asad, S., Atyera, M., Augsburg, B., Awasthi, M., Ayesiga, G. E., Bancalari, A., Björkman Nyqvist, M., … Omer, S. B. (2021). COVID-19 vaccine acceptance and hesitancy in low- and middle-income countries. *Nature Medicine*, *27*(8), 1385–1394. https://doi.org/10.1038/s41591-021-01454-y

Solis-Moreira, J. (2021). *Study finds COVID vaccination rates differ by occupation*. 1–6. https://www.news-medical.net/news/20211114/Study-finds-COVID-vaccination-rates-differ-by-occupation.aspx P

Sun, L., Hu, J., Gao, H., Wang, S., Wang, B., Wang, J., Li, H., Wang, J., Yuan, C., & Zhang, X. (2022). Long-term effect of mobile phone-based education and influencing factors of willingness to receive HPV vaccination among female freshmen in Shanxi Province, China. *Human Vaccines and Immunotherapeutics*, *18*(5). https://doi.org/10.1080/21645515.2022.2051990

THE COLLEGE OF PHYSICIANS OF PHILADELPHIA. (2022). *Cultural Perspectives on Vaccination*. https://historyofvaccines.org/vaccines-101/ethical-issues-and-vaccines/cultural-perspectives-vaccination

THE LEARNING NETWORK. (2022). What's Going On in This Graph? | Vaccination by Country. *The New York Times*.

Yunusa, U., Ibrahim, A. H., Ladan, M. A., & Gomaa, H. E. M. (2022). Effect of mobile phone text message and call reminders in the completeness of pentavalent vaccines in Kano state, Nigeria. *Journal of Pediatric Nursing*, *64*, e77–e83. https://doi.org/10.1016/J.PEDN.2021.12.026

*name of corresponding author