*Warsaw Econometric Challenge*

*Fourth Edition*

***What were drivers of the level of Covid-19 vaccination in Poland?***

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# Introduction

**Importance.** Coronavirus disease (COVID-19) is an infectious disease caused by the SARS-CoV-2 virus that affects all people in different ways (WHO, 2024). Most people infected with the virus develop a mild to moderate respiratory illness and recover without special treatment, but some become seriously ill and die.

Poland, like many other countries, has active vaccination campaigns. The COVID-19 vaccine, like other vaccines, is designed to protect people from contracting and spreading the disease, thereby reducing public mortality. According to the Cigna website (2021), vaccines help our bodies build immunity and prepare individuals to resist severe forms of the disease. It should be noted that the licensed COVID-19 vaccines are safe and effective and meet the same standards and clinical research requirements as other medicines. However, not all members of society choose to be vaccinated (Cigna, 2021). The question therefore arises: what determines vaccination coverage? In this report, we will examine the political, economic, demographic, geographic and social factors that may influence the public's decision to vaccinate.

**Problem.** Despite the preventive measures taken in Poland, vaccination rates in different regions and demographic groups show fundamental problems related to vaccine availability, public confidence and age categories. Understanding these factors is important for collective immunization and economic recovery.

**Aim:** To analyze the drivers of COVID-19 vaccination in Poland and their impact on vaccination rates in Polish municipalities.

**Objectives:**

1. To examine and identify the main drivers of COVID-19 vaccination rate in Poland.
2. To investigate the significance of the factors of vaccination against the coronavirus on the vaccination rate.
3. Investigate how the neighborhood effect affects vaccination rates.

**Methods**. Comparative analysis of scientific literature and data; binary regression analysis.

Related to the research objectives, it can be ended up with **hypotheses**:

*Hypothesis 1. Bigger voivodeships have a higher vaccination rating.*

*Hypothesis 2. Differences in vaccination rates exist between Eastern and Western Poland.*

*Hypothesis 3. Older people tend to be more vaccinated than younger people.*

*Hypothesis 4. Living in the city a higher vaccination rating is received.*

*Hypothesis 5. Trust in government leads to greater propensity to get vaccinated.*

*Hypothesis 6. The neighborhood effect has a positive effect on the propensity to vaccinate against COVID-19.*

# Literature review

There have been several studies examining the drivers of COVID-19 vaccination. Naidoo et al (2023) identified age, education and gender as the most important variables. Wong et al (2022) found that the decision to vaccinate was influenced by: source of income, good health status, perception and knowledge of COVID-19 vaccines, pandemic exposure, and risk to family members. In Poland, the main barriers to uptake of the COVID-19 vaccine were related to concerns about vaccine safety, patients' religious beliefs and negative narratives (Marcinowicz et al., 2023). The results of this study highlight the importance of disseminating reliable information to the public from trusted sources. In addition to education, gender, age, income, health and knowledge, other potentially important factors include unemployment, political views, geography and externalities such as neighbourhood effects.

## 1.1. Importance of vaccination for Poland

By 2022, 33 vaccines had been approved by regulatory authorities in different countries and more than 10 billion doses had been administered worldwide (Machado, Hodel & et. al, 2022). The impact of the COVID-19 pandemic on the Polish economy has led to a strong vaccination campaign in Poland.

High vaccination coverage reduces the risk of the virus spreading and increases a country's collective immunity, where a large proportion of the population in an area is immune to a particular disease. If enough people are immune to the coronavirus, the likelihood of infection is reduced, which is an important way to protect public health and reduce mortality. In addition, the high number of infections could overwhelm the health system, reducing its capacity to provide adequate care to all existing and potential patients, including those with COVID-19. Vaccination helps control morbidity and reduces the cost to the country of subsequent quarantine, while fewer infections reduce the economic damage caused by business closures and other restrictive measures. At the same time, effective vaccination can help build public confidence in the government and the health system by demonstrating the government's ability to respond effectively to the crisis and care for the health of its citizens. Vaccination can also affect the migration of citizens, for example, those who are fully vaccinated or have a negative COVID-19 test result are given the opportunity to migrate abroad.

Thus, the concentration of vaccinated citizens in Poland influences the overall public health and mortality in the country, the burden on the health care system, the Polish economy and the public's trust in the government, which is why it is important for the Polish government to increase the number of people vaccinated against corona virus.

## 1.2. Vaccination and unemployment rates

During the Covid-19 pandemic, the unemployment rate increased as companies made less profit or went bankrupt. One of the justifications for vaccination was the lifting of the quarantine and the return to work. In a longitudinal study of counties in the US, higher unemployment was found to lead to higher vaccination rates in a county (Guo et al., 2022). Meanwhile Adler-Milstein et al. (2022), in a cross-sectional study of US communities, found that higher unemployment rates negatively affected vaccination rates. They are supported by Troiano and Nardi (2021), stating that the decision to vaccinate was lower among the unemployed than among the employed.

## 1.3. Vaccination rates and political views

An important factor in people's decision to vaccinate/not to vaccinate is trust in the government. In many countries, the development of COVID-19 has raised concerns about the safety of the vaccine and the government's handling of it. According to Lim and Moon (2023), who used a probit model in their study, found that political trust determines people's belief in vaccine safety and vaccination uptake. The same conclusion was reached by Jennings et al. (2023) using a regression of covariates, which found that distrust of government is an indicator of vaccination indifference. Wróblewski et al. (2022) conducted a study for Poland based on structural equation modeling. They came to the opposite conclusion – people who trust institutions and support the dominant party are more likely to oppose vaccination. However, more people are skeptical about the safety and effectiveness of vaccines than those who support them. Therefore, the next part of the study will try to refute/confirm these results.

## 1.4. Vaccination rates and education level

“Education is a key barrier to get vaccine“ as Adler-Milstein, Khairat, Zou (2022) stated. Authors searched what factors affect low vaccination uptake level and vaccination hesitancy in cross-sectional study of US communities. They found an inverse relationship between COVID-19 vaccine uptake and vaccine hesitancy. Study shows that vaccination hesitancy was positively associated with individuals speaking English less than well or just with high school diploma. So low vaccination levels were found in communities with a less educated population. Authors are saying that levels of education could be related to bad knowledge about vaccines. It could be related to not knowing enough about potential side effects, benefits of the vaccine, risks to remaining unvaccinated and vaccine effectiveness. Dong, Gardner, Nixon (2024) also found that variable such as postsecondary education percentage is negatively associated with unvaccinated percentage. So it means, higher education has positive effect for vaccination level and decreasing unvaccinated percentage.

## 1.5. Vaccination rates and income level

Dong, Gardner, Nixon (2024) study the determinant of COVID-19 vaccination rates at the U.S. country level. As dependent variable they took COVID-19 unvaccinated percentage. They found that multiple variables are negatively associated with unvaccinated percentage. Such examples are cumulative COVID-19 case rate, median household income, median age. But the strongest negative association is appearing for median household income. So it can be concluded that higher level of income motivates to get vaccine. Ferreira and etc. (2023) support this relationship between vaccination rates and the income level. In their study personal income was ranked as second most significant variable for vaccination rate. Bivariate analyses showed that individuals with higher personal income had higher vaccination rate.

## 1.6. Vaccination rates and age

Although COVID-19 is potential risk for all groups of age but the risk of serious illness from this virus increases with age (Australian Government Department of Health and Aged Care, 2024). Ndasauka‘s and etc. (2024) study agrees with current statement and show that the older individuals are more likely to get vaccinated than younger participants. Ferreira and etc. (2023) confirms this relationship. Their study was conducted in Netherlands and found that age was outstanding most important variable for vaccination rate and importance of this variable increasing by age. Only highest age group (80+) showed slightly lower impact than age group 67-79. However Adler-Milstein, Khairat, Zou (2022) are concluding opposite. In the study they found that the most highly hesitant unvaccinated individuals were elder individuals (over the age of 65 years). In this case vaccine hesitancy of elder people is considered as lower education level.

## 1.7. Vaccination rates and geographical factors

Geographical factors include area size and population distribution, which determine whether an area is rural or urban. According to Dijkstra et al. (2020), areas are divided according to population density:

* “Cities, which have a population of at least 50,000 inhabitants in contiguous dense grid cells (>1,500 inhabitants per km2);
* Towns and semi-dense areas, which have a population of at least 5,000 inhabitants in contiguous grid cells with a density of at least 300 inhabitants per km2;
* Rural areas, which consist mostly of low-density grid cells (<300 inhabitants per km2).”

Using a cross-sectional data set that included vaccination uptake and hesitancy and population characteristics based on the Social Vulnerability Index, it has been found that those living in urban areas are more likely to be fully vaccinated against COVID-19 (Hernández-Vasquéz et al., 2023). This is supported by Soorapanth et al. (2023), whom suggest that there is less availability of vaccines in rural areas. In Poland, it has been observed that in remote regions (rural areas and small towns) where the ruling party has the most support, the vaccination initiative is lower due to inequalities in information and medicine between urban and rural areas (Jarynowski & Wójta-Kempa, 2023). It is important to mention that the study emphasizes that mostly rural and small-town districts are located in the eastern part of Poland.

In addition, the size and density of a city have a significant impact on the increasing number of COVID-19 cases (Jarynowski & Wójta-Kempa, 2023). As the number of infections rises, people become more concerned about the risk and begin to get vaccinated, potentially contributing to higher vaccination rates in larger, more densely populated areas. However, it is important to note that as the prevalence of the disease decreases, so does the perceived need for vaccination decrease until the prevalence increases again to a certain extent. Nevertheless, achieving 100 percent population vaccination is not necessary to eradicate the disease, as herd immunity comes into play. This is related to the neighborhood effect stemming from vaccination, wherein a large number of vaccinated individuals in a neighborhood reduces the likelihood of disease transmission and shields even the unvaccinated from exposure. Furthermore, it diminishes the overall disease transmission rate within this population.

In addition to the size of Poland's administrative units and the distribution of its population, ethnic and economic disparities between eastern and western Poland are one of the main geographical factors contributing to differences in immunization coverage in the country. Poland is located on the border between Central Europe, developed Northern Europe and less developed post-socialist Eastern Europe. There are still historically determined differences between the more developed western part of Poland and the less developed eastern part (Nováček, 2014). This east-west divide also manifests itself in other post-socialist countries of Central Europe, such as Hungary, Slovakia or the Czech Republic (Enyedi, 2011), (Korec, 2009). In this context, there is a difference between the level of vaccination in eastern and western Poland, which may be due to a variety of factors influencing vaccination rates.

Western Poland is more economically developed than eastern Poland, so a better economic situation may allow easier access to health services, including vaccination. Western Poland has more urbanized areas and more densely populated cities, such as Wroclaw and Poznań, where the health infrastructure is better developed, making vaccination more accessible to citizens (Churski, P. & et. al., 2021). In addition to economic aspects, western Poland has a higher level of education, which often leads to greater health awareness (Churski, P. & et. al., 2021). Eastern Poland, on the other hand, is more conservative and may have stronger traditional values, which can sometimes be associated with skepticism about medical innovations, including vaccines. In conclusion, when assessing vaccination rates in Poland, it is important to analyze the drivers of vaccination between eastern and western Poland, as well as to take into account the size of Polish administrative units and the distribution of the population.

High vaccination rate is crucially importing in every country to reduce the risk of the virus spreading and increase a country's collective immunity. Unfortunately, not always it is manageable. There are various different factors that can affect individual’s behavior of getting vaccinated. It is very importing to find and analyze the most important factor in order to control COVID-19 pandemic.

1. **Research methodology and data**

Before conducting a research on the reasons for vaccination in Poland, it is important to discuss and 'tease out' the reasons that are relevant and meaningful for statistical analysis. In the light of what has already been discussed, vaccination rates in a country play an important role in each country's economy, and in the scientific literature this phenomenon is often discussed in the context of the analysis of the overall situation of a country. Thus, in order to better understand and analyze the interactions of vaccination drivers in Poland and due to non-linearity of errors, the research applies a discrete response (probit) model based on cross-sectional data on publicly available vaccination drivers in Poland.

As the probit model is used for the analysis, the dependent variable is defined as a binomial/dummy variable. Based on the distribution of vaccination rates defined by Michaud (2021), of which the low vaccination level of COVID-19 is considered if only 40-50 percent or less of population is vaccinated, the expression of the dependent variable for the purpose of the research is defined as:

(1)

Due to the non-linearity of the errors, it was decided to use a probit model with a distribution function defined as a normal cumulative distribution function. It is often observed in studies that the probit model is chosen over the logit model because of the normality of the distribution function.

However, due to the nonlinearity of the estimated likelihoods with respect to the explanatory variables of the model, the interpretation of the probit model is somewhat complicated and requires a larger number of steps, so it was decided to apply one of the marginal effects methods, i.e. the average marginal effects (AME) method. The latter method is based on the average of the marginal effects derived from all the participants in the sample for a given regressor. Therefore, the AME estimates reveal the average change in the probability of a regressor increasing by one unit.

The research used 2020-2021 cross-sectional data containing 2,477 unique items, which were used to identify the determinants of vaccination rates against COVID-19 in Poland. Of the total number of items, 788 individuals took the value of one for the dependent variable and 603 individuals took the value of zero.

The choice of the independent variables was determined by the studies reviewed and the available data, so the selected and statistically significant independent variables can be divided into 5 groups, covering characteristics such as: demographic (age), social (share of education completed in the municipality, number of primary care facilities per capita in the municipality, birth rate per 1,000 inhabitants), geographical (type of municipality, voivodships, historical partitions), economic (unemployment rate in the municipality) and political (share of voting population in the municipality).

In Poland, the assessment of the determinants of vaccination rates used an age-group variable, constructed as the proportion of persons in a municipality who are in a particular group. The distribution of these subgroups in the municipality was combined into 4 larger groups: *age\_5\_19* variable includes the proportion of persons in the municipality in the 5-19 age group; *age\_20\_39* variable includes the proportion of persons in the municipality in the 20-39 age group; *age\_40\_64* variable includes the proportion of persons in the municipality in the 40-64 age group; and *age\_65\_84* variable includes the proportion in the municipality in the 65-84 age group. Extension of the variables describing demographic characteristics, such as the inclusion of a variable describing gender in the model, was not possible due to the unidentified significant impact on vaccination rates in different municipalities. This is also reflected in the proportional distribution of sexes in the sample groups.

In order to integrate the influence of social factors on vaccination rates, variables on the share of education attained in the municipality were included, such as *education\_share\_primary*, which describes the share of people who have attained the primary level of education; *education\_share\_vacational*, describing the share of persons with vocational education; *education\_share\_secondary*, describing the share of persons with secondary education; *education\_share\_higher*, describing the share of persons with higher education. In order to assess the accessibility of health facilities, a variable *hc\_adivces\_per\_capita* was also constructed, describing the number of primary care facilities per capita in the municipality. Also to assess the relationship between birth rates and vaccination rates, a birth rate variable (*birthrate\_per\_1000\_persons*) was also included to express the proportion of births per 1000 inhabitants in the municipality.

Taking into account the different development and historical consequences of the geographical areas existing in Poland, 3 factor variables were included, including: a municipality type dummy variable (*urban*), which takes the value 1 if the municipality type is urban; groups of municipalities classified as counties in terms of population density, from which dummy variables were constructed, taking 1 value if the municipality belongs to the group of *voivodeships\_1* belonging to the voivodships śląskie, małopolskie, *voivodeships\_2* – if mazowieckie, dolnośląskie, łódzkie and pomorskie, *voivodeships\_3* – if podkarpackie, wielkopolskie, kujawsko-pomorskie, świętokrzyskie, opolskie, *voivodeships\_4* – if lubelskie, zachodniopomorskie, lubuskie, warmińsko-mazurskie, podlaskie. In order to estimate the differences in historical transformations for the research question, and thus also for the eastern and western areas of the country, the historical partitions variable was included, the categories of which were constructed in a dummy form, and therefore take the value 1 if the municipality is classified as *historical.partitions\_austrian* (territory of austrian historical partition), *historical.partitions\_russian* (territory of russian historical partition), *historical.partitions\_prussian* (territory of prussian historical partition).

In order to assess the economic factors that may influence vaccination rates, *unemployment\_rate* was included to reflect the unemployment rate in the municipality. An attempt was also made to include the effect of income on vaccination rates in the municipality, unfortunately the factor was identified as statistically insignificant. Also, based on the literature analysis, the variable *voting* was included to describe the characteristics of politics, which reflects the proportion of people who vote in government elections in the municipality. The latter variable reflects people's involvement in the country's politics and, consequently, people's trust in the government.

On the basis of the independent variables discussed above, a binomial probit model was constructed, with the variables identified as significant, and the expression of the model itself defined as:

(2)

AMEs were calculated from the estimates obtained from the variables by fitting the model, and their impact on vaccination rates is discussed in the next section of the article.

To further examine the neighborhood effect on vaccination rates, we developed a Linear Mixed Effects Model. This model utilizes both fixed and random effects.

Fixed effects are variables directly incorporated into the model whose values can vary. For this study, we're focusing on population density. This effect indicates how the vaccination rate percentage changes with shifts in population density.

On the other hand, random effects are variables whose values aren't directly determined but are included to assess the diversity or structure in the model unexplained by fixed effects. Here, we've included a random effect associated with voivodeships. This enables us to estimate disparities in vaccination percentage levels across different counties, which may be indicative of neighborhood effects.

Population density and voivodeship random effects were selected as model variables because:

1. With larger cities hosting more inhabitants, there's a greater pool of potential vaccine recipients and enhanced accessibility to healthcare services. This factor can influence vaccination percentages. Furthermore, higher population densities tend to foster more opportunities for neighborhood effects.
2. Incorporating random effects linked to voivodeships allows us to gauge variations in vaccination percentage rates among different counties, irrespective of population density. This facilitates an assessment of whether neighborhood effects on vaccination exist, as we can discern statistically significant differences among various counties.

1. **Empirical research**

Table 1. shows all independent variables in the estimated model considered as statistically significant variables (when p-value is < 0.1) and having impact for our dependent variable *y* (percentage of fully vaccinated equal and more than 50 % | percentage of fully vaccinated less than 50 %).

|  |  |
| --- | --- |
| **Variables** | **Probit\_AME** |
| (Intercept) | -1191.225224\*\*\* |
| urban | 14.582340\*\* |
| voivodeships\_1 | 67.915631\*\*\* |
| voivodeships\_2 | 6.590398\* |
| voivodeships\_3 | 7.471933**.** |
| historical.partitions\_austrian | -91.094838\*\*\* |
| historical.partitions\_russian | -38.534728\*\*\* |
| education\_share\_primary | 9.694832\*\*\* |
| education\_share\_vocational | 9.769004\*\*\* |
| education\_share\_secondary | 11.417574\*\*\* |
| education\_share\_higher | 8.059161\*\* |
| age\_20\_39 | -4.811791\*\*\* |
| age\_40\_64 | 4.310081\*\*\* |
| age\_65\_84 | 1.408875**.** |
| hc\_advices\_per\_capita | 1.907047\* |
| unemployment\_rate | 2.159899\*\*\* |
| birthrate\_per\_1000\_persons | 1.018060\*\* |
| voting | 2.992473\*\*\* |

**Table 1. Summary of statistically significant variables of probit model with AME**

Estimated probit model shows that the group of largest voivodeships has the 67.91 p.p. bigger probability of having higher vaccination rate (50 % and more) comparing to the group of the smallest voivodeships. Second group of largest voivodeships and third group are also having bigger probability (6-7 p.p.) than the group of the smallest voivodeships. Hypothesis 1 is confirmed. The size of voivodeships is important factor for having a higher vaccination rating.

The historical partitions of Poland (which can also define eastern and western Poland) appeared as the most statistically significant variables in this model. Comparing to Prussian partition, Austrian partition has the 91 p.p. smaller probability of having higher vaccination rate (50 % and more). Comparing to Prussian partition, Russian partition has the 38.5 p.p. smaller probability of having higher vaccination rate (50 % and more). Hypothesis 2 is confirmed. Between Eastern and Western Poland exist significant differences of the level of vaccination rates. Prussian partition is considered as western Poland meanwhile Russian and Austrian partitions as eastern Poland. According results western Poland is much more vaccinated. These differences confirm reviewed literature where is saying that Western Poland is more economically developed than Eastern Poland, so a better economic situation could allow easier access to healthcare services.

Analyzing how different age groups determine vaccination level, model also shows statistically significant differences. *Age\_20\_39* variable shows that increasing 1 % of proportion of persons with the age 20-39 in the municipality, probability of getting higher vaccination rate is decreasing by 4.8 p.p. Meanwhile increasing 1 % of proportion of persons with the age 40-64 in the municipality, probability of getting higher vaccination rate is increasing by 4.3 p.p. A little bit smaller probability (1.4 p.p.) of getting higher vaccination rate is for 65-84 years group. Nevertheless Hypothesis 3 is confirmed by this research. Older people tend to be more vaccinated than younger people.

Estimated regression found that there are statistically significant differences between urban and rural areas regarding level of vaccination rate. Urban areas have the 14.58 p.p. bigger probability of having higher vaccination rate than rural areas. Hypothesis 4 is confirmed – higher vaccination rate is reached in cities. These findings are closely related to Hypothesis 1. Living in city and larger voivodeship are the key factors to individuals to get more vaccinated.

Our performed analysis shows that increasing 1 % of voting percentage for government elections in the specific county, probability of getting higher vaccination level is increasing by 2.99 p.p. As in the methodology part was described, voting variable is considered as trusting in the government. So Hypothesis 5 is confirmed. Trust in the government leads to greater propensity to get vaccinated.

Looking at the Linear Mixed Effects Model to further explore the neighborhood effect, we measured Equation 3:

*percent\_vaccinatedij* = *β0 +β1 ×population\_densityij + b0i +ϵij* (3)

Where:

*β*0 is the intercept coefficient of the model, which indicates the average vaccination percentage when the population density is zero;

*β*1 is the coefficient of population density, which indicates how the vaccination percentage changes for each unit increase in population density;

*population\_densityij*is the population density in the *i* county, where the *j* record is located;

*b*0*i* is the random effect associated with *county\_code*, indicating how the vaccination percentage varies between different counties. It is directly included in the model;

*ϵij* is the random error term in the i county, where the j record is located, indicating unaccounted or unforeseen factors affecting the vaccination percentage.

After calculating the equation, we found that the variance is 38,37 and the standard deviation is 6,195. This shows that there are significant differences in the level of vaccination between different voivodships (table 2).

|  |  |  |
| --- | --- | --- |
| Random effects | | |
| Name | Variance | Standard deviation |
| county\_code (Intercept) | 38,37 | 6,195 |

**Table 2. Random effects**

It was estimated that a one unit increase in population density increases the vaccination rate by 0,004917 (table 3).

|  |  |  |  |
| --- | --- | --- | --- |
| Fixed effects | | | |
| Name | Estimate | Standard errors | t value |
| population\_density | 4,969e-03 | 2,128e-04 | 23,35 |

**Table 3. Fixed effects**

Evaluating the differences in vaccination percentages between different counties and taking into account population density, we can assume that a neighborhood effect may exist, especially if we observe a relationship between the vaccination rates of different counties, since different counties include different municipalities that may affect neighboring municipalities in the same in voivodships. In this way Hypothesis 6 is confirmed. The neighborhood effect has a positive effect on the propensity to vaccinate against COVID-19. Additionally, the groups of different size voivodeships in the probit model were constructed according to population density. Hypothesis 6 can also be explained and confirmed by findings for Hypothesis 1.

Other variables that were included in the model and were shown as statistically significant variables are economic and social factors. Considering economic factors, by increasing 1 % of unemployment rate in the municipality probability of getting more vaccinated is increasing by 2.16 %. This supports Guo et al. (2022) findings.

Analyzing social factors on vaccination rate, increasing 1 % of proportion of births per 1000 inhabitants in the municipality increase probability of getting more vaccinated by 1.01%. While increase by one primary care facility per capita in the municipality gets probability of higher vaccination rate bigger by 1.9 %. Finally, considering education levels, all types of educations are making positive effect for increasing probability of getting higher vaccination rate. But comparing share of persons with higher education and secondary education, increase 1 % of share of persons with higher education in specific municipality increase the probability of getting more vaccinated more than it is with higher education. These results argue with our reviewed literature. For Poland ‘s case this study did not find that higher education means higher vaccination rate.

Non-significant income variable does not support our reviewed literature. Also, education’s level impact for higher vaccination level is still debatable. Despite importance of economic, social and political factors for higher vaccination rate the main drivers of the level of Covid-19 vaccination in Poland is geographical factors. In the Poland the urban and more density areas are considered as having higher vaccination level. Also, huge difference is seen in different regions of Poland. Western part of Poland is characterized by much higher vaccination level.

**Conclusions and recommendations**

In contrast to the literature analysis, income and gender were statistically insignificant and had no effect on full COVID-19 vaccination rates in Poland. Nevertheless, the study confirmed all the hypotheses proposed:

1. There is a positive correlation between the size of the Poland`s voivodships and vaccination rates, i.e. the larger the voivodship, the higher the number of fully vaccinated people.
2. Poland's historical division into West and East Poland is one of the most important drivers of full vaccination in the country. Also, the vaccination rate in Western Poland is more than a third higher than in Eastern Poland.
3. Vaccination rates depend on the age distribution of the population. Nevertheless, the concentration of the population aged 20-39 contributes the least to vaccination rates in Poland.
4. People living in urban areas are also more likely to be vaccinated than those living in rural areas. The size of Poland's voivodships and urbanization are related and are the main drivers of the level of Covid-19 vaccination in Poland.
5. Poland`s citizens political trust in the government can influence vaccination rates in Poland.
6. The effect of neighborhood is strong, because there are statistically significant differences between different counties in the level of vaccination percentage, and there is also a relationship with population density, which may indicate community interaction and influence on vaccination percentage*.*

Given the multiple factors influencing COVID-19 vaccine uptake in Poland, it is imperative to formulate strategic recommendations that address both systemic and community-specific barriers. By addressing the nuanced challenges of vaccine distribution and uptake, Poland can make significant progress in achieving widespread immunization and mitigating the impact of the pandemic. Below are some recommendations for the Polish government to help increase the level of COVID-19 vaccination in Poland:

1. Reduce the gap between Eastern and Western Poland by increasing vaccination infrastructure in the eastern part of the country and promoting vaccination in rural areas.
2. Educate 20-39 year old groups to increase their vaccination uptake, thereby helping to increase collective immunity in Poland. This will not only encourage individuals to be vaccinated, but also create the conditions for a village effect.
3. It is recommended to promote civic engagement so that more members of society would participate in elections and trust their elected government, relying on its encouragement to get vaccinated.

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