The impact of vaccine lotteries on COVID-19 vaccination rates: Evidence from Poland

Bachelor Thesis

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1 Introduction

In March 2020, the world came to a sudden stop due to the spread of COVID-19. Governments took drastic and unprecedented steps to slow the spread of the virus: Shops were shut down, schools and universities were closed and millions of workers had to work from their home office or kitchen desk.

Just a year after the first COVID-19 cases appeared in China, the first vaccines against COVID-19 were approved. With them came the hope of a return to normality and a severe reduction of the death toll of the pandemic. At the beginning of the vaccination effort in Europe, the supply of vaccines was not able to meet the demand at the necessary speed and scale (Bongardt & Torres, 2021). Therefore, a shortage of vaccines lead to rationing: Vaccines were only provided to the most vulnerable groups of the population, such as healthcare workers or the elderly. When vaccines became widely available, policymakers had to learn that a considerable share of people were hesitant or unwilling to receive the vaccine (Steinert et al., 2022). Globally, the COVID-19 vaccine was one of the most relevant and hotly contested topics of 2021, demonstrated by Google Trends[1], which placed the COVID vaccine as the 3rd most searched news story of the entire year of 2021.

The problem of vaccine hesitancy led governments to think in new ways again, with many deciding to offer various sorts of incentives to get vaccinated (Wyllie, 2023). One of these incentives were vaccine lotteries. A vaccine lottery, in the context of this thesis, refers to a lottery with cash or non-cash prizes, in which vaccinated people could participate at no additional cost, thereby acting as a possible reward for vaccination. Policymakers hoped that this would persuade additional people to get vaccinated, increasing the total vaccination rate of the population.

Several lotteries of this sort were implemented around the world, whose effects have been widely investigated. Dubé et al. (2022) analysed the effectiveness of a vaccine lottery in Québec (Canada) and found a small positive impact on vaccination rates. A survey, conducted by Jun and Scott (2022), concluded that a vaccine lottery in Australia successfully increased willingness to get vaccinated. Several lotteries have also been implemented in the US. Studies suggest that most but not all of the lottery programs in US states were successful in increasing vaccine uptake (Robertson et al., 2021; Acharya and Dhakal, 2021; Fuller et al., 2022). There have been three vaccine lotteries implemented in Europe, in Romania, Slovakia and Poland. Poland was the first European country to implement such a policy and offers good preconditions

[1] see https://trends.google.de/trends/yis/2021/GLOBAL/

(data availability, detailed information about the lottery) to investigate the effect of such a policy.

In order to spur the national vaccination campaign, the Polish government announced the lottery (Service of the Republic of Poland, 2021b) on May 25, 2021, around five months after the authorisation of the first COVID-19 vaccines in the EU and the subsequent start of the Polish vaccination campaign. It was open from July 1, 2021 until September 30, 2021. The main prize of the lottery was a cash prize of one million zł (zloty)[2], but it also included smaller cash and non-cash prizes and a lottery-like incentive scheme for municipalities.

Among with other vaccination incentives in Europe, Kuznetsova et al. (2022) shortly evaluated the effects of this lottery on daily vaccinations using a time-series model, suggesting a positive effect of the policy. To this day, there has however been no study evaluating the Polish vaccine lottery in detail. This thesis therefore adds a new case study to the existing literature on the effects of COVID-19 vaccine lotteries.

The quasi-experimental empirical analysis consists of two parts. To begin with, a regression discontinuity design was employed to evaluate the effect of the lottery on daily vaccinations, similar to the analysis of Kuznetsova et al. (2022). The objective behind a regression discontinuity design is to exploit the existence of a cutoff/threshold value. Using the day of announcement as the cutoff value, the effect of the lottery is estimated. The main analysis is conducted using the synthetic control method based on Abadie and Gardeazabal (2003), a popular method for comparative case studies. The idea behind the synthetic control method is to create a synthetic control unit as a combination of multiple control units (donor pool), to then estimate the average treatment effect of the policy/intervention. Out of a donor pool of six other Eastern European countries and using additional predictor variables, a synthetic control unit ("Synthetic Poland") is constructed to evaluate the effect of the policy on vaccination rates of both fully vaccinated and people with at least one dose. Data on daily vaccinations and vaccination rates (both fully vaccinated and at least one dose), published by the respective governments/government agencies and collected by Our World in Data (Mathieu et al., 2021) as well as additional data from Eurostat (2023) and the Wellcome Global Monitor, collected by Our World in Data (2020), are exploited for the analysis.

The empirical analysis finds no evidence for a significant increase in the share of the population vaccinated against COVID-19. It suggests that the lottery might have

[2]At the time of announcement on 25/05/2021, one million zł were equal to around 220,000 €, at an exchange rate of 0.22 zł to €

incentivized some people who would have gotten vaccinated anyway to do this earlier, to take advantage of the lottery, thereby potentially increasing the vaccination rate temporarily by around five percentage points.

Chapter 2 provides background information about the existing literature and the policy. Chapter 3 discusses the methodology and the data used for the empirical analysis. The results are presented in Chapter 4 and discussed in Chapter 5.

2 Background

2.1 Literature review

Incentives in public health

Tobacco and alcohol consumption, obesity, viral diseases: Governments are facing many challenges from a public health perspective. Behavioural economics can offer several ways to influence the decisions of individuals, in order to encourage socially desirable behaviour. The least severe form are nudges.

Nudging is a concept mainly brought to the public through the work of Thaler and Sunstein (2008). The authors define a nudge as an intervention that "alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives" (p. 6). Nudging can be applied in various ways, but it is often connected to health lifestyle topics, such as nutrition and diet (Ledderer et al., 2020). For example, in an experiment in Denmark (Friis et al., 2017), the objective was to promote the consumption of vegetables in the setting of a self-serving buffet, which included salads and other dishes in large bowls. As a nudge, the food environment was changed by arranging green plants and herbs around the food bowls. In a second experiment, salad was pre-portioned into smaller take-away bowls. The results showed that the intake of energy from vegetables of the participants can be increased by pre-portioning the salad. Although many studies evaluating the impact of nudges find positive effects of the respective interventions, these results should be interpreted with caution, since a lot of studies, including Friis et al. (2017), were conducted in the lab and may therefore not be reproducible in a real-world setting (Ledderer et al., 2020).

Besides nudging, policymakers can significantly change economic incentives. This has especially been applied in drug policy, for example regarding alcohol and tobacco consumption. Both in developed and developing countries, it has been shown that raising prices (through higher taxation) can lead to reduced consumption of tobacco (Yeh et al., 2017; Immurana et al., 2021) as well as alcohol (Daley et al., 2012).

Beyond taxation, governments could also use other financial incentives to motivate changes in individual behaviour, such as (small) cash payments or lotteries. Several meta-analyses found that such incentives can be successful in inducing behaviour changes at the individual level. For example, Giles et al. (2014) evaluated 16 studies on issues such as smoking cessation, health screenings, physical activity and vaccinations. The authors found that financial incentives are effective at encouraging healthy behaviour. This finding was also confirmed by Mantzari et al. (2015), who evaluated 34 studies and additionally concluded that this effect is stronger for the most deprived individuals, thereby possibly reducing health inequalities. Lotteries have also been shown to be effective in certain public health settings. Björkman Nyqvist et al. (2018) found that the introduction of a lottery program reduced HIV incidence in Lesotho. Lotteries also increased cycling (Ciccone et al., 2021) and walking activity (Patel et al., 2018) as well as participation in chlamydia screenings (Niza et al., 2014) under specific settings.

Incentives to increase COVID-19 vaccination rates

When a considerable degree of citizens were unwilling to get vaccinated in Europe (Steinert et al., 2022), governments thought about ways to encourage their citizens to get vaccinated, using incentives as well as other measures.

A very widely used tool were vaccine passports (e.g. in Europe (Niestadt & Claros, 2021). Access to social gatherings (e.g. restaurants, bars, clubs, stadiums), international travel and quarantine regulations was made subject to certified vaccination against COVID-19. Besides ethical concerns, for example potential disqualification of minorities from social life (Gostin et al., 2021), the evidence on the effectiveness of such regulations is mixed. A synthetic control analysis of six countries found that COVID passports were successful in increasing daily vaccinations in countries with lower than average vaccination rates. In other countries these regulations were less effective (Mills & Rüttenauer, 2022). In Eastern Europe, a comparison between Poland (very restricted use of COVID passports) and Lithuania (wide use of COVID passports) suggested a positive effect on vaccination rates (Walkowiak et al., 2021). It should be noted that COVID passports may also have negative effects on vaccine uptake, since frustration about reduced autonomy might lower willingness to get vaccinated (Porat et al., 2021).

Besides the carrot-and-stick approach, governments have also used nudges and economic incentives, such as cash payments and non-cash rewards to increase COVID-19 vaccination rates. Using a randomised control trial, Campos-Mercade et al. (2021) found that even "small" cash payments of around 24 US dollars can significantly increase vaccination rates, while small nudges, such as information about the safety and effectiveness of the vaccine, were not successful. While some studies also suggest a measurable positive effect of cash payments on vaccination rates (Wong et al., 2022; Klüver et al., 2021; H. Kim and Rao, 2021), there is also evidence against its effectiveness. Jacobson et al. (2022) suggested that neither behavioural nudges (reminder to get vaccinated via text message) nor cash payments could increase vaccination rates among the hesitant citizens. Sprengholz et al. (2021) also found that cash incentives did not increase willingness to get vaccinated.

A special version of economic incentives are lotteries. The majority of studies on COVID-19 vaccine lotteries dealt with lotteries in the US. Studies on vaccine lotteries in Louisiana and Massachusetts found different effects. Whereas the lottery in Louisiana increased vaccine uptake (Wang et al., 2023), a vaccine lottery in Massachusetts did not significantly increase vaccination rates, although prizes were higher (Y. Kim et al., 2023). When evaluating several state vaccine lotteries, the available evidence suggests that most, but not all of these policies were successful in increasing vaccine uptake (Robertson et al., 2021; Acharya and Dhakal, 2021; Fuller et al., 2022).

A specific focus can be observed with respect to Ohio. There are several studies evaluating the Ohio Vax-A-Million lottery (Ohio Department of Health, 2021), which was one of the first COVID-19 vaccine lotteries in the US. In total, a majority of the reviewed literature casts a positive light on the efficacy of the lottery. There have been four studies evaluating the lottery using the synthetic control method. These studies constructed a synthetic Ohio out of a donor pool of other US states. Three of these four studies found small positive effects of the lottery on vaccine uptake (Brehm et al., 2022; Barber and West, 2022; Sehgal, 2021) and one did not find a significant effect (Lang et al., 2022). Regarding studies using other methods, Mallow et al. (2022) also found a positive effect of the lottery on vaccination rates, while Walkey et al. (2021) did not find such an effect.

2.2 Institutional background

The Polish vaccination campaign started on December 27, 2020, when a nurse from a Warsaw Hospital received the first vaccine dose (Waligóra, 2021). Until September 2021[3], all of the vaccines approved by the EU (Vaxzevria (AstraZeneca), Comirnaty (Pfizer/BioNTech), Spikevax (Moderna) and Janssen (Johnson & Johnson)) were used for vaccinations. Citizens who wanted to get vaccinated had to register and select their preferred vaccine prior to the vaccination. In May 2021, the waiting time between the first and the second dose (Janssen required only one dose) was set at five weeks. In the first weeks and months of the vaccination campaign, vaccines were

[3]Vaxzevria and Spikevax were no longer used

only available to health care workers and senior citizens. By the start of May 2021, vaccines became widely available (Koschalka, 2021).

In general, vaccination rates in Poland have been low compared to the rest of the EU, with the Polish vaccination rate at around 50% by the end of October 2021, compared to an EU average of around 65%. In the context of Eastern Europe, vaccination rates have been relatively close to the average. Many Eastern European countries experienced relatively low vaccination rates (Mathieu et al., 2021). In the media, a general distrust into the government and a lack of educational campaigns (Vaccines Today, 2021) as well as chaotic and conflicting communication by government officials (Wanat, 2021) have been cited as potential reasons for the low vaccine uptake in Poland.

Table 2.1: The Polish vaccine lottery consisted of four types of draws and included cash and non-cash prizes

	Cash prizes	**Non-cash prizes**
Instant	$13,000 * 500$ zł $39,000 * 200$ zł	-
Weekly	$60 * 50,000$ zł	720 electric scooters
Monthly	$6 * 100,000$ zł	6 small vehicles
Main	$2 * 1,000,000$ zł	6 middle class vehicles

Source: Service of the Republic of Poland (2021b)

To increase vaccination rates, Poland decided to implement a vaccine lottery. The lottery, which is investigated empirically in this thesis, was open from July 1, 2021 to September 30, 2021. It was announced on May 25, 2021 (Charlish & Florkiewicz, 2021). The policy had two main elements: A lottery for all adult fully vaccinated people (two doses) (Service of the Republic of Poland, 2021b) and a monetary incentive scheme for municipalities (Service of the Republic of Poland, 2021a). The main prize of the lottery was a cash prize of one million zł (awarded twice), but it also included smaller monthly, weekly and daily cash prizes along with non-cash prizes (cars and electric scooters), amounting to a total cost of roughly 140 million zł (Wilczek, 2021). A detailed overview of the lottery is depicted in Table 2.1. Citizens were able to enter the lottery both online and by phone. It was organized by the state-owned polish lottery company Totalizator Sportowy, which also operates other popular lotteries in Poland. Poland's lottery can be seen as a mixture of different types of lotteries. Especially in the US, state governments have focused on lotteries with high rewards and relatively low winning probabilities (e.g. Ohio, Massachusetts with prizes of one million dollars). Another possibility could be the use of relatively low prizes (e.g. below 1000 dollars) with higher winning probabilities. The Polish policy included both relatively small prizes (instant prizes) but also larger prizes (main draw), thereby combining both elements. The vaccine lottery to be considered as the most similar to Poland's is the one implemented in Romania, in October 2021, which also included a similar mixture of larger and smaller prizes (Health Ministry of Romania, 2021).

As part of the monetary incentive scheme for municipalities, the municipality with the highest percentage of the vaccinated in the country received two million zł. Three other municipalities who had the highest percentage of the vaccinated in their respective comparison group[4] received one million zł each. 500 other municipalities, who were among the fastest in the country to reach a vaccination rate of 67%, won 100,000 zł each.

[4]There were three groups: Municipalities with a population of up to 30,000 people, cities with a population of 30,000 - 100,000 and large cities with a population above 100,000.

3 Methods and data

3.1 Regression discontinuity design

Regression discontinuity designs are a method to estimate treatment effects in settings in which the treatment assignment is determined by whether the running variable X_i exceeds a certain cutoff/threshold value c. Formally, the treatment status is defined as:

$$D_i = \begin{cases} 1 & \text{if } X_i \geq c \\ 0 & \text{if } X_i < c \end{cases} \tag{3.1}$$

In the application of the Polish lottery, the running variable X_i refers to the date and the cutoff value c to the announcement date of the lottery (May 25, 2021). Treatment therefore occurs once the lottery is announced. This specific application is an example of a sharp regression discontinuity design, in which the probability of treatment changes from 0 to 1 at the cutoff. The discontinuity of the treatment status around the cutoff allows for an examination of the two sides, by comparing the limits at the cutoff value. The treatment effect for the outcome variable Y_i at the cutoff is defined as the difference between these limits:

$$\begin{aligned} \tau &= E[Y_1 - Y_0 | X_i = c] \\ &= \lim_{x \downarrow c} E[Y_1 | X_i = c] - \lim_{x \uparrow c} E[Y_0 | X_i = c] \end{aligned} \tag{3.2}$$

In the application of the Polish lottery, the effect is estimated using a polynomial form. The identifying equation for the estimation, in which the specific functional form is left open, is given by:

$$Y_i = f(X_i) + \beta D_i + \epsilon_i \tag{3.3}$$

This can also be adjusted two allow for different functions to the left and to the right of the cutoff, which will be employed in this thesis:

$$Y_i = f_l(X_i) I\{X_i < c\} + f_r(X_i) I\{X_i \geq c\} + \beta D_i + \epsilon_i \tag{3.4}$$

3.2 Synthetic control method

The synthetic control method was first established by Abadie and Gardeazabal (2003) in order to investigate the economic effects of terrorism in the basque country and further developed by Abadie et al. (2010). Abadie (2021) is a summary of these prior developments as well as the requirements and inference methods and can be regarded as the basis of this section.

Synthetic control methodology has been applied widely in economics, but also in other social sciences such as political science. For instance, it has been used to evaluate the economic effects of European integration (Campos et al., 2019) or the effect of natural disasters on economic growth (Cavallo et al., 2013), by constructing synthetic control countries without European integration or natural disasters. It has also been used to investigate democratic backsliding (Meyerrose, 2020). Its area of application are comparative case studies, in which the comparison of two different cases can allow for conclusions about a certain policy or intervention, which might be present only in one of the two examined cases.

Formal definition

Researchers want to investigate the effect of a policy or intervention on a selected variable. The variable of interest is the outcome variable Y_{jt} for $J+1$ units from $t = 1$ to T. The first unit ($j = 1$) is the treated unit (treatment occurs for $t > T_0$), while all other units are untreated. The intervention (in this analysis the announcement of the lottery) occurs at $T_0 + 1$, meaning that there are T_0 pre-intervention time periods. There are a total of k predictors per unit, which include the pre-intervention observations of the outcome variable $(Y_{j1}, Y_{j2}, ..., Y_{jT_0})$ as well as additional time invariant unit level characteristics $\mathbf{Z}_j$ (as outlined in Section 3.2). These k total predictors can be summarized by the $(k \times 1)$ vectors $\mathbf{X}_j = (Y_{j1}, Y_{j2}, ..., Y_{jT_0}, \mathbf{Z}'_j)'$ for units $j = 1, ..., J+1$. It is then possible to combine all of the predictors of the untreated units, in order to obtain the $(k \times J)$ matrix $\mathbf{X}_0 = (\mathbf{X}_2, \mathbf{X}_3, ..., \mathbf{X}_{J+1})$[5].

The average treatment effect is defined as the difference between the potential outcome of the treated unit with intervention (Y^I_{1t}) and its potential outcome without

[5] $$\mathbf{X}_0 = \begin{bmatrix} Y_{21} & Y_{31} & \dots & Y_{J+11} \\ Y_{22} & Y_{32} & \dots & Y_{J+12} \\ \vdots & \vdots & \ddots & \vdots \\ Y_{2T_0} & Y_{3T_0} & \dots & Y_{J+1T_0} \\ \mathbf{Z}'_2 & \mathbf{Z}'_3 & \dots & \mathbf{Z}'_{J+1} \end{bmatrix}$$

the intervention (Y_{1t}^N):

$$\tau_{1t} = Y_{1t}^I - Y_{1t}^N \ \text{ for } \ t > T_0 \tag{3.5}$$

By definition, for $t > T_0$, the outcome with intervention is known and the outcome without intervention is hypothetical for the treated unit. To estimate the treatment effect, it is therefore sufficient to estimate Y_{1t}^N.

The simplest idea to estimate Y_{1t}^N might be the use of a difference-in-differences with matching approach. One could choose the closest unit j^*, the best single control (Doudchenko & Imbens, 2016), as the control unit. This best single control solves:

$$j^* = \arg \min_{j>1} ||\mathbf{X}_j - \mathbf{X}_1|| \tag{3.6}$$

Taking a difference then results in an estimator for the average treatment effect:

$$\hat{\tau}_{1t} = Y_{1t}^I - Y_{j^*t} \tag{3.7}$$

Using a single control approach does not seem like a desirable estimation method. Firstly, in many cases (including the Polish lottery) a single control does not achieve a good pre-treatment fit, especially when cross-unit differences are relatively large. Secondly, a difference-in-differences approach requires the parallel trend assumption, which might not hold in this setting. Parallel trend requires that without treatment, the difference between treatment and control group does not change over time. In the application of the Polish vaccine lottery, this means that the difference in the vaccination rates of Poland and country j^*, the closest unit pre-intervention, would have to be be constant if there were no lottery. Because of the large number of country specific factors influencing vaccination rates, changes in the gap between treatment and control unit seem relatively likely, thereby potentially violating the assumption.

The synthetic control method developed by Abadie and Gardeazabal (2003) proposes to use a weighted average of donor pool units as a synthetic control unit, thereby not experiencing the problems of a single control estimation (synthetic control does not require parallel trend assumption). The synthetic control and the following estimator for the average treatment effect are defined as:

$$\hat{Y}_{1t}^N = \sum_{j=2}^{J+1} w_j Y_{jt} \tag{3.8}$$

$$\hat{\tau}_{1t} = Y_{1t}^I - \hat{Y}_{1t}^N \ \text{ for } \ t > T_0 \tag{3.9}$$

The weights $\mathbf{W} = (w_2, w_3, ..., w_{J+1})'$ are chosen, such that the synthetic control matches as closely as possible the pre-intervention path of the predictors of the outcome variable for the treated unit. Consequently, the weights have to be chosen such that this difference is minimized. The optimal weights $\mathbf{W}^\star = (w_2^\star, w_3^\star, ..., w_{J+1}^\star)'$ solve:

$$\begin{aligned} \mathbf{W}^* = \arg\ \min \quad & ||\mathbf{X}_0\mathbf{W} - \mathbf{X}_1|| \\ \text{s.t.} \quad & w_j \in [0,1] \\ & \sum_{j=2}^{J+1} w_j = 1 \end{aligned} \tag{3.10}$$

This is subject to the weights being non-negative and summing up to one, a crucial assumption in the original framework proposed by Abadie and Gardeazabal (2003). In several extensions to this original framework (e.g. Doudchenko and Imbens (2016)), this assumption has been relaxed to allow for negative weights, it will however be kept in this thesis. It is then possible to plug in the optimal weights $\mathbf{W}^\star$ from the constrained minimization to obtain the estimated average treatment effect from (3.x):

$$\hat{\tau}_{1t} = Y_{1t}^I - \sum_{j=2}^{J+1} w_j^\star Y_{jt} \ \text{ for } \ t > T_0 \tag{3.11}$$

Inference

Based on Abadie et al. (2010), the most common way of inference in synthetic control is permutation, through the use of placebo effects. A synthetic control unit is constructed for all the untreated countries in the control group, as if there was a treatment for these countries. If the magnitude of the effect for the treated unit is extreme compared to the placebo synthetic controls of the untreated units, the effect can be regarded as significant. In order to perform this analysis, the gaps between the synthetic control and the actual outcome can be plotted for all selected countries ("placebo plot"), in order to visually compare the size of the effects. One potential problem of this concept is the difficulty of obtaining a satisfactory pre-treatment fit for all units in the donor pool, especially when making use of a relatively small donor pool. Additionally, inference based on visual interpretations can be considered as vague, since it does not rely on a quantitative measure, such as a p-value.

A possibility of quantification is to measure the ratio of the post-intervention fit relative to the pre-intervention fit. First of all, the root mean squared prediction error (RMSPE) of the synthetic control is defined:

$$R_j(t_1, t_2) = (\frac{1}{t_2 - t_1 + 1} \sum_{t=t_1}^{t_2} (Y_{jt} - \hat{Y}_{jt}^N)^2)^{\frac{1}{2}} \tag{3.12}$$

It is then possible to compute r_j, which measures the quality of the fit in the post-intervention period compared to pre-intervention and is given by the ratio of the post-intervention RMSPE and pre-intervention RMSPE:

$$r_j = \frac{R_j(T_0 + 1, T)}{R_j(1, T_0)} \tag{3.13}$$

A p-value can then be computed for the permuted test:

$$p = \frac{1}{J+1} \sum_{j=1}^{J+1} I_+(r_j - r_1) \tag{3.14}$$

where $I_+(\cdot)$ is an indicator function that returns one for non-negative arguments and zero otherwise.

Requirements

Several requirements should be fulfilled in order to obtain a valid synthetic control estimation, outlined by Abadie (2021). Firstly, the evaluated policy/intervention should - in principle - be able to produce a sufficiently large effect. When the effect of an intervention is too small, it may not be possible to distinguish this effect from other shocks to the outcome variable. Additionally, the volatility of the outcome variable should not be too high, to prevent “over-fitting”, meaning that the synthetic control might react to certain pre-treatment patterns of the outcome variable which could not be present post treatment (Hollingsworth & Wing, 2022), generating a biased estimation.

Secondly, there needs to be a suitable comparison/control group. Countries that are also subject to similar interventions or other shocks to the outcome variable in the given time frame, should be excluded from the donor pool. If this were not done, a negative shock to the outcome variable in one of the donor pool countries could lead to false conclusions. It could be mistakenly determined that the country of interest experienced a negative effect because of the examined intervention, which might only be the case because of the shock in one of the donor pool countries. Furthermore, researchers should try to select countries for the donor pool which are not too different from the treated country. Otherwise, it might be difficult to obtain a good fit of the synthetic control unit before the intervention.

Thirdly, it is crucial not to be subject to an anticipation effect, meaning that economic agents anticipate the enactment of a policy. In contrast, if agents were to anticipate the intervention before its actual implementation, the synthetic control analysis could not successfully estimate the investigated effect. Too many pre-treatment observations would then be used for the constrained minimization, which generates the weights of the synthetic control unit.

Next, there should be no spillover effects of the treated unit on untreated units. If this were the case, the post-treatment values of the synthetic control unit (which, by definition, consists of untreated units) would be affected by the treatment, thereby violating the basic principle of the synthetic control method.

Lastly, regarding the data, it is crucial to have a sufficient number of pre-treatment observations of the outcome variable, so that a satisfactory fit of the synthetic control unit can be obtained. A larger number of pre-intervention outcomes improves the fit of the synthetic control unit, increasing its robustness and interpretability.

Strengths and weaknesses

Applying the synthetic control method in comparative case studies offers several advantages (Abadie, 2021). Firstly the fit of the synthetic control is transparent. A graph of the actual unit and its synthetic control and a table such as Table 3.1, which presents the predictors of actual and Synthetic Poland, outline the differences between the two units, allowing for a quick evaluation of whether the use of a synthetic control is appropriate in this application. Transparency is also an advantage with respect to the composition of the synthetic control unit. A clear list of the different weights provides the opportunity to assess the fulfillment of some of the requirements of the synthetic control, e.g. the spillover effect. The problem of a possible spillover effect could be disregarded, if the country this might apply to has a weight of 0 or very close to 0. Another advantage might be that only pre-intervention outcomes are used to construct the synthetic control unit. This could prevent researchers from changing the specifications of the synthetic control to achieve a certain result (e.g. a significant result (p-Hacking)), after initially constructing it. Still, it has to be noted that it is possible to compare the results of different specifications and select the specification which is “preferred”, but the described advantage might make this more unlikely.

Besides these advantages, the synthetic control method itself also has some disadvantages and weaknesses (Bouttell et al., 2018). One disadvantage is that there is a lack of quantitative criteria for crucial requirements. As seen in Section 3.1, the similarity of donor pool countries is a relevant criterion for a valid synthetic control, there is however no clear definition of what exactly constitutes similarity. It is not uncommon that assumptions leave room for differing interpretations in econometric applications (e.g. exclusion restriction of an instrument in IV approach), but the argument of similarity can be made in many directions. Another possible problem is the judgement of the quality of the fit. There is no objective measure to evaluate the pre-treatment fit of a synthetic control unit, meaning that the evaluation is always subject to a possible bias of the researcher.

3.3 Data and approach

First, a regression discontinuity design is employed to evaluate the effect of the lottery on daily COVID-19 vaccinations in Poland, similar to the analysis by Kuznetsova et al. (2022) who also investigated this effect.

The data for this analysis as well as the main synthetic control analysis, which investigates the impact of the policy on the vaccination rates, is taken from a data set created by Our World in Data (Mathieu et al., 2021). This data set is a collection of the number of daily vaccinations, vaccination rates along with other vaccination-related indicators from all countries of the world, coming directly from the respective government/government agency and collected by Our World in Data. If provided by the governments, the data set offers a daily time series of the described indicators.

One of the most important aspects in the practical application of the synthetic control method is the choice of the donor pool. As outlined in Section 3.1, the treated country should not be an outlier compared to its control units. It is therefore sensible to select countries that are similar to Poland, both in general and, most importantly, with respect to their vaccination rates. Eleven Eastern European countries (BG, CZ, EE, GR, LV, LT, HR, HU, RO, SI, SK) were initial candidates for the donor pool[6], because of the resemblance in vaccination rates as well as a similarities in other variables (see Table 3.1). From this list, several countries are dropped, who implemented similar interventions or experienced other shocks to the vaccination rate in the given time frame: Greece (cash incentive[7]), Slovakia

[6]Austria was also considered, but its vaccination rate is high compared to the other potential donor pool countries and the general differences to Poland are relatively large (e.g. in terms of GDP per capita).

[7]see Koutantou (2021)

(lottery incentive[8]) and Romania (lottery incentive[9]). Estonia, Czechia and Slovenia implemented some small incentive schemes for general practicioners (Estonia and Slovenia)[10] and state employees (Czechia)[11], but these are not considered as a big enough shock to vaccination rates, since larger parts of the public were not directly targeted. Estonia, Czechia and Slovenia are therefore not removed. Lithuania offered a cash incentive[12] to its citizens, but only in October (after the end of the lottery), meaning that it does not have to be removed when restricting the analysis to an end date of September 30, 2021. Bulgaria organised a small raffle, giving out around 100 smartwatches to the vaccinated (Radio Bulgaria, 2021). Such a policy is not comparable to a full scale lottery (Poland, Slovakia and Romania) and should not have led to a large shock to the outcome variable, meaning that Bulgaria stays in the donor pool.

Another important aspect in the choice of donor pool countries is the availability of data. For most of the mentioned initial candidates, several observations are missing. Sometimes these missing values follow a specific pattern (e.g. Poland: observations are missing on Sundays in a specific time frame) while there is no specific pattern for other countries. Linear interpolation is used to replace the missing observations, by drawing a straight line between the two adjacent data points. Other imputation techniques were also considered. Some of these, such as last observation carried forward (LOCF) or mean imputation do not seem attractive in the given setting, since the vaccination rate is a monotonically increasing function.

It was not possible to obtain a reasonable trend for all of the countries using linear interpolation, namely for Croatia and Hungary. As a consequence, these two countries are also removed from the donor pool. The donor pool therefore consists of six countries: Bulgaria, Czechia, Estonia, Latvia, Lithuania and Slovenia.

In order to improve the fit of the synthetic control unit, additional predictors ($\mathbf{Z}_j$) are used. As seen in Section 3.1, the choice of these variables is crucial in determining the optimal weights of the synthetic control unit. GDP per capita, the share of elderly (over 65), the share of people (15-64) with tertiary education and population density are all relevant determinants of COVID-19 vaccine uptake (Viswanath et al., 2021; Walkowiak and Walkowiak, 2021). Data on these variables is taken from Eurostat (2023). Additionally, the share of elderly vaccinated against Influenza as well as trust

[8] see Lopatka (2021)

[9] see Health Ministry of Romania (2021)

[10] GPs were offered a cash incentive for a specific number of vaccinations (Baltic News Network, 2021; Slovenia Times, 2021)

[11] Additional holiday (Euronews, 2021)

[12] see Lithuanian National Radio and Television (2021)

Table 3.1: Predictors of Poland, Synthetic Poland and donor pool mean

	Poland	**Synthetic Poland**	**Mean donor**
GDP per capita[a]	$12,810$	$17,302.694$	$14,203.333$
Influenza vaccination rate[b]	0.104	0.170	0.156
Population density[c]	123.600	89.509	68.433
Share with tertiary education[d]	0.289	0.306	0.310
Share of elderly[e]	0.182	0.203	0.203
Trust in science[f]	0.872	0.884	0.877

[a] in USD, 2020 (Eurostat)
[b] among elderly (over 64), 2019 (Eurostat)
[c] in persons per km^2, 2019 (Eurostat)
[d] 15 to 64 years, 2020 (Eurostat)
[e] over 64 years, 2020 (Eurostat)
[f] 2020 (Wellcome Global Monitor)

in science are possibly additional indicators of vaccine openness. One would expect countries with higher Influenza vaccination rates (before the spread of COVID-19) to have higher COVID-19 vaccination rates, mainly due to a more prevalent culture of individual health prevention, specifically vaccines. A similar reasoning applies to trust in science. When citizens generally place more confidence in scientists, one would expect them to be more likely to get vaccinated (Rozek et al., 2021). Data on influenza vaccination rates is also extracted from Eurostat (2023), while data from the Wellcome Global Monitor, collected by Our World in Data (2020), is employed for the variable trust in science (share of people who answered “a lot” or “some” to the question “How much do you trust science?”).

Table 3.2: Slovenia takes up the largest weight of the synthetic control unit (share of the fully vaccinated)

Country	**Weight**
Bulgaria	0.043
Czechia	0.107
Estonia	0.005
Latvia	0.214
Lithuania	-
Slovenia	0.631

Another important aspect in the practical application of synthetic control methodology is the time of intervention. Although the actual lottery started on July 1, 2021, the time of announcement (May 25, 2021) is chosen as the time of intervention, since the date of completing the initial vaccination protocol (having received two doses) was not relevant for entry into the lottery. If the lottery had an effect, it would be expected to be observable from the time of announcement (plus a potential lag, since there is a waiting time between first and second dose).

In order to inspect the robustness of the synthetic control, two robustness checks are carried out. Firstly, the date of intervention is changed to the start of the lottery as well as backdated by one month, to assess the overall robustness but also to specifically investigate the presence of an anticipation effect. Secondly, a “leave-one-out” analysis is employed, with respect to the additional predictor variables and the donor pool countries. Each country and predictor is left out of the constrained minimization once, while holding all other specifications constant.

The data analysis was carried out in R using the synth and SCtools packages, generating Synthetic Poland. Table 3.1 shows descriptive statistics of the predictors of Poland, Synthetic Poland and the donor pool mean of the predictors. Table 3.2 presents the composition of Synthetic Poland, for the analysis of the share of the fully vaccinated, with the respective unit weights. The data and R scripts can be found in the corresponding GitHub repository [13].

[13]See appendix for further information

4 Results

To begin with, a regression discontinuity design is employed to estimate the effect of the lottery on daily vaccinations, using a cutoff of May 25, 2021 (announcement of the lottery).

Figure 4.1: Regression discontinuity analysis does not suggest increase in daily vaccinations around the day of announcemnt of the lottery

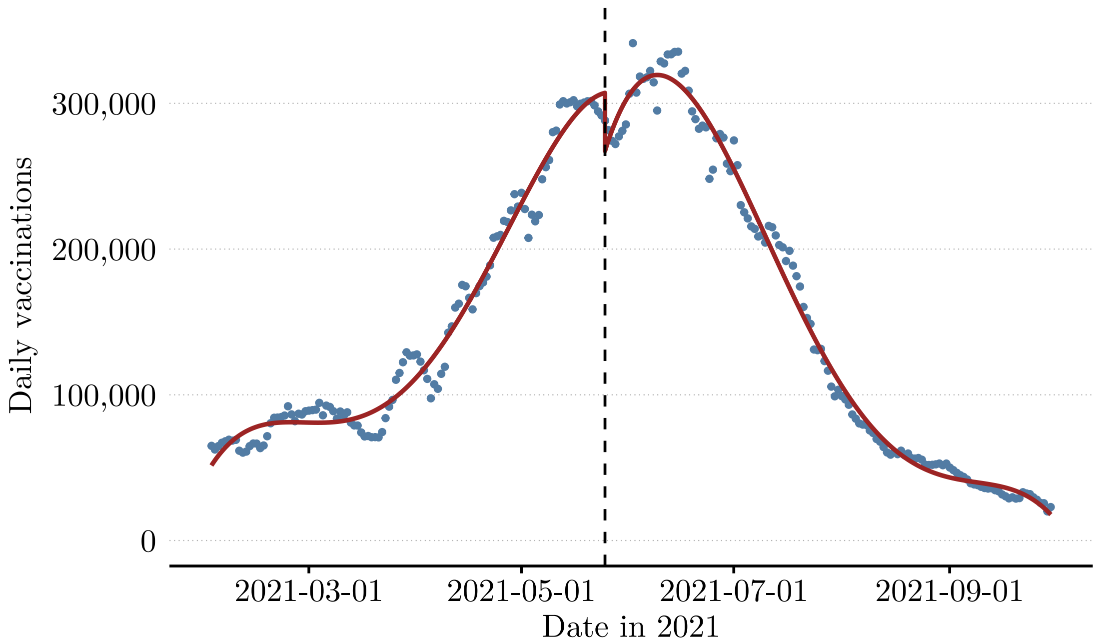
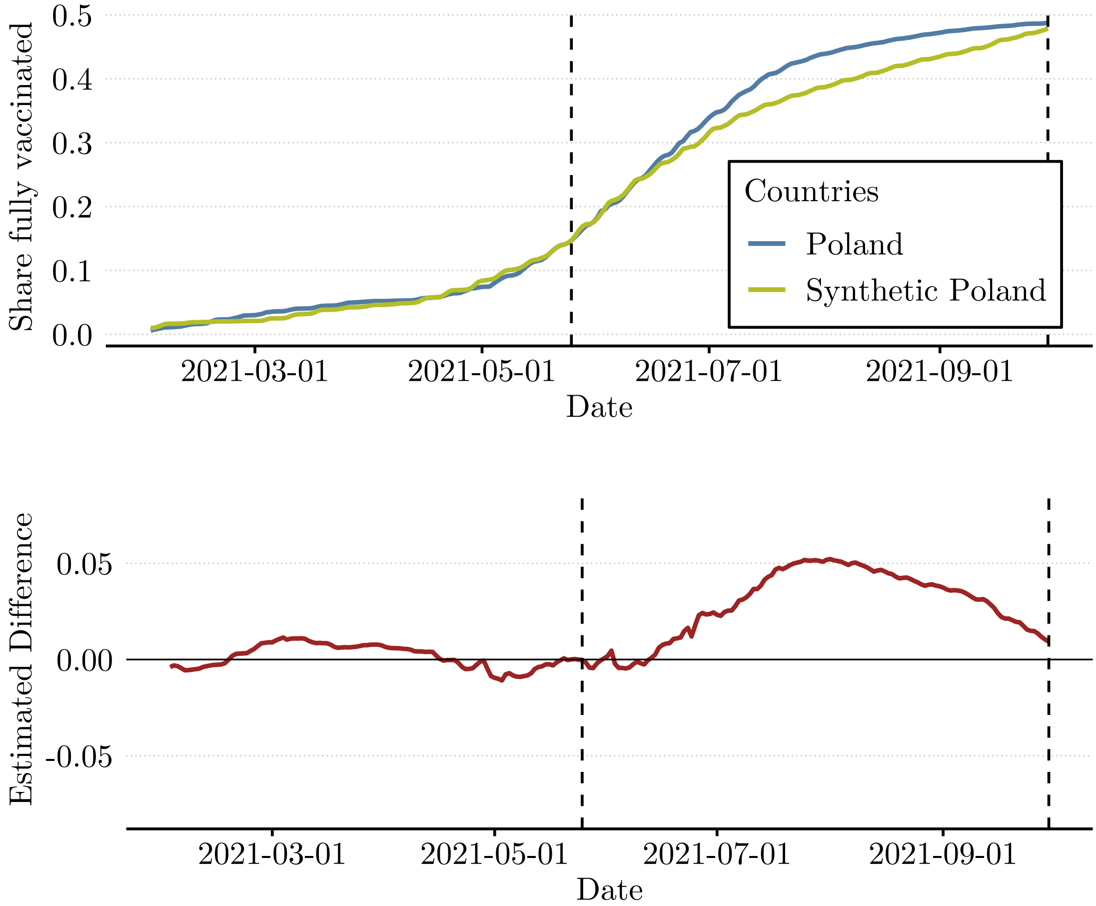


Figure 3.1 presents the results of the analysis. By comparing the intercepts at the cutoff, it can be observed that the lottery did not increase daily vaccinations at the time of announcement, with the difference in the limits being negative (point estimate: -39,788.34). As the figure shows, the lottery was announced when daily vaccinations were close to their all time high. A few weeks after the start of the lottery, there was a strong decrease in daily vaccinations. In order to make statements about the effect of the lottery on vaccination rates, a further analysis is needed to evaluate this effect specifically.

The synthetic control method is therefore applied, as described in Section 3.2. Figure 4.2 plots the vaccination rate (fully vaccinated) for both Poland and Synthetic Poland. The pre-treatment fit of the synthetic control unit is not perfect, but relatively good, with a maximum variation of around one percentage point from

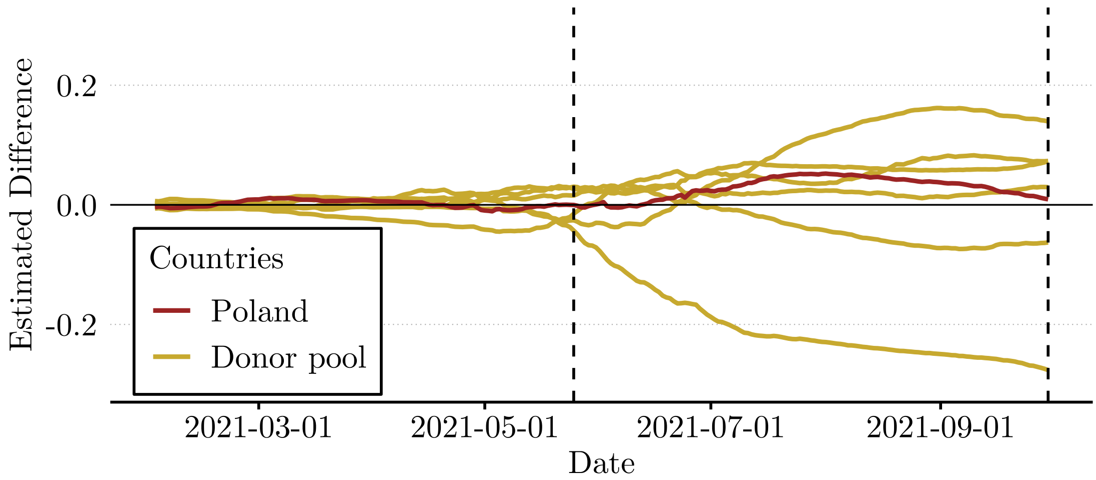
Figure 4.2: The synthetic control analysis of the share of the population fully vaccinated against COVID-19 shows a decoupling between Poland and Synthetic Poland, as well as a subsequent narrowing of the gap



actual Poland. Following a short lag after the intervention, a slow decoupling between Poland and its synthetic control unit can be observed. This difference continues to increase to a maximum of around five percentage points, around the end of July/beginning of August. As time progresses, the gap tends to decrease again, and by the end of September (end of the lottery), the vaccination rates of Poland and synthetic Poland are nearly back to the same level, with a remaining difference of around one percentage point.

In order to answer whether the estimated effect of one percentage points is statistically significant, it is necessary to employ the permutation based inference techniques discussed in Section 4.1. Figure 4.3 presents the placebo study. As observable, the magnitude of the effect of Poland is not comparably high. In fact, the effect for Poland is the least extreme of all of the selected units. This finding is also confirmed quantitatively. Using the discussed test procedure, a p-value of 0.5714 is obtained, meaning that the observed effect is not statistically significant. Therefore, the hypothesis that the lottery had no effect in increasing vaccination rates cannot be rejected.

Figure 4.3: Estimated differences between actual and synthetic control units do not suggest a signficant effect. The synthetic control units of the donor pool countries are placebos (constructed as if there was a treatment).

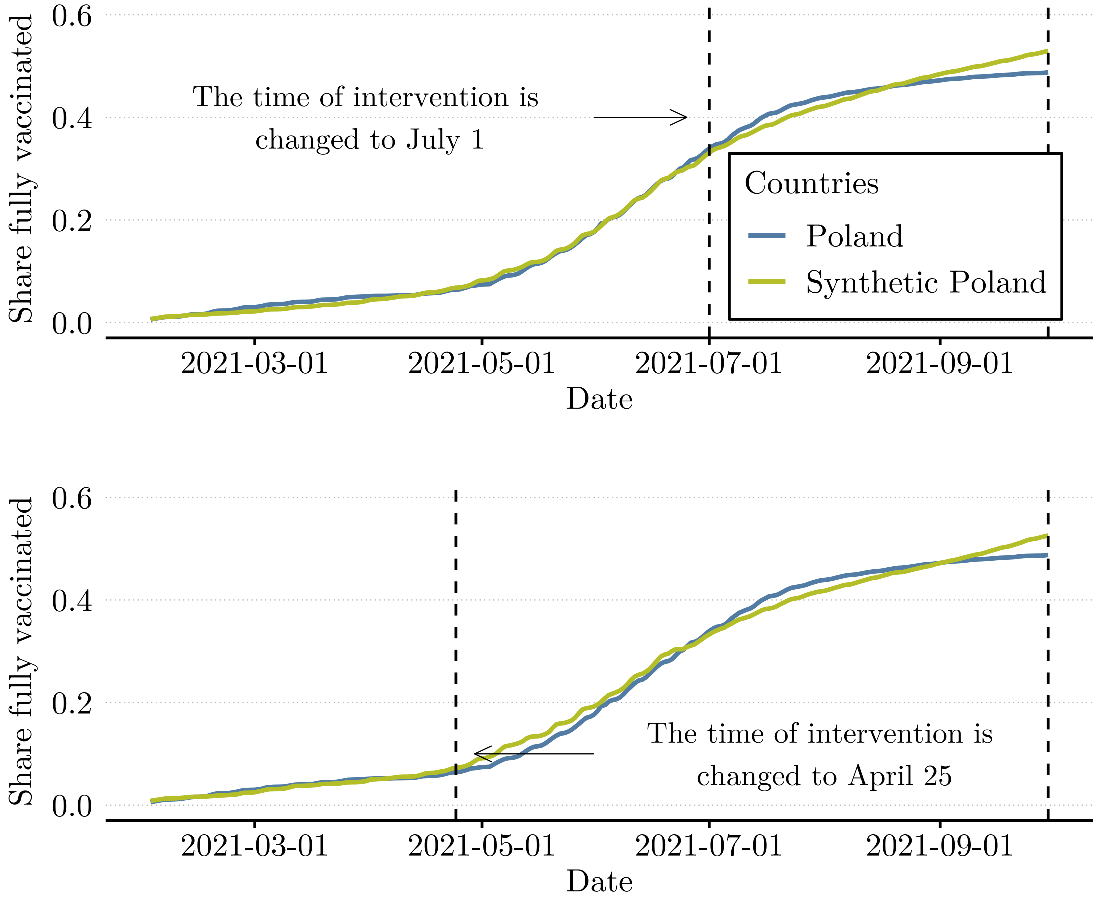


As introduced, a synthetic control analysis of the share of the population with at least one dose of any COVID-19 vaccination is also carried out. While the results show differing patterns compared to the presented analysis (possibly suggesting a negative impact of the lottery), there also seems to be no statistically significant effect, with a p-value of 0.1429. The corresponding figure can be found in the appendix.

Robustness checks

Next, the robustness of the synthetic control of the share of the fully vaccinated is assessed. Firstly, the time of the intervention is changed. As discussed earlier, there are two plausible intervention points: The announcement and the start of the lottery, with the announcement being the preferred option. In order to inspect how robust the synthetic control unit is, July 1, the start of the lottery is now used as the intervention point. As the upper panel of Figure 4.4 shows, changing the time of intervention from May 25 to July 1, 2021 has a considerable effect on the synthetic control unit (largest absolute change of a single weight: 0.631 (Slovenia)), but although the direction of estimated effect changes, this effect can also not be regarded as significant. Importantly, a lag after the announcement of the lottery is visible with both specifications.

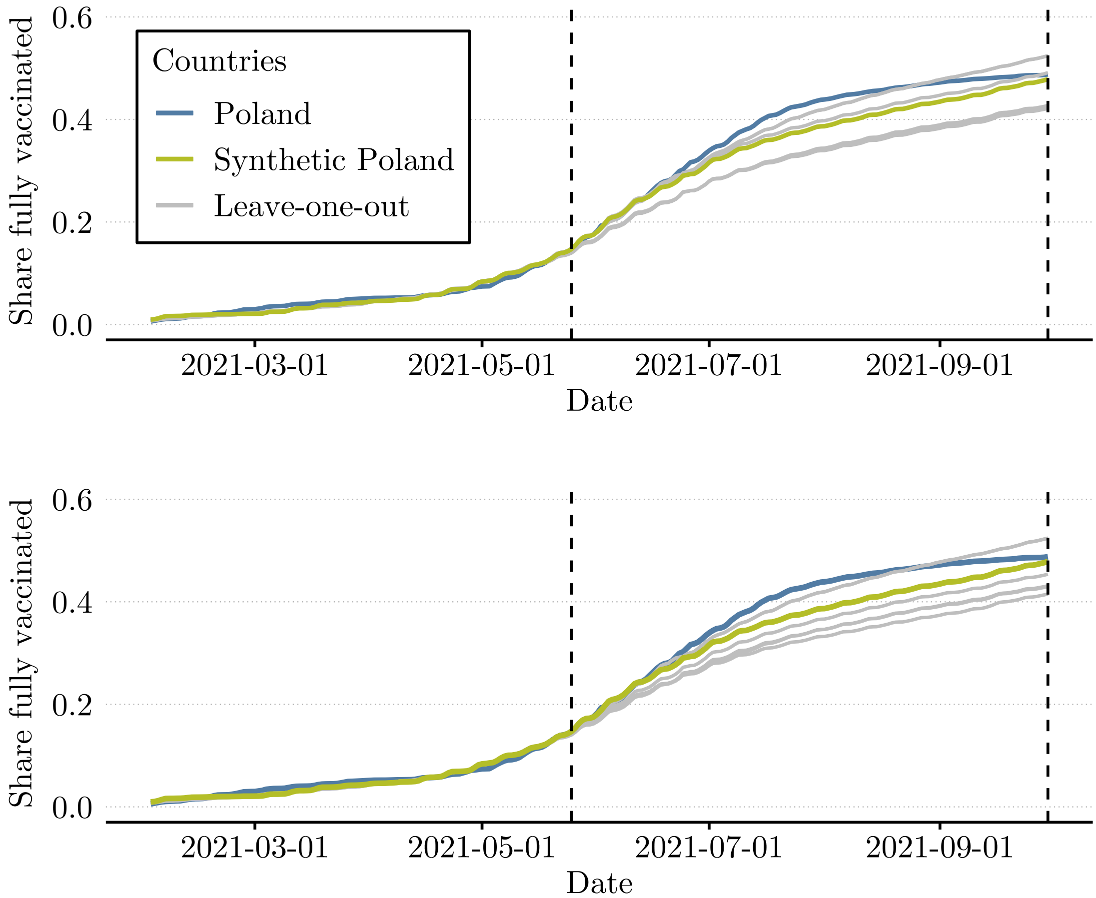
Figure 4.4: Changes in the time of intervention have considerable effects on the synthetic control unit, but the main conclusion remains unchanged



A second way of changing the time of intervention is backdating, meaning that the effect is estimated using an arbitrary earlier intervention time. If the synthetic control is robust, no drastic changes from the baseline result in figure 4.1 will be expected. A new synthetic control unit is therefore constructed, with a "fictional" intervention time one month (April 25, 2021) prior to the actual announcement. As observable in the lower panel of Figure 4.4, the changes are clearly visible (largest absolute change of a single weight: 0.827 (Estonia)), but the new synthetic control is still able to track the path of actual Poland until the intervention occurs relatively well. Similar to the first change of intervention time, the estimated effect is also not significant.

Another possible robustness check is to leave out certain predictors or countries. Figure 4.5 presents the result of a leave-one-out analysis of synthetic Poland, leaving out all of the predictors once, while keeping the others in, repeating the same with respect to donor pool countries (solving the constrained minimization with only five countries). This robustness check also shows considerable effects on the synthetic control unit. In both the upper and the lower panel of the figure, large differences (around ten percentage points) in the estimated effect arise.

Figure 4.5: Leave-one-out analysis with respect to predictors (upper panel) and donor pool countries (lower panel) generates large discrepancies in the estimated effect



5 Discussion

The results of the synthetic control analysis show that there was no statistically significant increase in the vaccination rate of the fully vaccinated. A similar analyses of the share of the population with at least one dose confirmed this main result, while also showing very different patterns. Additionally, the results of a regression discontinuity design, applied to daily vaccinations around the intervention date, do not suggest an increase in daily vaccinations around the day of announcement.

Interpreting the presented results is not easy, since the synthetic control becomes less reliable with increasing time after the intervention. One possible interpretation of the results pictured in Figure 4.2 might nonetheless be that people who would have gotten vaccinated anyways decided to do this earlier, to take advantage of the lottery. This could potentially explain the temporarily larger gap (decoupling between the two units and subsequent narrowing of the gap) between Poland and Synthetic Poland. So, while the lottery was not successful in getting more people vaccinated, it could have possibly induced people to get vaccinated earlier.

The robustness checks show that the main finding (no significant effect) is robust with respect to the time of intervention, thereby confirming that this application of the synthetic control method does not suffer from an anticipation effect. But, since considerable differences in the overall pattern of the synthetic control unit arise, the interpretability of Figure 4.2 is further diminished.

When performing the leave-one-out analysis, larger discrepancies (ten percentage points) in the estimated effect are observable, also with respect to its direction. Given the relatively low number of donor pool countries and predictor variables, this result is not particularly surprising and underlines the importance of the specification of a synthetic control analysis. Although making small adjustments to the specification of the analysis might seem trivial, it potentially changes the overall interpretation of the result quite considerably (direction of the effect).

There are several limitations of this application of the synthetic control method, restricting the internal validity of the results and the derived interpretation.

Firstly, the composition of donor pool countries is not ideal, with a low number of countries as well as considerable differences between the control units. As a consequence, the number of possible combinations of the weights is limited, e.g. compared to a synthetic control analysis of the lottery in Ohio (for example Barber and West (2022)), where all other US States (minus states that implemented similar policies) can in principle be selected for the donor pool. The low number of donor pool countries is also problematic for the inference procedure, since it is difficult to obtain a good fit of the synthetic control unit for six different countries, potentially also limiting the interpretation of the inference procedure: One of the placebo synthetic controls estimates a negative effect of more than 20 percentage points if there was a lottery in one of the donor pool countries. This seems to be very unrealistic. Therefore, not only the interpretability but also the main result itself (no significant effect), should be treated with caution.

Ohio is also a good example regarding the similarity between the treated unit and the donor pool units. Other US states are often very similar to Ohio, both in terms of general characteristics as well as vaccination rates (Mathieu et al., 2021). Although the donor pool countries in this thesis are selected to be not too different compared to Poland[14], cross-country differences are expected to be larger than cross-state differences. In total, the low number of donor pool countries and a restricted similarity between Poland and the donor pool limit the validity of the synthetic control analysis, since it might not have been possible to obtain an optimal fit of the synthetic control unit.

Secondly, the effect of the vaccine lottery might be too small to be relevant for a synthetic control analysis. The effect on vaccination rates that has been estimated for similar lotteries is often relatively small (e.g. Barber and West (2022): 1.5%). Poland's lottery offers more prizes, but a lower main prize than some lotteries in North America. It might therefore be conceivable that the effect of the given policy in Poland is too small for a synthetic control analysis, since the effect of the intervention might not be distinguishable from other relatively small shocks to the vaccination rate (e.g. a public marketing campaign to get vaccinated).

Another possible limitation of this analysis are the imputed values. As explained in Section 3.2, some countries in the donor pool did not report their vaccination rates on all days, including the country of interest (Poland). Although the results of the interpolation look reasonable for all of the donor pool countries, this might still have a negative effect on the credibility of the presented synthetic control, since undesired changes in the chosen weights of the synthetic control unit could have been caused.

At the same time, there are also requirements of the synthetic control which this application should fulfill. Firstly, no signs of an anticipation effect are observed, as discussed. Secondly, the possibility of spillover effects: There is no plausible argument for the presence of spillover effects. Since countries who adopted similar incentive policies were removed, no country in the donor pool used the Polish lottery

[14]See table 3.1 for a comparison between Poland and the average of the donor pool

as an example for similar action. Lastly, the number of pre-intervention outcomes does not represent a problem. The outcome variable is taken into account from February 1, 2021 until the day before the announcement (May 24, 2021). Since daily data is used, a total of 113 pre-intervention observations of the outcome variable are used, meaning that the number of predictors in the optimization is high (all 113 pre-intervention observations plus the additional predictor variables).

To improve the internal validity, two additional predictor variables were considered, but ultimately not selected. One of these was a "political variable", since differences in vaccine uptake exist across party preferences. While this problem might be the most well-known in the US (Ruiz & Bell, 2021), it is also believed to be a relevant predictor of vaccine uptake (even before COVID-19) in Europe (Schernhammer et al., 2022; Kennedy, 2019). But, when using other European countries as a donor pool, it is difficult to compare political beliefs across countries, mainly because of large differences in party ideologies. One could use the vote share for parties along the groups in the European Parliament, but this is not unproblematic: There are large differences between parties within certain groups[15] and the very wide political landscape in Europe may make differences in attitudes toward the COVID-19 vaccine very hard to compare.

Another predictor which was considered is trust in government, with the data also available from the Wellcome Global Monitor. Trust in government is potentially highly volatile. For example, when an unpopular government is replaced by a new government, this might increase the trust into the public sector dramatically in a very short time span. The problem of high volatility should have been especially pronounced in a time of crisis like the COVID-19 pandemic, where large variations in infection rates could have lead to quick changes in public opinion. While there may also exist deep-rooted cross-country differences in trust in government (e.g. possibly higher distrust in former soviet influenced countries compared to western countries (Costa-Font et al., 2021)), the presence of the described volatility means that the variable trust in government is not selected.

To summarize, it is important to note that the causal interpretation of the given results should not be overstated, because of the outlined threats to internal validity. As shown in Section 2.1, even when investigating the same lottery (Ohio), studies can show differing results, since the specification of the synthetic control analysis can have large consequences on the estimated effect. Regarding the external validity,

[15]For example, the Renew Europe group in the EP consists of liberal parties in a very broad sense, including both left of centre liberal parties and liberal-conservative parties.

this thesis presents only one case study of vaccine lotteries. While the results do not suggest a significant effect of the lottery on the vaccination rate, the applicability of these results on (at first glance) comparable policies is limited, mainly because of differences in the design of lotteries, initial vaccination rates as well as other country-specific predictors.

6 Conclusion

As seen, nudging and the use of economic incentives can be successful in inducing changes in individual health behaviour, e.g. increasing physical activity. Lotteries and other incentives may have also contributed to increasing vaccination rates in the COVID-19 pandemic, for example in Ohio, where several studies using the synthetic control method found positive effects on vaccine uptake (Mallow et al., 2022; Brehm et al., 2022; Barber and West, 2022; Sehgal, 2021).

In order to empirically assess the impact of vaccine lotteries on vaccination rates in this thesis, a vaccine lottery implemented in Poland, from July 1, 2021 to September 30, 2021 was examined. The lottery consisted of cash and non-cash prizes of around 140 million zł. To estimate the effect of this program on vaccination rates, the synthetic control method was selected. Synthetic Poland was constructed out of a donor pool of six other Eastern European countries.

The results of the main analysis show no signs of a statistically significant (p-value: 0.5714) increase in the vaccination rate (fully vaccinated) compared to the hypothetical scenario without the lottery. This main finding is also confirmed by a synthetic control analysis of the rate of the population with at least one dose of any COVID vaccination, as well as a regression discontinuity analysis of daily vaccinations around the announcement date, with both analyses not suggesting a significant increase. It can however be observed that vaccination rates (fully vaccinated) increase in the short-run, thereby possibly suggesting that people who would have gotten vaccinated anyways may have chosen to do this earlier, as a result of the lottery.

References

Abadie, A. (2021). Using synthetic controls: Feasibility, data requirements, and methodological aspects. *Journal of Economic Literature*, *59*(2), 391–425. https://doi.org/10.1257/jel.20191450

Abadie, A., Diamond, A., & Hainmueller, J. (2010). Synthetic control methods for comparative case studies: Estimating the effect of california's tobacco control program. *Journal of the American Statistical Association*, *105*(490), 493–505. https://doi.org/10.1198/jasa.2009.ap08746

Abadie, A., & Gardeazabal, J. (2003). The economic costs of conflict: A case study of the basque country. *American Economic Review*, *93*(1), 113–132. https://doi.org/10.1257/000282803321455188

Acharya, B., & Dhakal, C. (2021). Implementation of state vaccine incentive lottery programs and uptake of COVID-19 vaccinations in the united states. *JAMA Network Open*, *4*(12), e2138238. https://doi.org/10.1001/jamanetworkopen.2021.38238

Baltic News Network. (2021). Estonia to motivate vaccination with bonuses to vaccinators. Retrieved February 27, 2023, from https://bnn-news.com/estonia-to-motivate-vaccination-with-bonuses-to-vaccinators-226536

Barber, A., & West, J. (2022). Conditional cash lotteries increase COVID-19 vaccination rates. *Journal of Health Economics*, *81*, 102578. https://doi.org/10.1016/j.jhealeco.2021.102578

Björkman Nyqvist, M., Corno, L., de Walque, D., & Svensson, J. (2018). Incentivizing safer sexual behavior: Evidence from a lottery experiment on HIV prevention. *American Economic Journal: Applied Economics*, *10*(3), 287–314. https://doi.org/10.1257/app.20160469

Bongardt, A., & Torres, F. (2021). Europe's vaccine paradox: From supply to demand issues. *Intereconomics*, *56*(3), 130–131. https://doi.org/10.1007/s10272-021-0966-9

Bouttell, J., Craig, P., Lewsey, J., Robinson, M., & Popham, F. (2018). Synthetic control methodology as a tool for evaluating population-level health interventions. *Journal of Epidemiology and Community Health*, *72*(8), 673–678. https://doi.org/10.1136/jech-2017-210106

Brehm, M. E., Brehm, P. A., & Saavedra, M. (2022). The ohio vaccine lottery and starting vaccination rates. *American Journal of Health Economics*, *8*(3), 387–411. https://doi.org/10.1086/718512

Campos, N. F., Coricelli, F., & Moretti, L. (2019). Institutional integration and economic growth in europe. *Journal of Monetary Economics*, *103*, 88–104. https://doi.org/10.1016/j.jmoneco.2018.08.001

Campos-Mercade, P., Meier, A. N., Schneider, F. H., Meier, S., Pope, D., & Wengström, E. (2021). Monetary incentives increase COVID-19 vaccinations. *Science*, *374*(6569), 879–882. https://doi.org/10.1126/science.abm0475

Cavallo, E., Galiani, S., Noy, I., & Pantano, J. (2013). Catastrophic natural disasters and economic growth. *The Review of Economics and Statistics*, *95*(5), 1549–1561. https://doi.org/10.1162/REST_a_00413

Charlish, A., & Florkiewicz, P. (2021). Poland dangles lottery jackpot to boost COVID vaccination drive. *Reuters*. Retrieved February 1, 2023, from https://www.reuters.com/business/healthcare-pharmaceuticals/poland-dangles-lottery-jackpot-boost-covid-vaccination-drive-2021-05-25/

Ciccone, A., Fyhri, A., & Sundfør, H. (2021). Using behavioral insights to incentivize cycling: Results from a field experiment. *Journal of Economic Behavior & Organization*, *188*, 1035–1058. https://doi.org/10.1016/j.jebo.2021.06.011

Costa-Font, J., Garcia-Hombrados, J., & Nicińska, A. (2021, April 14). *The institutional origins of vaccines distrust: Evidence from former-communist countries* (preprint). In Review. https://doi.org/10.21203/rs.3.rs-400867/v1

Daley, J. I., Stahre, M. A., Chaloupka, F. J., & Naimi, T. S. (2012). The impact of a 25-cent-per-drink alcohol tax increase. *American Journal of Preventive Medicine*, *42*(4), 382–389. https://doi.org/10.1016/j.amepre.2011.12.008

Doudchenko, N., & Imbens, G. (2016). Balancing, regression, difference-in-differences and synthetic control methods: A synthesis. *NBER Working Paper No. w22791*. https://doi.org/10.3386/w22791

Dubé, È., Dionne, M., & Rochette, L. (2022). Exploring the impact of quebec's vaccine lottery and vaccine passports on covid-19 vaccination intention: Findings from repeated cross-sectional surveys. *Human Vaccines & Immunotherapeutics*, *18*(6), 2100168. https://doi.org/10.1080/21645515.2022.2100168

Euronews. (2021). Czech workers given extra holiday for having COVID jab. Retrieved February 27, 2023, from https://www.euronews.com/2021/07/30/czech-workers-given-extra-holiday-for-having-covid-jab

Eurostat. (2023). Eurostat database [Data from 2019 and 2020]. Retrieved January 10, 2023, from https://ec.europa.eu/eurostat/de/data/database

Friis, R., Skov, L. R., Olsen, A., Appleton, K. M., Saulais, L., Dinnella, C., Hartwell, H., Depezay, L., Monteleone, E., Giboreau, A., & Perez-Cueto, F. J. A. (2017). Comparison of three nudge interventions (priming, default option, and perceived variety) to promote vegetable consumption in a self-service buffet setting (G. Kunze, Ed.). *PLOS ONE*, *12*(5), e0176028. https://doi.org/10.1371/journal.pone.0176028

Fuller, S., Kazemian, S., Algara, C., & Simmons, D. J. (2022). Assessing the effectiveness of COVID-19 vaccine lotteries: A cross-state synthetic control methods approach (T. Pereira, Ed.). *PLOS ONE*, *17*(9), e0274374. https://doi.org/10.1371/journal.pone.0274374

Giles, E. L., Robalino, S., McColl, E., Sniehotta, F. F., & Adams, J. (2014). The effectiveness of financial incentives for health behaviour change: Systematic review and meta-analysis (H. R. Baradaran, Ed.). *PLOS ONE*, *9*(3), e90347. https://doi.org/10.1371/journal.pone.0090347

Gostin, L. O., Cohen, I. G., & Shaw, J. (2021). Digital health passes in the age of COVID-19: Are "vaccine passports" lawful and ethical? *JAMA*, *325*(19), 1933. https://doi.org/10.1001/jama.2021.5283

Health Ministry of Romania. (2021). Press release on vaccine lottery. Retrieved February 15, 2023, from https://www.ms.ro/2021/09/20/loteria-de-vaccinare-in-linie-dreapta/

Hollingsworth, A., & Wing, C. (2022, June 1). *Tactics for design and inference in synthetic control studies: An applied example using high-dimensional data* (preprint). SocArXiv. https://doi.org/10.31235/osf.io/fc9xt

Immurana, M., Boachie, M. K., & Iddrisu, A.-A. (2021). The effects of tobacco taxation and pricing on the prevalence of smoking in africa. *Global Health Research and Policy*, *6*(1), 14. https://doi.org/10.1186/s41256-021-00197-0

Jacobson, M., Chang, T. Y., Shah, M., Pramanik, R., & Shah, S. B. (2022). Can financial incentives and other nudges increase COVID-19 vaccinations among the vaccine hesitant? a randomized trial. *Vaccine*, *40*(43), 6235–6242. https://doi.org/10.1016/j.vaccine.2022.08.060

Jun, D., & Scott, A. (2022). Association between COVID-19 vaccination rates and the australian 'million dollar vax' competition: An observational study. *BMJ Open*, *12*(8), e062307. https://doi.org/10.1136/bmjopen-2022-062307

Kennedy, J. (2019). Populist politics and vaccine hesitancy in western europe: An analysis of national-level data. *European Journal of Public Health*, *29*(3), 512–516. https://doi.org/10.1093/eurpub/ckz004

Kim, H., & Rao, V. R. (2021). Vaccination diffusion and incentive: Empirical analysis of the US state of michigan. *Frontiers in Public Health*, *9*, 740367. https://doi.org/10.3389/fpubh.2021.740367

Kim, Y., Kim, J., & Li, Y. (2023). Did massachusetts COVID-19 vaccine lottery increase vaccine uptake? (J. A. Campbell, Ed.). *PLOS ONE*, *18*(1), e0279283. https://doi.org/10.1371/journal.pone.0279283

Klüver, H., Hartmann, F., Humphreys, M., Geissler, F., & Giesecke, J. (2021). Incentives can spur COVID-19 vaccination uptake. *Proceedings of the National Academy of Sciences*, *118*(36), e2109543118. https://doi.org/10.1073/pnas.2109543118

Koschalka, B. (2021). Poland to reduce wait between doses to five weeks for all covid vaccines. *Notes from Poland*. Retrieved February 15, 2023, from https://notesfrompoland.com/2021/05/10/poland-to-reduce-wait-between-doses-to-five-weeks-for-all-covid-vaccines/

Koutantou, A. (2021). Greece offers its young people cash and phone data to get COVID shots. Retrieved February 26, 2023, from https://www.reuters.com/world/europe/greece-unveils-incentives-boost-vaccination-rates-young-people-2021-06-28/

Kuznetsova, L., Diago-Navarro, E., Mathu, R., & Trilla, A. (2022). Effectiveness of COVID-19 vaccination mandates and incentives in europe. *Vaccines*, *10*(10), 1714. https://doi.org/10.3390/vaccines10101714

Lang, D., Esbenshade, L., & Willer, R. (2022). Did ohio's vaccine lottery increase vaccination rates? a pre-registered, synthetic control study. *Journal of Experimental Political Science*, 1–19. https://doi.org/10.1017/XPS.2021.32

Ledderer, L., Kjær, M., Madsen, E. K., Busch, J., & Fage-Butler, A. (2020). Nudging in public health lifestyle interventions: A systematic literature review and meta-synthesis. *Health Education & Behavior*, *47*(5), 749–764. https://doi.org/10.1177/1090198120931788

Lithuanian National Radio and Television. (2021). Lithuanian government approves 100-euro payments for seniors who get vaccinated. Retrieved February 27, 2023, from https://www.lrt.lt/en/news-in-english/19/1514375/lithuanian-government-approves-100-euro-payments-for-seniors-who-get-vaccinated

Lopatka, J. (2021). Slovaks to start lottery, offer bonuses to boost COVID-19 vaccination rates. Retrieved February 27, 2023, from https://www.reuters.com/business/healthcare-pharmaceuticals/slovaks-start-lottery-offer-bonuses-boost-covid-19-vaccination-rates-2021-07-02/

Mallow, P. J., Enis, A., Wackler, M., & Hooker, E. A. (2022). COVID-19 financial lottery effect on vaccine hesitant areas: Results from ohio's vax-a-million program. *The American Journal of Emergency Medicine*, *56*, 316–317. https://doi.org/10.1016/j.ajem.2021.08.053

Mantzari, E., Vogt, F., Shemilt, I., Wei, Y., Higgins, J. P., & Marteau, T. M. (2015). Personal financial incentives for changing habitual health-related behaviors: A systematic review and meta-analysis. *Preventive Medicine*, *75*, 75–85. https://doi.org/10.1016/j.ypmed.2015.03.001

Mathieu, E., Ritchie, H., Ortiz-Ospina, E., Roser, M., Hasell, J., Appel, C., Giattino, C., & Rodés-Guirao, L. (2021). A global database of COVID-19 vaccinations. *Nature Human Behaviour*, *5*(7), 947–953. https://doi.org/10.1038/s41562-021-01122-8

Meyerrose, A. M. (2020). The unintended consequences of democracy promotion: International organizations and democratic backsliding. *Comparative Political Studies*, *53*(10), 1547–1581. https://doi.org/10.1177/0010414019897689

Mills, M. C., & Rüttenauer, T. (2022). The effect of mandatory COVID-19 certificates on vaccine uptake: Synthetic-control modelling of six countries. *The Lancet Public Health*, *7*(1), e15–e22. https://doi.org/10.1016/S2468-2667(21)00273-5

Niestadt, M., & Claros, E. (2021, October 26). *Domestic use of EU digital covid certificates*. EPRS | European Parliamentary Research Service. Retrieved February

15, 2023, from https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/698763/EPRS_BRI(2021)698763_EN.pdf

Niza, C., Rudisill, C., & Dolan, P. (2014). Vouchers versus lotteries: What works best in promoting chlamydia screening? a cluster randomized controlled trial. *Applied Economic Perspectives and Policy*, *36*(1), 109–124. https://doi.org/10.1093/aepp/ppt033

Ohio Department of Health. (2021). Ohio vax-a-million details announced. Retrieved February 23, 2021, from https://odh.ohio.gov/media-center/odh-news-releases/odh-news-release-05-17-21

Our World in Data. (2020). Share of people who trust science, 2020. Retrieved February 1, 2023, from https://ourworldindata.org/grapher/share-people-trust-science?tab=chart

Patel, M. S., Volpp, K. G., Rosin, R., Bellamy, S. L., Small, D. S., Heuer, J., Sproat, S., Hyson, C., Haff, N., Lee, S. M., Wesby, L., Hoffer, K., Shuttleworth, D., Taylor, D. H., Hilbert, V., Zhu, J., Yang, L., Wang, X., & Asch, D. A. (2018). A randomized, controlled trial of lottery-based financial incentives to increase physical activity among overweight and obese adults. *American Journal of Health Promotion*, *32*(7), 1568–1575. https://doi.org/10.1177/0890117118758932

Porat, T., Burnell, R., Calvo, R. A., Ford, E., Paudyal, P., Baxter, W. L., & Parush, A. (2021). “vaccine passports” may backfire: Findings from a cross-sectional study in the UK and israel on willingness to get vaccinated against COVID-19. *Vaccines*, *9*(8), 902. https://doi.org/10.3390/vaccines9080902

Radio Bulgaria. (2021). Bulgaria’s ministry of health launches a raffle for vaccinated people. Retrieved February 22, 2023, from https://bnr.bg/en/post/101534199/bulgarias-ministry-of-health-launches-a-raffle-for-vaccinated-people

Robertson, C., Schaefer, K. A., & Scheitrum, D. (2021). Are vaccine lotteries worth the money? *Economics Letters*, *209*, 110097. https://doi.org/10.1016/j.econlet.2021.110097

Rozek, L. S., Jones, P., Menon, A., Hicken, A., Apsley, S., & King, E. J. (2021). Understanding vaccine hesitancy in the context of COVID-19: The role of trust and confidence in a seventeen-country survey. *International Journal of Public Health*, *66*, 636255. https://doi.org/10.3389/ijph.2021.636255

Ruiz, J. B., & Bell, R. A. (2021). Predictors of intention to vaccinate against COVID-19: Results of a nationwide survey. *Vaccine*, *39*(7), 1080–1086. https://doi.org/10.1016/j.vaccine.2021.01.010

Schernhammer, E., Weitzer, J., Laubichler, M. D., Birmann, B. M., Bertau, M., Zenk, L., Caniglia, G., Jäger, C. C., & Steiner, G. (2022). Correlates of COVID-19 vaccine hesitancy in austria: Trust and the government. *Journal of Public Health*, *44*(1), e106–e116. https://doi.org/10.1093/pubmed/fdab122

Sehgal, N. K. (2021). Impact of vax-a-million lottery on COVID-19 vaccination rates in ohio. *The American Journal of Medicine*, *134*(11), 1424–1426. https://doi.org/10.1016/j.amjmed.2021.06.032

Service of the Republic of Poland. (2021a). Competitions for municipalities are starting. Retrieved December 10, 2022, from https://www.gov.pl/web/szczepimysie/do-wygarnia-zdrowie-i-miliony-zlotych-ruszaja-konkursy-dla-gmin

Service of the Republic of Poland. (2021b). National lottery vaccination program. Retrieved December 10, 2022, from https://www.gov.pl/web/loteria

Slovenia Times. (2021). Government to promote vaccination by incentivising GPs. Retrieved February 27, 2023, from https://sloveniatimes.com/government-to-promote-vaccination-by-incentivising-gps/

Sprengholz, P., Eitze, S., Felgendreff, L., Korn, L., & Betsch, C. (2021). Money is not everything: Experimental evidence that payments do not increase willingness to be vaccinated against COVID-19. *Journal of Medical Ethics*, *47*(8), 547–548. https://doi.org/10.1136/medethics-2020-107122

Steinert, J. I., Sternberg, H., Prince, H., Fasolo, B., Galizzi, M. M., Büthe, T., & Veltri, G. A. (2022). COVID-19 vaccine hesitancy in eight european countries: Prevalence, determinants, and heterogeneity. *Science Advances*, *8*(17), eabm9825. https://doi.org/10.1126/sciadv.abm9825

Thaler, R. H., & Sunstein, C. R. (2008). *Nudge: Improving decisions about health, wealth, and happiness.* [Pages: x, 293]. Yale University Press.

Vaccines Today. (2021). Poland's vaccine scepticism – a european problem. Retrieved February 2, 2023, from https://www.vaccinestoday.eu/stories/polands-vaccine-scepticism-a-european-problem/

Viswanath, K., Bekalu, M., Dhawan, D., Pinnamaneni, R., Lang, J., & McLoud, R. (2021). Individual and social determinants of COVID-19 vaccine uptake. *BMC Public Health*, *21*(1), 818. https://doi.org/10.1186/s12889-021-10862-1

Waligóra, M. (2021). How does poland's COVID-19 vaccine rollout compare to other countries? *Notes from Poland*. Retrieved February 15, 2023, from https://notesfrompoland.com/2021/02/08/how-does-polands-covid-19-vaccine-rollout-compare-to-other-countries/

Walkey, A. J., Law, A., & Bosch, N. A. (2021). Lottery-based incentive in ohio and COVID-19 vaccination rates. *JAMA*, *326*(8), 766. https://doi.org/10.1001/jama.2021.11048

Walkowiak, M. P., & Walkowiak, D. (2021). Predictors of COVID-19 vaccination campaign success: Lessons learnt from the pandemic so far. a case study from poland. *Vaccines*, *9*(10), 1153. https://doi.org/10.3390/vaccines9101153

Walkowiak, M. P., Walkowiak, J. B., & Walkowiak, D. (2021). COVID-19 passport as a factor determining the success of national vaccination campaigns: Does it work? the case of lithuania vs. poland. *Vaccines*, *9*(12), 1498. https://doi.org/10.3390/vaccines9121498

Wanat, Z. (2021). Poland's vaccine skeptics create a political headache. *Politico*. Retrieved February 2, 2023, from https://www.politico.eu/article/poland-vaccine-skeptic-vax-hesitancy-political-trouble-polish-coronavirus-covid-19/

Wang, Y., Hernandez, J., & Stoecker, C. (2023). Moving the needle: Association between a vaccination reward lottery and COVID-19 vaccination uptake in louisiana. *Public Health Reports*, *138*(1), 68–75. https://doi.org/10.1177/00333549221120676

Wilczek, M. (2021). Poland announces million-zloty lottery to boost covid vaccine registration. *Notes from Poland*. Retrieved February 15, 2023, from https://notesfrompoland.com/2021/05/25/poland-announces-million-zloty-lottery-to-boost-covid-vaccine-registration/

Wong, C. A., Pilkington, W., Doherty, I. A., Zhu, Z., Gawande, H., Kumar, D., & Brewer, N. T. (2022). Guaranteed financial incentives for COVID-19 vaccination: A pilot program in north carolina. *JAMA Internal Medicine*, *182*(1), 78. https://doi.org/10.1001/jamainternmed.2021.6170

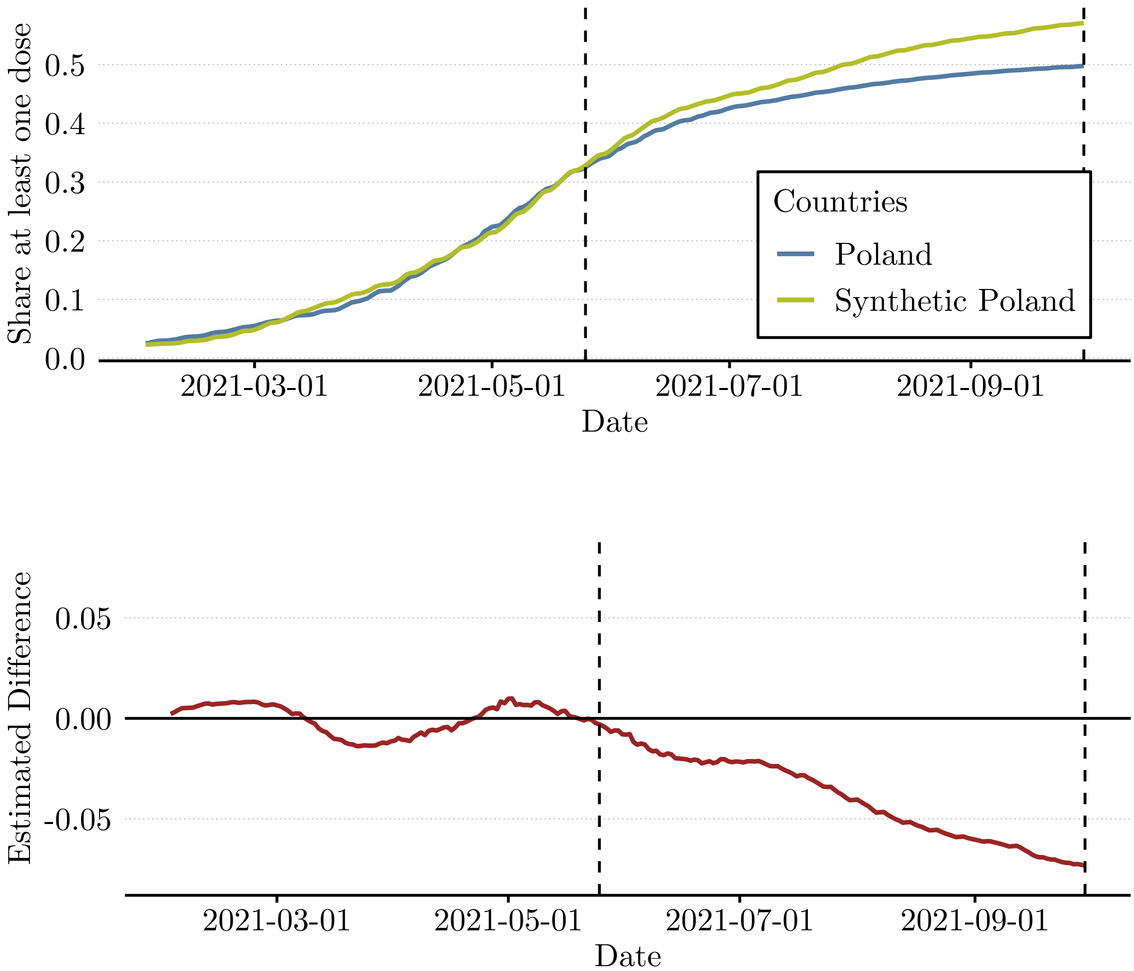
Wyllie, J. (2023). Jewellery, drugs and live chickens: The covid vaccine incentives on offer across the globe. *The Press and Journal*. Retrieved February 22, 2023, from https://www.pressandjournal.co.uk/fp/lifestyle/health-and-wellbeing/3378943/jewellery-drugs-and-live-chickens-the-covid-vaccine-incentives-on-offer-across-the-globe/

Yeh, C.-Y., Schafferer, C., Lee, J.-M., Ho, L.-M., & Hsieh, C.-J. (2017). The effects of a rise in cigarette price on cigarette consumption, tobacco taxation revenues, and of smoking-related deaths in 28 EU countries– applying threshold regression modelling. *BMC Public Health*, *17*(1), 676. https://doi.org/10.1186/s12889-017-4685-x

Appendix

GitHub repository: https://github.com/benediktstelter/bachelor_thesis
All of the data of the covariates and the R scripts used to analyse the data can be found in folder "scripts_data", along with some additional information in README.

Figure A.1: The analysis of the share of the population with at least one dose of any COVID vaccination shows different patterns, but also does not suggest a sginificant effect



Affidavit

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