CHARLES UNIVERSITY
FACULTY OF SOCIAL SCIENCES
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The Effect of Financial Incentives on Vaccination Rates: Quasi-Experimental Evidence from Slovakia.

Master's thesis

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Declaration of Authorship

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Prague, January 3, 2023

Peter Kravec

Abstract

This study examines the impact of financial incentives on vaccination against COVID-19. The researched intervention was provided to Slovak citizens who turned 60 by the end of 2021 at the latest. Depending on the order of the dose, they were paid a reward of €200 to €300. Using a regression discontinuity analysis with a control group of people who had been just below the bonus entitlement threshold, the result indicates a positive effect of incentives on vaccination rate in the group on the first, second and booster doses uptake. This incentive was paid to approximately 847,000 senior citizens at a total cost of €245 million. The number of people convinced can be estimated from 52,000 to 113,000. The number of saved lives may be estimated to range from 211 to 461. A comparison of benefits and the costs of the incentive indicates that the benefits did not exceed the costs.

JEL Classification	I12, I18, I1
Keywords	Financial incentives, Regression discontinuity, Benefit-Cost analysis, COVID-19, Vaccination
Title	The Effect of Financial Incentives on Vaccination Rates: Quasi-Experimental Evidence from Slovakia.

Abstrakt

Táto práca skúma vplyv, takzvaného, očkovacieho bonusu na zaočkovanosť proti COVIDU-19. Táto finančná incentíva bola poskytnutá Slovákom ktorí dovŕšili hranicu 60 rok, najneskôr k Decembru 2021. V závislosti od poradia dávky im bola poskytnutá finančná náhrada vo výške od €200 do €300. Použitím metódy regresnej diskontinuity a kontrolnej skupiny, ktorá hraničila s nárokom na získanie bonusu, bol zistení kladný štatisticky významný vplyv takejto finančnej incentívy na zaočkovanosť proti ochoreniu COVID-19. Tento vplyv bol prítom pri každej zo skúmaných dávok. Incentíva bola vyplatená približne 847,000 seniorom. Náklady na túto intervenciu dosahovali približne €245 miliónov. Počet presvedčených je možné odhadnúť na 52,000 až 113,000. Počet intervenciou zachránených životou je možné odhadnúť na 211 až 461. Napriek priaznivým výsledkom, porovnanie nákladov a benefitov nepriniesol dĺžkaz o návratnosti tohoto plošného opatrenia.

Klasifikace JEL	I12, I18, I1
Klíčová slova	Finančná incentíva, Regresná diskontinuita, COVID-19, Očkovanie, Analýza benefitov a nákladov
Název práce	Efekt Finančných Incentív na Zaočkovanosť: Kvázi-Experimentálny Dôkaz zo Slovenskej Republiky

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Motivation During the pandemic of COVID-19, we witnessed a strong anti-vaccination campaign, which resulted in a negative attitude towards vaccination against COVID-19. Slovakia was failling behind in vaccination against COVID-19, especially in the population of the most vulnerable and oldest residents, in comparison to others EEA countries. This unfavourable fact was fully manifested at the end of November 2021, with hospitals reaching capacity and the government forced to implement a lockdown. In response to the situation and uncertainty associated with the omicron variant of the coronavirus, the Slovak government introduced a financial incentive, i.e. vaccination bonus, for vaccination against COVID-19 for the elderly(60+) population. The amount of the financial incentive that was automatically paid to the authorized recipient depended on the vaccination status.

The measure therefore represents a large-scale experiment in which real rewards for vaccination were used. The effect of such large-scale measures has not yet been well studied and there is insufficient evidence for their effectiveness.

Hypotheses:

1. The financial incentive has a significant impact on vaccination with the first dose of the vaccine against COVID-19.
2. The financial incentive has a significant on vaccination with the second dose of the vaccine against COVID-19.
3. The financial incentive has a significant on vaccination with the booster dose of the vaccine against COVID-19.
4. The measure is effective in terms of financial costs incurred.

Methodology In the case of the first doses of vaccines, we will estimate the impact of the intervention on vaccination using regression discontinuity. we obtain this estimate as the difference in vaccination between the group that received the intervention and the one that was not entitled to it. We will confirm these results with the Bass diffusion model. For the second and booster doses, we will use only the RD design to estimate the incentive effect.

To estimate the benefit-cost ratio, we count all the costs related to vaccinations, i.e. the cost of the incentive plus the cost of the vaccination itself. As benefits, we count saved years of healthy life and saved hospitalization costs. Since vaccination against covid does not guarantee complete protection and its effect decreases over time, we calculate the benefit as the difference between individual doses over time. In the case of an unvaccinated resident, this calculation is obvious.

Expected Contribution: The effect of such large-scale measures has not yet been well studied and there is insufficient evidence for their effectiveness. This thesis provides such evidence and in a significant way enriches existing knowledge about the real functionality of similar measures.

The results not only enrich the literature on the functionality of financial motivations for vaccination against COVID-19 in the senior population but the thesis can also be used as a guide for evaluating other interventions that are associated with vaccination against COVID-19 and to evaluate their cost-effectiveness when parameters are changed. At the same time, the thesis can help in the more effective setting of public policies.

Outline:

1. Introduction to the topic and to the used methods.
2. Literature review.
3. Data: We will explain the structure of used data. We will also present data processing.
4. Financial incentives: We will introduce the reader to the financial incentives and settings to which the vaccination bonus in Slovakia is subject
5. Methodology: A more in-depth explanation of the statistical methods and method of calculation.
6. Results: We will present the obtained results in the order of the stated hypotheses.

7. Conclusion: We will summarize my findings and their implications for policy and future research.

Chapter 1

Introduction

During the pandemic of COVID-19, we witnessed a strong anti-vaccination campaign, which resulted in a negative attitude towards vaccination against COVID-19. Slovakia was failling behind in vaccination against COVID-19, especially in the population of the most vulnerable and oldest residents, in comparison to others EEA countries. This unfavourable fact was fully manifested at the end of November 2021, with hospitals reaching capacity and the government forced to implement a lockdown. In response to the situation and uncertainty associated with the omicron variant of the coronavirus, the Slovak government introduced a financial incentive, i.e. vaccination bonus, for vaccination against COVID-19 for the elderly(60+) population. The amount of the financial incentive that was automatically paid to the authorized recipient depended on the vaccination status.

The measure therefore represents a large-scale experiment in which real rewards for vaccination were used. The effect of such large-scale measures has not yet been well studied and there is insufficient evidence for their effectiveness. This thesis provides such evidence and in a significant way enriches existing knowledge about the real functionality of similar measures.

In the thesis, we use quasi-experimental methods to estimate how relatively high financial incentives helped to improve the unfavourable development in vaccination against COVID-19 in the population of seniors over 60. We start from the regression discontinuity design model in which we compare the vaccination of people just above the age threshold for receiving the bonus with people just below. Using the triangular kernel, we give a higher weight to those who are closer to the administratively chosen threshold of 60 years. The

chosen method may have several drawbacks that are related to the control group, namely capacity limitations, a feeling of unfairness and an artificially created image of the unnecessariness of vaccination. Some of them cannot be verified with complete certainty based on the available data. In order to control the distortion of the results from the title of the control group, it is possible to verify the results obtained by us with a synthetically created control group.
Last but not least, it is reasonable to assume that the decision to vaccinate would be less sensitive to additional financial motivation in older people. This assumption is based on the fact that with increasing age, the probability of a difficult course as well as death increases. For the elderly, we, therefore, work with two scenarios:

1. Constant effect of the bonus across age groups.
2. Constantly weakening effect of the bonus until the age limit of 75 years, when the bonus ceases to have an effect.

The results in the case of the first doses are also confirmed by the Bass model, with the help of which we tried to model a counterfactual scenario of what vaccination would look like below the threshold for bonus eligibility, as well as above this threshold without the vaccination bonus.

We also combine quasi-experimental results with cost-benefit analysis, what enables us to evaluate the measure not only from the point of view of the effectiveness of the financial incentive but also the overall cost-effectiveness of the measure. For the costs of vaccination against COVID-19, we take both the costs of the financial incentive and the costs of the vaccination itself, i.e. vaccination doses, administration of vaccination. As direct benefits, we consider saved years of a healthy life, saved costs for hospitalization in the case of a severe course of the disease, and the impact of increased vaccination on GDP.

The protection vaccines provide in terms of reduced probabilities of hospitalization and death are taken from the consensus literature. A life-year saved is valued in accordance with the Ministry of Health decree on the entry of new drugs into the market and expected years of life remaining for seniors in the control group are adjusted for quality. The value of prevented hospitalization of COVID patients is calculated using administrative data on payments to health insurance companies.

Due to the unavailability of data, some benefits of vaccination are omitted. In particular, it is about the following outpatient care that could be prevented by vaccination, which also including the costs of a long COVID. That creates not only additional costs for health care but also reduces the patient's productivity and his overall well-being. The calculation also does not include the costs of delayed health care for non-COVID pacients caused by the overcrowding of hospitals during the epidemic peak. Last but not least, we ignore the cost of sick leave, but these are negligible in relation to the target population. This omission might result in a slight underestimation of the overall benefits of the measure. On the other hand, overestimation of the effect of the measure due to the control group, decreasing effectiveness of vaccines and the possible overestimation of saved years of life in connection with comorbidities, may overestimate the estimated benefits.

In the thesis, we present an ex-post scenario in which the omicron variant dominates, and we also hypothesize an ex-ante scenario in which the omicron variant would have the same mortality and hospitalization risk as the delta variant. The second mentioned scenario is presented in view of the time of adoption of the measure when it was not yet known what characteristics the omicron variant would have, and there were just indications of its significantly higher infectivity compared to the delta variant.

Using the mentioned methods, we obtained statistically significant results, which indicate that the financial motivation was effective across all three doses (only marginally so in case of second dose) of the vaccine. In the area of cost-effectiveness, the measure fell short of expectations and the costs exceeded the benefits, depending on the scenario we used, in almost all cases.

Standard economic theory talks about the positive effect of financial(extrinsic) incentives on performance. Despite the theory, agents in economics do not always behave as rationally as one might expect. The question of the correct setting, cost-effectiveness, financial motivations and consequently their impact on vaccination, in general, was not widely covered by literature. The results not only enrich the literature on the functionality of financial motivations for vaccination against COVID-19 in the senior population but the thesis can also be used as a guide for evaluating other interventions that are associated with vaccination against COVID-19 and to evaluate their cost-effectiveness when parameters are changed. At the same time, the thesis can help in the more effective setting of public policies. Last but not least, as a general principle, we recommend targeting a similar intervention at smaller group of people before starting a comprehensive measure. A smaller experiment will help to refine the measure by setting its parameters and verifying its effectiveness on a representative sample, which can help prevent inefficient spending of public funds/resources.

The thesis is structured as follows:
In chapter 2, we provide a brief review of the literature, first, we briefly look at financial incentives from a general point of view, then we provide an overview of financial incentives in the field of health, and then we target the literature that deals with financial incentives in the field of vaccination against covid. In chapter 3, we present the data we use in our work, and also explain the data processing that had to be done. In chapter 4, we present the detailed setting of the vaccination incentive/vaccination bonus. In chapter 5, there is an overview of the methods used to estimate the effect of the regression discontinuity vaccination bonus and also the Bass model. In this chapter, we also explain how to calculate the Cost-benefit analysis. Chapter 6 provides a summary of the results, a review of imperfections and, last but not least, recommendations for further research in the given area.

Chapter 2

Literature

In the next chapter, we will briefly summarize the existing literature, first of all for financial incentives in general, then we will look at how financial incentives work in healthcare and, last but not least, we will look at how financial incentives had an impact on vaccination against COVID-19.

Angrist *et al.* (2009) evaluated strategies that were introduced for the purpose of increasing the academic results of freshmen at the university. Freshmen were divided into three groups. The first group received academic support services, the second had the opportunity to receive a financial scholarship. In the third group, participants could receive both a support service and a scholarship. The support service was used mostly by women and participants in the mixed group from the perspective of the intervention. The authors assessed that the female students who were part of the mixed group had better results. The authors also point to the fact that the students maintained these better results during the second year of study, while the intervention was provided only during the first year. What is more interesting is that no change was observed in male students.
Barrera-Osorio *et al.* (2019) examined the effect of three conditional financial transfers for secondary education. Socio-economically disadvantaged students from Bogota, Columbia were randomly divided into these three groups. One group had to postpone a third of the initiative. The second group received an incentive to enrol in tertiary education directly. The authors conclude that direct payment of the enrollment is not a better form of support than forcing to postpone a third of the incentive. On the other hand, the families that were forced to save had a higher share of enrollments at the four-years university. Compared to others, families that had paid tertiary enrollment had a higher

probability of enrolling in lower-quality colleges.

In this way, he summarized generally focused financial incentives in a comprehensive meta-analysis of ravens. The authors state that financial motivations do not always confirm their theoretical basis of effectiveness. After correction for publication bias, they came to the conclusion that only laboratory results are associated with statistically significant results.

2.1 Financial incentives related to health

Before we review the literature on the effectiveness of financial incentives in the field of health, it is worth mentioning that, according to Promberger & Marteau (2013), these incentives do not reduce intrinsic motivation. On the other hand, they also claim that, at the same time, the motivation to apply "healthy" habits is generally low. These findings can be applied especially to smoking cessation and a healthy lifestyle. Focusing on smoking van den Brand *et al.* (2021) claims that financial motivation works best together with medication and other factors at the same time. Cahill *et al.* (2015) claims that financial incentives work, however, only if they are continuous, i.e. if they are paid for abstinence from smoking. The authors also point out that these incentives work better with pregnant recipients, but with them, there is also a more significant assumption of intrinsic motivation for smoking cessation.
Angrist *et al.* (2009) evaluated financial incentives to support healthy habits. This incentive was launched in New York and its costs were estimated at approximately $42 million. Ex-post they evaluated the influence of financial motivation on gym attendance. The authors summarize the findings from two studies, in both of which they found a positive effect of the incentive on attendance compared to the control group. They mainly point to the fact that a greater effect was observed in people who did not visit the gym on a regular basis. In the second study, they directly focused on health indicators such as weight, waist size and heart rate. In this case, they found a positive impact of the measure on overall physical activity.

Financial incentives promoting vaccination against viral diseases such as influenza, Human papillomavirus (HPV) and hepatitis B show a significant increase in vaccination compared to the scenario without financial incentives. Bronchetti *et al.* (2015) conducted a study on more than 9,000 US students links a financial incentive with an 11 p.p. increase in influenza vaccination.

This increase represents a doubling of the reference vaccination rate.
Yue *et al.* (2020) investigates the impact of various high financial incentives on influenza vaccination in the senior population (65+). The authors divided the participants into 4 groups. 3 groups were offered a financial incentive in the amount of 10 to 30 Singapore dollars(SGD), while the participants had to cover the cost of the vaccine in the amount of 32 SGD. The baseline group received SGD 10 for completing the questionnaire. The authors found that it was most effective to give participants 20 SGD, as an increase to SGD 30 did not significantly increase vaccination rates. The effect of the financial incentive was estimated at approximately 7.5 p.p. Authors assess that the intervention was more effective for seniors who are no longer part of the labour market. Mantzari *et al.* (2015) investigated whether financial incentives can bring about the desired effect in HPV vaccination. The study was conducted on 17-18 year old British girls. The participants were offered a reward in the form of vouchers in the nominal amount of 56€. The authors point to the increased completion of vaccination, but the results still fell short of the required values, therefore the authors call for the consideration of other alternatives to achieve the desired goal.

Chakrabarti *et al.* (2021) examined the effect of conditional financial motivation to increase vaccination against tetanus. The research was conducted on a sample of approximately 200,000 people in India and found the effect of the financial incentive to be approximately 3. p.b. In the case of that measure, however, it must be noted that the financial reward was linked to a group of measures not exclusively for increasing vaccination against tetanus. It could be an indirect effect of the incentive.
In the case of Nigeria, Okoli *et al.* (2014) concluded that financial incentives had only a moderate effect on overall vaccination against tetanus. But the incentive was not related to the primary increase in tetanus vaccination, in this case, the incentive was provided if the participant attended antenatal care (ANC), skilled delivery and postnatal care. Therefore, it is rather an indirect increase in vaccination with the help of a stimulus. On the other hand, abc observed a positive correlation between the level of the financial incentive and the degree of its functionality in relation to tetanus vaccination. A randomized study was conducted in rural areas of Nigeria. For the group that was given an incentive of only 5 Nigerian nairas, the uptake rate was more than 54% at 300 nairas, the vaccination rate reached almost 76%, and at 800 nairas it was up to 85.5%. The authors declare an exchange rate of 150 nairas =$1. At the same

time, they claim that the results between the groups that received 800 and 300 nairas are statistically significantly different from the group with the claim of only 5 nairas. On the other hand, the study does not confirm or refute the statistically significant differences between the groups with a higher incentive (300 vs 800 nairas). The authors state that the biggest barrier to vaccination was the cost of travelling to get the vaccine.

Moran *et al.* (1996) investigated whether educational materials in the form of brochures, leaflets or lotteries for influenza vaccination work better. The authors investigated the effect on a sample of 797 patients who were randomly divided into 4 groups. One group was a control group and the other received a leaflet that highlighted important factors regarding influenza vaccination. In addition to the already mentioned groups, a notice was sent to the participants, which made vaccination against influenza conditional on receiving a lottery ticket. Participants could win in the lottery a grocery voucher. The last group received a combination of both mentioned nudges. The authors found a positive effect of renting educational material, the lottery also brought a significantly positive result. However, the combination of these measures did not lead to higher influenza vaccination rates.

Yokley & Glenwick (1984) focused on the vaccination of preschool children, researching 4 procedures that should encourage parents to provide them with vaccination. 1133 immunization-deficient preschool children were randomly divided into 6 groups. The first group received a prompt and a general prompt, the second also received a prompt, but focused more on the client. Another group had a specific prompt and increased public health clinic access. The next group received a specific prompt and a monetary incentive. The last two groups served as control groups, one control group was contacted but outside of the measures that were mentioned and the other was not contacted at all. Each of the 4 procedures, except for the general prompt, had a positive effect on vaccination. The authors also state that the group that received a financial incentive in addition to prompts performed the best among the other groups.

Birkhead *et al.* (1995) investigated the effect of several measures to encourage vaccination against measles. The study focused on newborns whose ages ranged from 12 to 59 months and who were eligible for measles vaccination. He divided the participants into 3 groups. The first group obtained an escort to a nearby pediatric clinic where the child could be vaccinated. The second group received WIC food vouchers more often, every month, compared to every 2 if their child was vaccinated. The last group received a passive referral for immunization. In the group that received food vouchers, it was 2.9 times more likely that the child was vaccinated compared to the control group. On the other hand, the authors state that the biggest improvement was in the group that got a ride to the clinic where the child could be vaccinated. In conclusion, the authors recommend a combination of escort and vouchers to improve vaccination against measles.

2.2 Financial incentives related to the vaccination against COVID-19

Several states tried to reverse the unfavourable development in vaccination against covid with a financial incentive. financial incentives were introduced more often in the United States, European states rather went in the direction of restrictions for the unvaccinated population, even if this also applies to some states in the US. In addition to direct financial incentives in the form of cash or vouchers for various goods and services, lotteries also appeared in the US. In the lotteries, it was possible to win classic financial prizes, but quite bizarre prizes were also drawn, such as a fishing license.

Regarding the general setting of financial incentives, Brewer *et al.* (2022) summarized, based on general knowledge of health behaviour, which incentive methods work best for vaccination against COVID-19, the authors underline the 3 most important recommendations. In general, the incentive must be certain and for everyone, what is explicitly against lotteries, whether financial or non-financial. Secondly, it must be delivered immediately. Last but not least, the recipient must appreciate it. The aforementioned fishing license may serve as an example, which may not be interesting for everyone in the target population. In line with these conclusions, Schwalbe *et al.* (2022) summarizes the lessons we have learned from the covid vaccination as well as other vaccinations. The authors state that the effect of cash or vouchers is only marginal and the effect on vaccine hesitancy is unconvincing. They state that lotteries do not have a consistently positive effect. In the case of non-financial incentives, no positive effect was demonstrated.

2.2.1 Lotteries

Acharya & Dhakal (2021) indicate that lottery incentives may be associated

with lower vaccine hesitancy and increased vaccination, but their success depends at least on the state in which they are implemented. Their claims are supported by the results of difference-in-difference (DiD) and augmented synthetic control (ASC) analysis. They used vaccination data obtained from the Household Pulse Survey (HPS) and also used daily vaccination data from 11 states that implemented a lottery and 28 states that did not.
Barber & West (2022) evaluated the lottery in Ohio, by creating a control group with states that did not implement it, they obtained an estimate that financial incentives increased vaccination by approximately 0.7 p.p. The authors state that the lottery cost approximately $68 per person they managed to convince, but they do not consider it cost-effective. This result was also confirmed by Sehgal (2021). The authors also looked at the lottery in Ohio, in contrast to Barber & West (2022), they obtained a higher effect of the lottery at the level of 0.98 p.p. They also state that the costs per person convinced are lower than in the case of Barber & West (2022), namely $49 per person convinced. Contrary to previously mentioned papers, Walkey *et al.* (2021) conducted an interrupted time series study using autoregressive segmented regression. Using the mentioned methodology, no significant influence of the lottery on vaccination was demonstrated.

On the other hand, Dave *et al.* (2021) and Sload *et al.* (2022) take into account 19 states in which the vaccination lottery was adopted and find out among them whether the announcement of this lottery led to an increase in vaccination. In the case of both studies, the authors did not find any statistically significant effect of the lottery on vaccination.
In line with this statement, Law *et al.* (2022) also did not show a statistically significant effect of the lottery on vaccination. The authors compared 15 states that implemented a vaccination lottery and 31 states that did not.

The results indicate that lotteries are not a guaranteed way to increase vaccination rates, on the other hand, the introduction of lotteries does not statistically significantly reduce the willingness to be vaccinated, as some might claim.

2.2.2 Incentives in the form of cash or vouchers

Campos-Mercade *et al.* (2021) studied how to set a nudge on the Swedish population. They divided the population into 5 equal groups, one representing the control group, while the others received either a financial incentive in different amounts or were presented with materials whose goal was to inform about vaccination against covid. The best of these alternatives was the financial incentive that increased vaccination against covid by approximately 4.2 p.p. compared to the control group.

Using a synthetic control group, Kim & Rao (2021) found a statistically significant effect of $50 prepaid cards on vaccination in Detroit. The prepaid card helped to increase the weekly rate of vaccination with the first dose from 0.86% in the control group to 1.25% of the previously unvaccinated, which represents an increase of almost 44.19%. However, this effect was not long-lasting and after 4 weeks the authors received a positive but statistically insignificant result of this measure. However, the authors did not indicate how this measure had an effect on the overall vaccination rate. At the same time, this measure did not speed up the pace of revaccination with the second dose.
Using a factorial survey experiment, Klüver *et al.* (2021) found a statistically significant hypothetical effect of a financial incentive in the amount of 25 euros. This effect was at the level of approximately 1 p.p., while at the level of €50 it was already 2.2 p.p. also significant. However, this study took place in Germany, where no financial incentive was in place. We say hypothetically because the authors focused on the intention to get vaccinated, not on actual vaccination. Contrary to Klüver *et al.* (2021), Sprengholz *et al.* (2021) also looked at the intention to vaccinate in Germany, in a hypothetical scenario with rewards for vaccination ranging from 25€to 200€, no connection was found between the rewards and the intention to vaccinate.
On the other hand, Sprengholz *et al.* (2022) states that a significant change in Germany would be brought about by a reward of 3,250€, however, such a monetary incentive requires high costs to put into practice and affects the cost-effectiveness of the measure itself, states the author.

Jacobson *et al.* (2022) found no proof of the functionality of the $10 or $50 incentive for vaccination uptake. The authors conducted research in California on a sample of more than 2,000 people. They also focused on other interventions such as different public health messages or a simple vaccination appointment scheduler. Health messages increased the intention to get vaccinated, but none of the interventions brought success in practice.
Andresen *et al.* (2022) about 346 individuals who previously refused vaccination, whether they could be vaccinated if a financial incentive were in force, and almost 27% said that they could be vaccinated under the condition of a $600 reward, if it was increased to $1200, this willingness would increase to 30%.

Participants who believed that they had already overcome COVID-19 wanted to be vaccinated to a greater extent under the conditions of a $1200 reward.

Chapter 3

Data

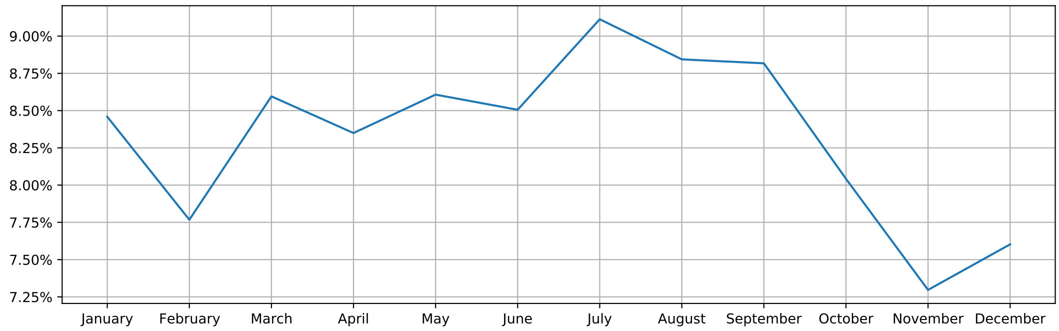
In this chapter, we introduce the data we have worked with. Demographic data are obtained from the statistical office of the Slovak Republic and from the united nations statistics division.
Source of the Data related to the vaccination bonus is Národné Centrum Zdravotníckych informácií (NCZI). To the national register, the data are reported by the health workers or by their support staff. We employed two data streams from the NCZI, the first one is the official GitHub of the NCZI, where are Covid datasets published for the public. The second dataset is available upon request.

3.1 Demographic Data

The source of demographic data on the population of the Slovak Republic is the Statistical Office of the Slovak Republic. We need information on the age distribution of citizens at the level of year and month, i.e. we need to know , how many citizens are precisely 60 years and one month old, etc. This information is later crucial for the RDD. The data provided by the Statistical Office alone are not sufficient to obtain desired information. To get the desired form of the population data, we employed the Register of Citizens(RoC). The RoC consists of the year and month of birth and the date of death. Since in the register there were more alive persons than was confirmed by the statistical office, we proceeded to recalculate of the data. Simply, we aggregated the data from the RoC on the annual level and compared them to the data provided by the statistical office. Once we have weights for the exact age, we are able to recalculate the population in the granularity of the month

Another way to do so is employing a dataset of Live births by month of birth from the united nations statistics division. The data for the Slovak Republic are available from 1988 until 2019. The weights are calculated as a share of born babies in a given month to the total number of born babies in the observed period. The weights are visualized on the following figure.

Figure 3.1: Distribution of newborns in months in the Slovak Republic from 1988 to 2019



Source: Author's visualization

In the case of employing the population weights calculated from the united nations statistics division. The result vaccination rate was quite spurious compared to the register of citizens, so afterwards we decided not to use the weights.

3.2 Data - Bass model

The entry data to the Bass diffusion model can be downloaded from the NCZI's GitHub as the open data in the form of .csv file. The data provides us with an overview of several key pieces of information about vaccination in the Slovak Republic. The number of doses is grouped by iso week, iso year, vaccine, gender, gender, age group, region district, and dose. The dataset is updated frequently. Updates consist of new data for the current week and corrections from previous weeks/months.

The Bass model is estimated based on the data from NCZI in weekly aggregation according to given age cohorts. When estimating the impact of the bonus using the bass model, as of 26/11/2021, we determined the population that could be convinced by the bonus as the population that had not been vaccinated until that time. This recalculation equalizes the differences between the sizes and the vaccination coverage between the individual age cohorts. In the event that we moved the start[1]of vaccination for a given cohort due to the fact that the given age cohort was not entitled to vaccination, we reflected this artificial increase in the eligible population for the first dose by deducting the people who were vaccinated before the start of the mass campaign.

These are hundreds of people who were given priority due to their profession. This number did not exceed 1.5% of the total population in the given age cohort[2].

3.3 Data - Regression discontinuity

The original dataset provided by the NCZI included the year and month of birth, gender, county code, date of first, second, third, and fourth vaccination and information on whether the vaccine was originally a single dosed or not The provided data set limits observations to only 55 to 66 years old citizens of the Slovak Republic who were vaccinated in the homeland. The original dataset set to be used contained 1.2 million observations.

To ensure data quality we had to preprocess data and delete some observations. Deleted observations belonged to at least one of the following categories:

- Missing date of birth.
- The individual dose was not administered chronologically, ie. the date of the first dose was later than the second one was.

The reason for the listed imperfections is that data was entered to the database manually by administrative workers in the mass vaccination centres.

3.4 Data procesing RDD

To ensure a credible result, we must transform the data from the raw dataset into the correct form. The key is to define the eligible population for the bonus and the population potentially convinced by the bonus, i.e. population that was vaccinated during the duration of the bonus. To do this, we need to merge several data sources into one (population, vaccination dataset). We calculate the age as of December 2021.

[2] At the beginning of the rollout there was a shortage of vaccines, we decided to fit data only on the part where the vaccine was publicly available.

[2] We assume that this fact did not disturb the diffusion process in the wider population

3.4.1 First doses

Firstly, we need to calculate how many citizens can get a vaccine, ie. population data in the structure of year and month.
Secondly, we are calculating how many citizens are vaccinated by the first dose (J&J vaccine included) until the bonus announcement, ie. 26.11.2021. The eligible population for the RDD is then calculated as population−Vaccinated until 26.11..
Thirdly, the possibly convinced population is determined as the population vaccinated during the bonus ie. the first dose obtained between 27.11.2021 and 31.1.2022.

The Vaccination rate (VR) entering the regression discontinuity model as the dependent variable is formulated as:

$$VR_{\text{First doses}} = \frac{\text{Possibly convinced population}}{\text{Eligible population}} \tag{3.1}$$

3.4.2 Second doses

We set the eligible population for the second doses bonus as a group which:

- Have the first dose before 26.11.2021 If one has the first after the date and before 31.1.2022 is entitled to the bonus for the first dose). If one has the J&J vaccine then it is not counted. **AND**
- (Have the second dose after 27.11.2021 (including)) **OR** (Do not have the second dose **AND** do not have the third dose.)

The second dose is required prerequisite to the third, so if one has the third dose and does not have the second dose it is spurious. It may be due to an administration error or the fact that the person may have taken the second dose abroad. abroad. Even in the case of vaccination abroad with the second dose and the third in the country, we cannot say whether it is among the eligible ones. Their consideration to the eligible population would cause an increase in the denominator, but not the numerator in the VR fraction.

The possibly convinced population is determined as:

- The date of the first dose is before 26.11.2021 (including). The same reason applies as in the eligible population. The J&J vaccine was excluded. **AND**

- The date of the second dose is between 27.11.2021 and 31.1.2022 (both including).

The Vaccination rate (VR) entering the regression discontinuity model as the dependent variable is then formulated as:

$$VR_{\text{Second doses}} = \frac{\text{Possibly convinced population}}{\text{Eligible population}} \tag{3.2}$$

3.4.3 Third doses

The number of administered booster doses is largely influenced by the previous development of the administered first and second doses, as registration was only possible after six months (later changed to three) from the completion of the original vaccination program, i.e. two doses. It is therefore better to compare age groups based on the share of booster doses given to the total number of people who were entitled to this dose in a given week

We set the eligible population for the third dose bonus as a group which:

- (The date of the second dose uptake is before 1.11.2021. (excluded) **AND** The date of the third vaccine is missing.) **OR**
- (The date of the second dose uptake is before 1.11.2021. (excluded) **AND** The date of the third vaccine is after 27.11.2021. (including)) **OR**
- (The date of the second vaccine is missing. **AND** The date of the third vaccine is between 27.11.2021 and 31.1.2022 (both included).)

The possibly convinced population is determined as:

- The date of the third dose is between 27.11.2021 and 31.1.2022 (both included).

The Vaccination rate (VR) entering the regression discontinuity model as the dependent variable is then formulated as:

$$VR_{\text{Third doses}} = \frac{\text{Possibly convinced population}}{\text{Eligible population}} \tag{3.3}$$

Chapter 4

Financial incentives

Before we move on to the financial incentive rules that we evaluated, it is necessary to mention a few pros and cons that policimakers should consider before implementing a similar measure.

Removal of the obstacles

Financial incentives remove potential obstacles for those who have to potentially spend significant financial resources, given their budget, to undergo an intervention. These costs e.g. travel expenses will be refunded. However, this argument is ancillary in the case of Slovakia, as the vaccine and its administration were fully covered by public health insurance. In the case of remote rural settlements, there was an outbound vaccination service in operation, which usually passed these settlements at least twice due to the characteristics of the vaccine substances.

A well-set financial motivation can also compensate, on average, for the mild discomfort (fever, nausea) that recipients can potentially face as a side effect after vaccination.

Short-term optimizations do not necessarily lead to a long-term optimum

When introducing financial incentives to increase vaccination rates, there is a risk of moral hazard in the future, as the recipient may later expect that his rational decision will be generously rewarded externally, and therefore that he will not only improve with the private benefit of improved personal health but also improve from the point of view of the overall financial wealth.

At the same time, measures set in this way can send a signal to them that if the state is not willing to compensate them for the intervention, then they do not really need it. However, these mechanisms are still not well-researched in the field of psychology.

Value for money

In the case of unprecedented financial incentives, the correct setting is key, the height of the incentive cannot be exceeded, because then the potential recipient can get the feeling that he is being "bribed" and the incentive set in this way will not have an effect on him.
At the same time, medium incentives will increase the loss of dead weight as this incentive will also be paid to someone who is in a counterfactual scenario, i.e. Without the incentive, e.g. vaccinated. In the case of underestimating the height, the consequence is obvious, i.e. that the desired effect, which the incentive was supposed to bring, does not occur. An example of good practice in relevant policies is considered to be the approach to research in laboratory conditions, where the correct setting of the approach is chosen and on the basis of which broad policies will be applied. Such program can help meaningful spending of public funds/goods.

Nevertheless, even in the case of a pilot program, it is not possible to set it quite correctly, for example, the mentioned long-lasting effects will not be possible to detect with such a pilot program. Eliminating such imperfections can be helped by a broad review process across scientific fields.

4.1 Financial incentives in Slovak Republic

After resolving the supply disruption that accompanied the beginning of mass vaccination, the Slovak Republic has started to lag behind the rest of the EEA countries in terms of vaccination against COVID-19.

The summer of 2021 brought no change. At that time the Slovak Republic was still at the tail of EEA in the vaccination uptake in the most vulnerable groups. The government tried to motivate people to get vaccinated until the Delta variant of the Coronavirus became dominant.
To that end, the government decided to introduce the vaccination lottery, as many US states had done before. In addition to the lottery, the government had implemented also an intermediation bonus for anybody who convinced the unvaccinated person to get a jab. Bonus amount from €30 to €90 depended on the age of the convinced. Vaccination resistance was too high and the schemes did not lead to any or a negligible increase in the number of newly vaccinated citizens.

Low vaccination coverage led to the overload of the healthcare system, consequently to the third Slovak lockdown. At the time of the announcement of the lockdown, the Omicron variant was first observed in South Africa. The uncertainty about the severity of the newly discovered variant and pressure on the hospitals resulted in the introduction of the vaccination incentive, marked as a vaccination bonus in the text.

4.2 Scheme of the vaccination incentive

Unlike previous financial incentives implemented by the Slovak government, the newly introduced was well targeted at the vulnerable population, seniors who reached the age of 60 by the end of 2021. The target group was paid an amount of €200 or €300 , depending on the vaccination status. Only a person, who satisfied age condition and who had a permanent or temporary residence in the territory of the Slovak Republic and at the same time completed vaccinations in Slovakia against COVID-19 was entitled to the bonus.
The first mention of the policy was on 26.11.2021. Since then several changes

had been made. The final version, which was approved by the parliament had the following structure[1]:

€200 for seniors who completed the second dose from 30.6.2021 to 31.1.2022 (seniors vaccinated with the second dose before 30.6.2021 could receive a bonus of €300 if they received the booster dose by 31.1.2022).

€200 for seniors who completed the first dose from 25.11.2021 to 31.1.2022 (seniors vaccinated with the first dose before 25.11.2021 could receive a bonus of €200 if they received the second dose by 31.1.2022).

€200 for seniors who received vaccination with a single dose vaccine before 15.1.2022 and by 15.3.2022 they received vaccination with a second (booster) dose.

€300 for seniors who received a booster dose before 31.1.2022.

The vaccination bonus was paid to 847 000 seniors at total cost €245 million. The largest part of expenses 92% consists of expenses for a €300 bonus paid to seniors who completed the booster dose.

	Bonus value	Number of recipients	Costs
Booster dose	€300	753 354	€226 006 200
Second dose	€200	53 210	€10 642 000
First dose	€200	38 969	€7 793 800
Single dose	€200	1 452	€290 400
Total		846 985	€244 732 400

Table 4.1: Expenditure on vaccination bonus for seniors

The data in Table 4.1 are as of 21.9.2022. The number of recipients and expenses may still change very slightly due to the updating of data from NCZI. The data for the 1st dose also includes people who managed to complete the second dose in the specified period, as they were already entitled to a bonus of €200 by virtue of having completed the 1st dose, so the decision to be vaccinated with the 1st dose could have been influenced by the bonus.

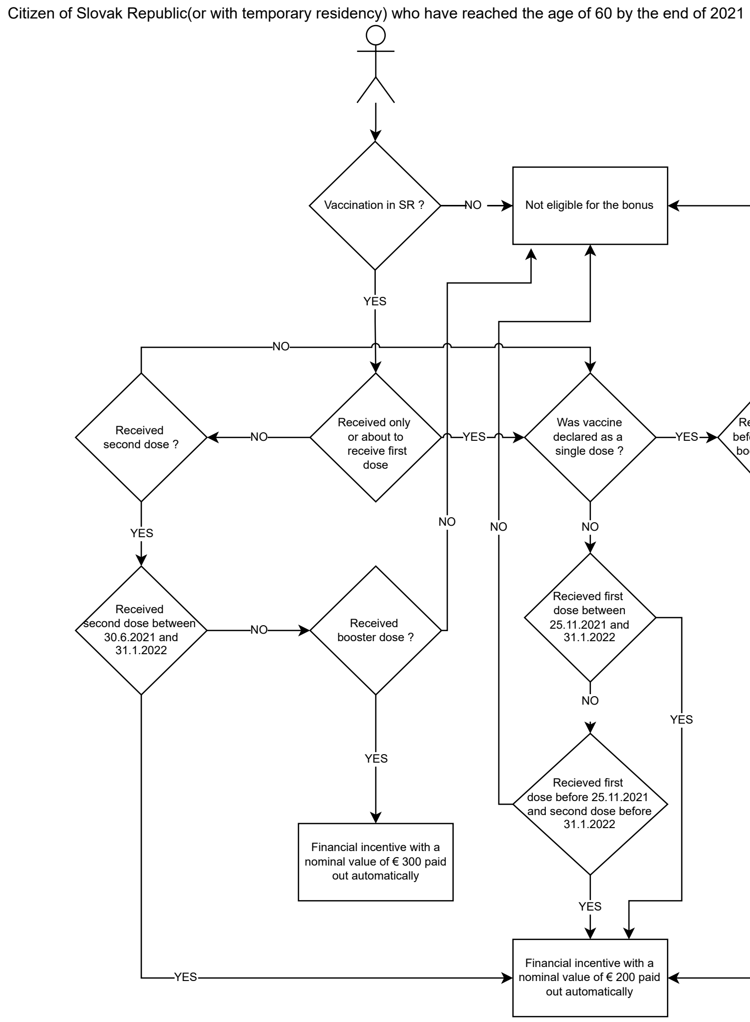
The structure implies that many citizens, who had been vaccinated before the announcement, regardless of the dose, were eligible to receive the bonus. Such a setting is generous and led to the widespread distribution of public

[1]The scheme is vizualized in Figure 6.3

funds. From the perspective of Cost-Benefit Analysis (CBA) the population which had been vaccinated before the start of the program is net cost and brings no benefit[2], i.e. deadweight loss.

[2]From the perspective of the CBA analysis. Vaccination still brings personal benefits.

Figure 4.1: Vaccination bonus scheme



Source: Author's visualization

Chapter 5

Methodology

In the following chapter, we focus on the used methodology. A brief introduction to Diffusion theory - Bass Diffusion model, Regression discontinuity design analysis and Cost-Benefit analysis. Besides main approaches, there were used statistical tests to confirm the assumptions.

5.1 Cost Benefit Analysis

The Cost-Benefit Analysis method, usually abbreviated CBA, is used to evaluate public sector projects. The method compares the benefits, which express any positive effects, with the costs or damages, which affect the negative effects of the policy.

The essence of the method is the analysis of the impact of the investment on the involved entities, the quantification of the detected effects and further the transfer to a financial unit. After that, we can use the criterion indicators of net present value, return, profitability index and payback period. [1]

5.1.1 Costs

Costs associated with the policy are the sum of vaccination costs and costs of the incentive based on the vaccination status of the participant.

[1] https://managementmania.com/sk/analyza-nakladov-a-prinosov-cba-cost-benefit-analysis

5.1.2 Benefits

To quantify the benefits of policy is to quantify the benefits of vaccination. Vaccination reduces the risk of severe cases and also reduces the risk of death. Vaccination also brings a reduction of the cost related to outpatient care and to subsequent patient care[2].
Higher vaccination rates can be also beneficial for GDP by reducing lockdown periods. The pressure on hospitals would be much lower in the scenario where a significant number of vulnerable people, mainly seniors, would be vaccinated. Lower pressure on hospitals would decrease waiting times, reduce the number of preventable deaths, and increase the quality of patients' lives.
Last but not least, the sick leave period is also shortened. This benefit is marginal considering the goal population (retirement age cohorts).

Since the protection by vaccination is not 100%, the vaccinated population has also a non-zero probability of severe cases or death. The difference between probabilities of the unfavourable outcome can be understood as a yield of the dose:

1. Benefits of the first dose = expected cost of illness of an unvaccinated senior - expected cost of illness of a senior vaccinated with one dose after 28+ days.

2. Benefits of the second dose = expected cost of disease of a senior vaccinated with one dose after 28+ days - expected cost of disease of a senior vaccinated with two doses after 0-3 months.

3. Benefits of a booster = expected cost of disease for a senior vaccinated with two doses at 25+ weeks - expected cost of disease for a senior vaccinated with a booster at 0-3 months.

Expecting costs of disease can be quantified based on the existing literature on vaccine effectiveness in conjunction with Slovak legislation and a cost report published by NCZI. Unfortunately, we are not able to include all of the benefits we mentioned in the benefits section. Costs of deferred healthcare during pandemic waves deserve considerable attention, but due to insufficient data and the nature of the matter, the calculation is not included. During writing the thesis we did not receive any access to the dataset of outpatient care nor to the

[2]Long covid is also included in the subsequent care of the patient.

subsequent care thus we were not able to compare this cost between vaccinated against the unvaccinated population and include it in the calculations.

Not including these costs has consequences that lead to a slight underestimation of the yield from the policy.

5.1.3 Expecting cost of illness

We are focusing mainly on the occurrence of severe outcomes of the illness, i.e. difficult course of the disease and death. Important inputs into the calculation are costs associated with hospitalization and lost years of life lived in health.

Costs associated with lost years of life

The damage caused by premature death is calculated financially at an average of 46,453 euros for one lost year of life lived in full health. This value is based on the decree of the Ministry of Health of the Slovak Republic no. 93/2018 Coll.[3]on the criteria for determining the significance of the drug's impact on public health insurance funds, on the evaluation criteria for the calculation of the coefficient of the threshold value and on the details of the calculation of the coefficient of the threshold value. This decree regulates the entry of new medicines into the market and establishes the conditions under which the new medicine can be covered by public health insurance. For the calculation, the maximum possible threshold value of the drug was used, set at 41 times the average wage in the Slovak economy from two years ago in 2020 (1,133 euros).

This amount is multiplied by the expected number of remaining years of life (depending on life expectancy) in each age group adjusted for quality of life and converted to a present value using a discount rate of 3.5% per year. The quality adjustment takes into account the fact that, on average, health status worsens with age, regardless of Covid-19. For this reason, the value of a year of a senior's life is, on average, lower than the value of a year of life lived in full health. The adjustment is based on British data (Briggs *et al.* (2021)), which probably overestimates the damage caused by premature death, as the British live on average more years in health than Slovaks. We used the ratio between QALE and LE in Table 1 in the mentioned study, with the parameters SMR=1 and qCM=1. This is a conservative estimate that does not take into account the fact that those who died of Covid-19 suffered to a greater extent

[3]https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2018/93/20180401.html

from associated diseases that reduced their quality of life. The claim is based on findings of Ferenci (2021).

Average costs for hospitalization of COVID patients in Slovak Republic

In the period from December 2021 to February 2022, the average costs of public health insurance for the hospitalization of a COVID patient ranged from 1,330 euros to 1,793 euros, depending on the age group (Table 5.1).

Age group	Cost (EUR)
40-49	1330
50-59	1365
60-69	1431
70-79	1793
80+	1443

Table 5.1: Average costs for hospitalization of COVID patients (Dec. 2021 to Feb. 2022)

Mentioned costs are multiplied by the probability that a senior infected with the virus will end up in the hospital or die. Since this probability is influenced by age, virus variant, vaccination status and length of time since the last dose, the expected costs of the disease vary significantly across these variables.

Method of calculating the probability of hospitalization or death after infection

In the thesis, we use two scenarios, the first "ex-post" scenario, which represents a situation in which the dominant variant of the coronavirus was omicron and the corresponding probabilities.

The second "ex-ante" scenario is that at the time of the adoption of the policy, the emerging omicron variant is at least as unfavourable from the point of view of the probability of death and hospitalization as was the dominant delta variant until then. This scenario is relevant from the point of view of evaluating the decision to introduce a vaccination bonus for seniors since at the time of this decision there was no information about the new, more infectious but less dangerous Omicron variant.

The methodology and principle of calculation do not differ across the variants, because only other parameters adapted to the variant enter the model. In the next part, we will therefore introduce the method of calculation that we used in the CBA analysis, the resulting table for the Omicron variant of the coronavirus is presented at the end of the subsection. The table for the Delta variant of the coronavirus can be found in the Appendix.

The basis for estimating probabilities is data on hospitalizations and deaths in Slovakia by age during the second wave of the pandemic at the beginning of 2021, before the widespread availability of the vaccine, when the alpha variant of the virus dominated[4]. The probability of hospitalization/death was estimated as the proportion of hospitalizations/deaths to the estimated total number of infected persons in a given period. The number of infected persons was estimated as four times the number of positive PCR tests. Fourfold was chosen based on the result of the Rippinger *et al.* (2021) and Böhning *et al.* (2020). Mentioned papers claimed, that the actual number of cases is roughly two to three times the number of detected cases.The higher chosen multiple compared to the studies takes into account the fact that the volume of testing in Slovakia was lower in the mentioned period than in the countries from which these studies originate, as well as the fact that the results of antigen tests were not included in the calculation due to the risk of double counting and also relatively higher error rate[5].

The probability of hospitalization and death of unvaccinated persons was subsequently updated on the basis of literature in view of the spread of new variants of the virus[6].

Several studies indicate that the Delta variant is more virulent and the probability of hospitalization and death is approximately twice that of the alpha variant. The modification chosen by us takes into account the results from the article Bast *et al.* (2021).

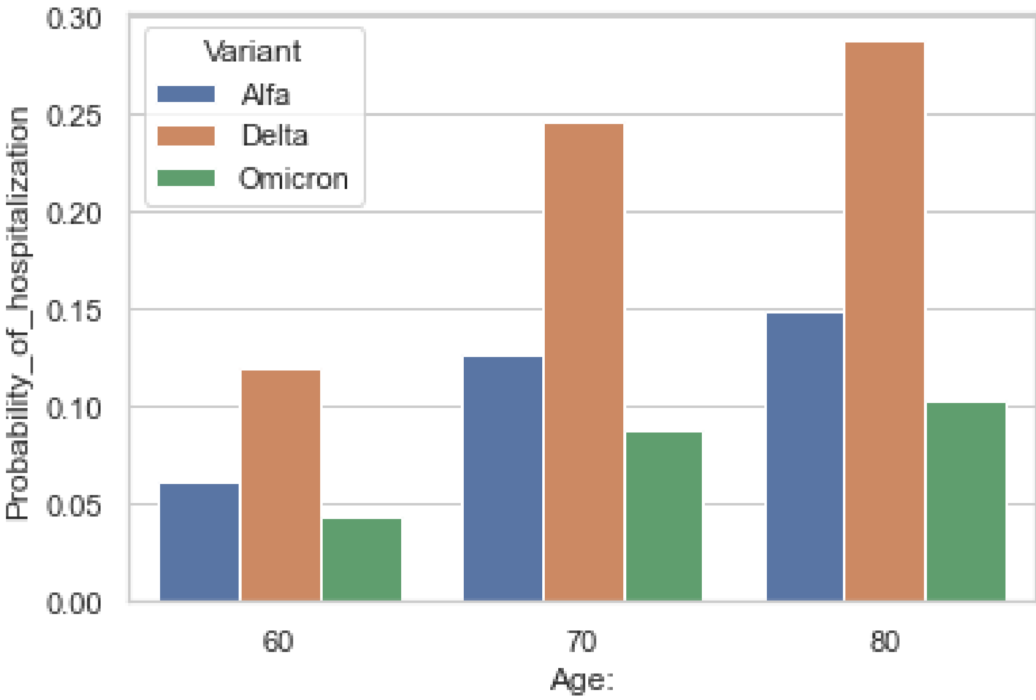
Davies *et al.*, Lewnard *et al.* (2022), Ward *et al.* (2022) claims that the Omikron variant, on the other hand, is much milder compared to Delta and the probability of hospitalization is lower by about 64%, while the probability of death is lower by about 89% in people in their sixties and by 72% in people aged 70 and over.

[5]The data we had at our disposal did not allow a good separation of the vaccinated (by individual doses) and the unvaccinated population for the purpose of estimating the probability of the observed phenomena.

[5]The main reason why we chose this method of calculation and not taking over the probabilities from foreign studies was that most of the studies that passed the resection procedure were carried out in countries that are ranked higher in the rankings of quality of life and availability of health care, which has a significant impact on the investigated phenomena .

Considering the above, the delta variant is associated with the highest probability of hospitalization and death among all the considered variants.

Figure 5.1: Probability of hospitalization of an unvaccinated patient due to age and variant of the coronavirus.



Source: Author's computation

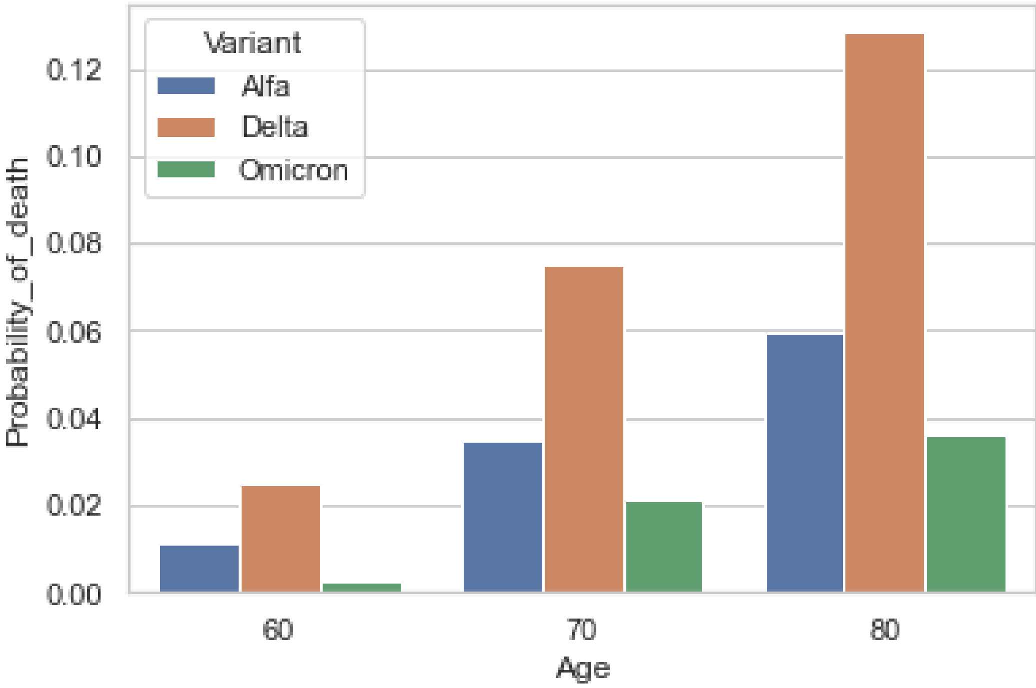
Subsequently, the probability of hospitalization and death of vaccinated persons in the case of the Omicron variant was calculated based on probabilities of the unvaccinated person in connection with the results of the literature regarding the effectiveness of vaccines **table bellow**. It should be emphasized, that these estimates are uncertain due to the novelty of the Omikron variant and rapidly emerging omicron subvariants may change probabilities over time [7].

Moreover, vaccine protection against the symptomatic course, severe course, or death is not constant over time. After reaching the maximum, it gradually decreases, which led to the introduction of a booster dose.

[6] We assume that the various variants and their effect on the monitored variables are statistically equal across the countries

[7] Estimate was made in June 2022. Probabilities are subject to change

Figure 5.2: Probability of death of an unvaccinated patient due to his age and variant of the coronavirus.



Source: Author's computation

Dose in the period	Hospitalization	Death
1. dose after 28+ days	52%	56%
2. dose 0-3 months	88%	95%
2. dose after 25 weeks	72%	59%
Booster dose 0-3 months	90%	95%

Table 5.2: Efficacy of the vaccine against the Omikron variant depending on doses and time since administration

5.2 Bass Diffusion Model

Generally, innovation diffusion theory attempts to describe how innovation is taken up in the general population. Oliu-Barton *et al.* (2022) inspired us to use the bass model for the purpose of determining the impact of the intervention. Oliu-Barton *et al.* (2022) used Bass to find out the effect of Covid-pass on vaccination uptake.

To estimate the effect of the incentive on the first dose uptake we will use the Bass Diffusion model. As a control group, we will use a group under the age of the bonus, ie. 60 years.

In our context, the vaccine is the innovation which is diffused to the population

	Prob. of hosp.	Cost of hosp.	Prob. of death	Lost years of life	Lost years adj. for qual.	PV of years of life lost	Total exp. costs
Non-vaccinated							
60-69	4,31%	1 431	0,27%	18	13	491 058	1 396
70-79	8,86%	1 793	2,11%	11	8	322 513	6 966
80+	10,36%	1 443	3,59%	6	4	184 587	6 777
Average	6,63%	1 570	1,05%	11	8	324 720	3 528
28+ days after the first dose							
60-69	2,07%	1 431	0,12%	18	13	491 058	617
70-79	4,25%	1 793	0,93%	11	8	322 513	3 075
80+	4,97%	1 443	1,58%	6	4	184 587	2 992
Average	3,18%	1 570	0,46%	11	8	324 720	1 558
0-3 months after the second dose							
60-69	0,50%	1 431	0,01%	18	13	491 058	74
70-79	1,04%	1 793	0,11%	11	8	322 513	359
80+	1,21%	1 443	0,18%	6	4	184 587	349
Average	0,78%	1 570	0,05%	11	8	324 720	183
25+ weeks after the second dose							
60-69	1,22%	1 431	0,11%	18	13	491 058	565
70-79	2,52%	1 793	0,87%	11	8	322 513	2 836
80+	2,94%	1 443	1,47%	6	4	184 587	2 760
Average	1,88%	1 570	0,43%	11	8	324 720	1 433
0-3 months after the booster dose							
60-69	0,43%	1 431	0,01%	18	13	491 058	73
70-79	0,89%	1 793	0,11%	11	8	322 513	356
80+	1,04%	1 443	0,18%	6	4	184 587	346
Average	0,66%	1 570	0,05%	11	8	324 720	182

Table 5.3: Expected direct costs of the disease according to age and dose in the case of the Omikron variant

and everybody is eligible to adopt or deny it.

The bass diffusion model is defined by the following differential equation:

$$\frac{f(t)}{1-F(t)} = p + qF(t) \tag{5.1}$$

where:

- p- coefficient of the innovation; $p > 0$
- q- coefficient of the imitation; $q > 0$
- $f(t)$ - portion of population that has been vaccinated at time t
- $F(t)$ - portion of population that has been vaccinated by time t; $0 < F(t) < 1$

The solution to the differential equation (5.1) is given by:

$$F(t)^8 = \begin{cases} \frac{1-e^{-(p+q)t}}{1+\frac{q}{p}e^{-(p+q)t}} & \text{where } t > {t_0}^9 \\ 0 & \text{otherwise} \end{cases} \tag{5.2}$$

Equation (5.8) can be further adjusted as:

$$F(t) = \begin{cases} \frac{pe^{(p+q)t}-p}{e^{(p+q)t}+q} & \text{where } t > t_0 \\ 0 & \text{otherwise} \end{cases} \tag{5.3}$$

From the equation (5.1) it is clear, that there are two types of "agents" in the model. The first one can be classified as an innovator and the second one as an imitator. Innovators decide to adopt an innovation independently of others. Apart from innovators, imitators are influenced by the number of previous adopters. The model allows us to estimate the potential market size before the diffusion ends.

The left-hand side of the equation (5.1) represents the proportion of those who have adapted from those who have not adapted by the time t. This proportion is equal to the sum of innovation and imitation effect multiplied by

[8] Full derivation is provided in the appendix

[9] t_0 is the time of the beginning of the diffusion process, ie. the beginning of mass vaccination in elderly people

the portion of the population which has been adapted by time t.
As time goes on the innovation effect fades and the imitation effect is increasing until the breaking point, where the number of the imitators reaches its peak. From the peak, the number of imitators is decreasing and is approaching 0 as increasing t.

To adapt to our topic, innovators are the share of the population, which were jabbed in the early stage of the process, most likely as soon as it was possible. Imitators lingered and their decision about vaccination was left for later.

To estimate the coefficients of the Bass model, ie. p,q and m, which stands for a forecasted population which are about to adapt to the innovation, we are using OLS estimated.

5.3 Calibration of the Bass Diffusion Model

Given we have historic data, we can fit the adoption curve.

To do so, we need to transform the equation (5.1) to the absolute number of vaccination in any period t. In the same way, we need to transform the cumulative vaccination up to time t.

- $s(t) = mf(t)$ - [10]Number of vaccinations in the any period t
- $S(t) = mF(t)$ - Cumulative vaccination up to t

Substituting the transformation for f(t) and F(t) in the equation (5.1) we obtain:

$$\frac{\frac{s(t)}{m}}{1-\frac{S(t)}{m}} = p + q\frac{S(t)}{m} \implies s(t) = [p + q\frac{S(t)}{m}][m - S(t)] \tag{5.4}$$

Equation (5.4) can be rewritten as :

$$s(t) = \beta_0 + \beta_1\, S(t) + \beta_2\, S(t)^2 \tag{5.5}$$

where:

- $\beta_0 = pm \implies p = \frac{\beta_0}{m}$

[10]m stands for a forecasted population which are about to adapt to innovation. The derivation with advanced description can be found here

- $\beta_1 = q - p$
- $\beta_2 = -q/m \implies q = -\beta_2 m$

Thus, equation (5.5) is suitable for estimating by regression. Regression coefficient $\beta_{1,2,3}$ may be used to determine the values m, p, q, since we obtained a system of three linear equations with three variables.

Adjusting the equation for β_1 by substituting for p and q (in the way as mentioned above, ie. equation (5.5)) we obtain:

$$\beta_1 = -\beta_2 m - \frac{\beta_0}{m} \tag{5.6}$$

The equation can be further modified to a quadratic equation with respect to m:

$$\beta_2 m^2 + \beta_1 m + \beta_0 = 0 \tag{5.7}$$

In this form, the equation is well-solvable by the standard method of solving quadratic equations.
Assuming $m > 0$, p and q can be calculated by pluging the m and *betas* to the equation (5.5).

5.4 Regression discontinuity analysis

Regression discontinuity analysis uses an artificial discontinuity in the probability that a person will receive an intervention. Since the division into the control group and the intervention group is not random and is determined exogenously, we classify this method as quasi-experimental.

The discontinuity in the probability of treatment is based on the treatment rule. Formally, this discontinuity is based on the so-called running variable and the value of which, when the participant exceeds, he jumps from the group with the right to the intervention to the group without the right to the intervention. Formally:

$$P(T = 1 \mid X) = \begin{cases} 1 & \text{if } X \geq \overline{X} \\ 0 & \text{if } X < \overline{X} \end{cases} \tag{5.8}$$

where:

- P(T) - Probability of being in the treatment group i.e. probability of being eligible for the bonus.[11]
- X - Number of months from turning 60 to the end of December 2021.
- $\overline{X}$ - Age limit of 60.

Individuals located just around the eligibility threshold are on average very similar, and the presence or absence of bonus eligibility concerns as random. Any significant jump in the outcome indicator at this threshold can therefore be interpreted as a causal effect of the intervention.

The causal effect or treatment effect of the intervention can be further broken down through expected values:

$$\mathbb{E}(Y \mid \overline{X}+) - \mathbb{E}(Y \mid \overline{X}-) = \mathbb{E}(Y \mid \overline{X} \leq X < \overline{X} + c) - \mathbb{E}(Y \mid \overline{X} - c \leq X < \overline{X}) =$$
$$\mathbb{E}(Y^T \mid T, \overline{X} \leq X < \overline{X} + c) - \mathbb{E}(Y^C \mid C, \overline{X} - c \leq X < \overline{X}) \rightarrow \mathbb{E}(Y^T - Y^C \mid \overline{X}) \text{ as } c \rightarrow 0$$

As $c \rightarrow 0$; $c \in \mathbb{R}$, the difference between the two groups in the absence of the treatment shrinks to 0.

RDD is implemented in the following form:

$$Y = \alpha + \theta D + \beta_1 X + \beta_2 XD + \epsilon \tag{5.9}$$

where:

- Y is the vaccination rate with a given dose (among persons entitled to a given dose) while the policy is in force
- X is the distance from age 60 in months (as of December 2021)
- D is a dummy variable equal to 1 in the ≥ 60 group and 0 in younger age groups.

The specified specification allows for a different slope coefficient on each side of the claim age limit (β_1 and β_2). The coefficient of discontinuity in Y is θ, which measures the "jump" in the claim boundary when $X = 0$.[12]

[11] In order to receive the bonus, it was necessary to undergo vaccination with the appropriate dose.

[12] X=0 $\iff$ Residents born 12/1961.

5.4.1 Assumptions of RDD

The most crucial assumptions for the Regression discontinuity approach are:

- The threshold is determined exogenously.
- The intervention is provided based on an observable continuous variable (age) and cannot be caused or influenced by the treatment.
- Individuals on either side cannot influence whether they will be assigned to the intervention or control group.
- The same threshold is not used to determine eligibility for another intervention that could affect the evaluated result.

It is clear, that all of the above-mentioned assumptions are met in our case.

An important decision in regression discontinuity analysis is determining the bandwidth on either side of the boundary within which the data enter the regression. If the band is set too narrow, the number of observations is limited, leading to less accurate estimates. If the band is set too wide, observations very far from the claim boundary enter the estimation, which can bias the results. In order to control this fact, we used in the thesis of the so-called triangular kernel, which allows us to give more weight to observations that are closer to the bonus threshold.

5.4.2 Pitfalls of the RDD

The selected method of estimating the impact of the vaccination bonus has several pitfalls that need to be reflected on:

1. **Local treatment effect:**
   The regression discontinuity analysis estimates the effect only close to the bonus eligibility age.

2. **Control Group:**
   Bonus could have indirectly influenced the behaviour of people under the eligibility threshold for lower vaccination.

5.4.3 Local treatment effect

The argument that people below the eligibility threshold are a suitable control group for people above this threshold is weaker the further we move away from this threshold. People's behaviour changes with age in ways that can affect the effectiveness of the vaccination bonus. As the risk of a severe course of the disease increases with age, one would expect, that vaccination uptake in the elderly would be less sensitive to additional financial incentives.

As a **solution**, besides triangular kernel, we offer an alternative scenario in which we take into account the possible overestimation of the impact of the bonus from the presentation of the local treatment effect on the entire population 60+. In the result chapter, we will present the following scenarios:

1. Constant bonus effect across age groups.

2. Constantly diminishing effect of the bonus until the age limit of 75 years, when the bonus ceases to have an effect.

5.4.4 Control group

The second pitfall of the chosen method is the fact that the bonus could have influenced the vaccination rate under the eligibility threshold. The estimated jump at the eligibility threshold may thus overestimate the actual impact of the vaccination bonus. The three most likely possible effects of the bonus on lower vaccination rates among younger age groups:

1. Capacity limitations
2. Feeling of unfairness
3. Signal regarding the degree of danger of the virus

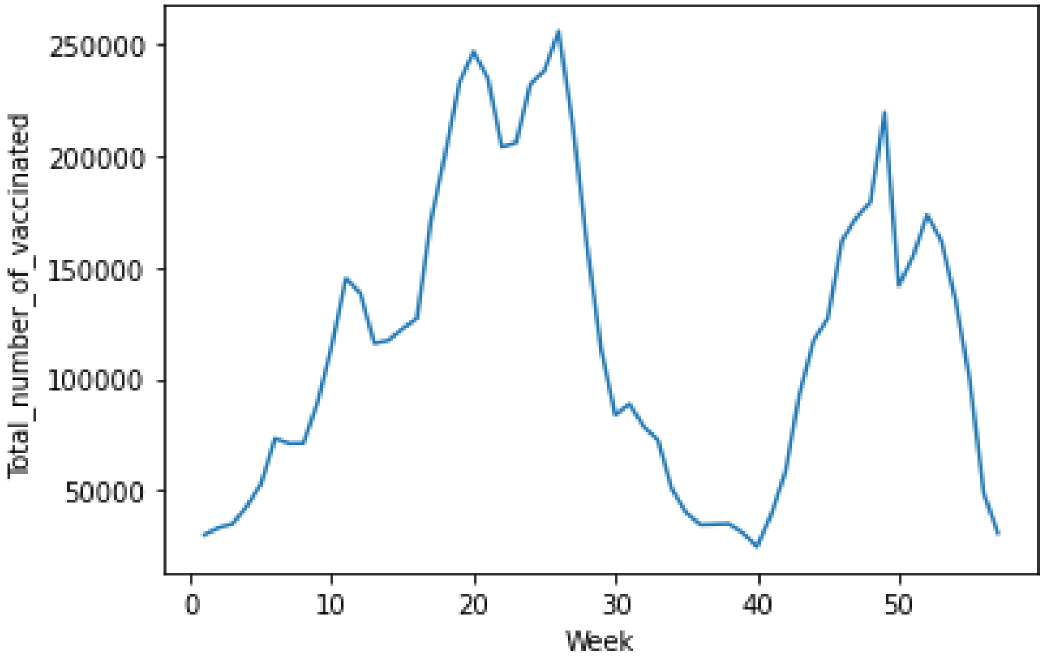
Capacity limitations

If the vaccination bonus increased the demand for vaccination from the elderly, with limited vaccination capacities and prioritizing older people over younger people, it may have happened that younger people had to wait longer for vaccination, which may have deterred some.

The booster dose was made available for people under 55 together with the announcement of the bonus, so it is not possible to find out what the gap was in the waiting time before the bonus was announced. For this reason, we compared the length of the period between the first and second dose and between the second and booster dose in the group of people over 60 years of age and in the group of people under 60 years of age, which does not indicate that capacity restrictions reduced vaccination in younger age groups. People under the age of 60 did not wait longer on average for the second dose after the bonus was announced than older people. In the case of the booster dose, younger people waited on average 6 days longer than older people, which, given the relatively long period of validity of the bonus (more than 9 weeks), could nuot have a significant impact on the vaccination rate.

As a cross-check, we compared the cumulative weekly number of vaccinations regardless of the order of doses. The interest peaked at week 49, 2 weeks after the vaccination bonus was announced. However, this peak was lower than the peaks we observed around week 25. Unfortunately, based on this comparison, we cannot say with complete certainty that the capacity was sufficient, as, between the 25th and 49th week, some capacity may have been cancelled. However, together with the already mentioned findings and especially with the length of the observed period, there is a stronger finding about sufficient capacities.

Figure 5.3: Total number of vaccinated in given week regardless of the dose order



Source: Author's visualization, NCZI

Feeling of unfairness

It may have seemed unfair to people just below the bonus eligibility threshold that they were not allowed to receive a financial incentive. Studies in the field of social psychology and neuroscience prove that people who feel that they are victims of unfair behaviour by others are willing to punish the "perpetrator" even at the cost of personal costs and even in a situation where, from the point of view of a cold comparison of personal benefits and costs, it is not rationally, and they feel good about such punishment (Fehr & Gächter (2002), de Quervain *et al.* (2004)). In this case, it could be, for example, the refusal of vaccination, which the state representatives recommended them to undergo, even at the cost of increased risk to their overall well-being.

Signal regarding the degree of danger of the virus

The design of the vaccination bonus could have created a discontinuity not only in the entitlement to financial assistance but also in the perception of the risk of the Covid-19 disease across age groups. Some people below the bonus eligibility threshold may have received the mistaken impression that the vaccination is not as beneficial for them as they originally thought.

The impact of the feeling of unfairness and a false sense of security in younger age groups due to the vaccination bonus for seniors cannot be directly observed. A comparison with data from the Czech Republic is consistent with such an effect. The negative impact of the bonus could be expected most in groups that found themselves just below the administratively determined threshold distinguishing risky from less risky groups and bonus recipients from others. For young people, such an announcement should not have a significant effect, since they already had reason to assume that they are much less risky than seniors, and therefore less worthy of financial motivation.

However, this reasoning is **speculative**, as there are other differences between Slovakia and the Czech Republic that could have influenced the development of vaccination across age groups. The Czech government in resignation introduced relatively strict restrictive measures for the unvaccinated from November 22, 2021, which strongly motivated vaccination across age groups. Vaccination with the first dose was also 15 percentage points higher on the date of the bonus announcement than in Slovakia, which indicates that Czechs were generally more inclined to vaccination than Slovaks. One of the reasons could be the negative attitude of a large part of the Slovak parliamentary opposition towards vaccination, which, given its voter base, probably affected older people more. It is also worth noting that the gap between the Slovak and Czech rates of vaccination is similarly large in the 75-79-year-old and 80+-year-old groups, who had no reason to feel deprived.

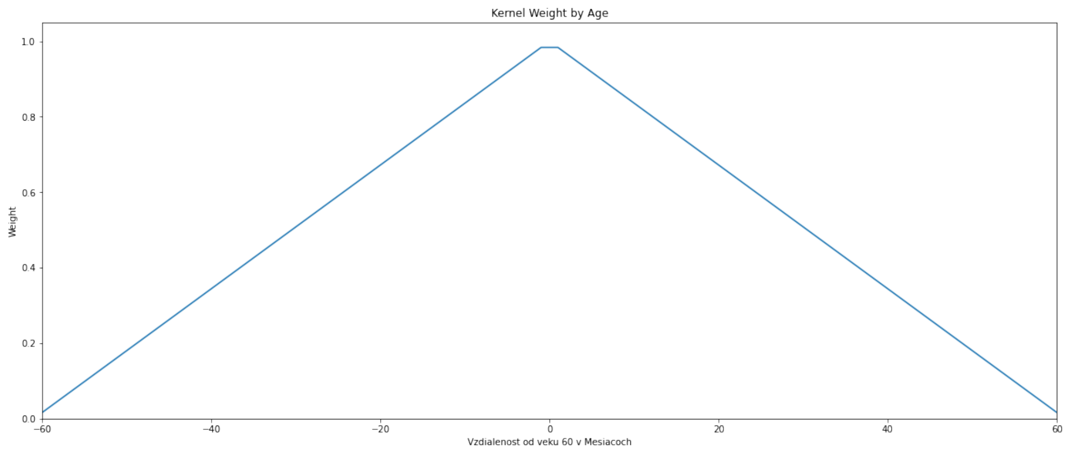
Both hypotheses are also consistent with the rapid decrease in vaccination in the age group below the bonus eligibility threshold after its announcement. However, this decrease was probably mainly due to the elimination of disadvantages for unvaccinated people. From September 2021, a Covid machine was in effect in Slovakia, which favoured fully vaccinated persons. With effect from 22.11.2021, the measures changed towards tightening the restrictions for the unvaccinated, which may explain the significant increase in interest in vaccination in the 47th week. However, from 25/11/2021, a state of emergency and a lockdown were introduced, which applied regardless of vaccination status. If this removal of the benefit for the vaccinated caused a decrease in vaccination in younger age groups, there is reason to assume that without the bonus, the number of new doses would also decrease among older people. **It follows that people just below the eligibility age are still a good control group for estimating the effect of the bonus on vaccination.**

5.5 Triangular Kernel

One way to account for the fact that observations closer to the boundary are more relevant is to give them more weight. A popular way to do this is by using the so-called triangular kernel, where the weight decreases linearly on both sides of the claim boundary, up to the band boundary. By employing the weights to the individual observation of vaccination rates we move to the usage of the weighted least squares method (WLS). The weights in the case of a five-years band on both sides of the border are shown in the graph below. The usage of the five-years band or sixty months is enough to capture an accurate estimate and at the same time, not too wide to obtain a bias. An undoubted advantage of using this band is also we can control our results with aggregated data.

$$Triangularkernelweight = 1 - \frac{|R - c|}{h} \tag{5.10}$$

Figure 5.4: Triangular kernel



Source: Author's computation

Chapter 6

Results

In the next chapter, we present the results of the empirical part, starting with the RDD, where we present the results for each dose separately. The result of the first dose of the vaccine is subsequently confirmed by the Bass diffusion model. Last but not least, based on the results of partial analyses, we will calculate the estimated profitability of the measure in the CBA subcategory.

6.1 RDD

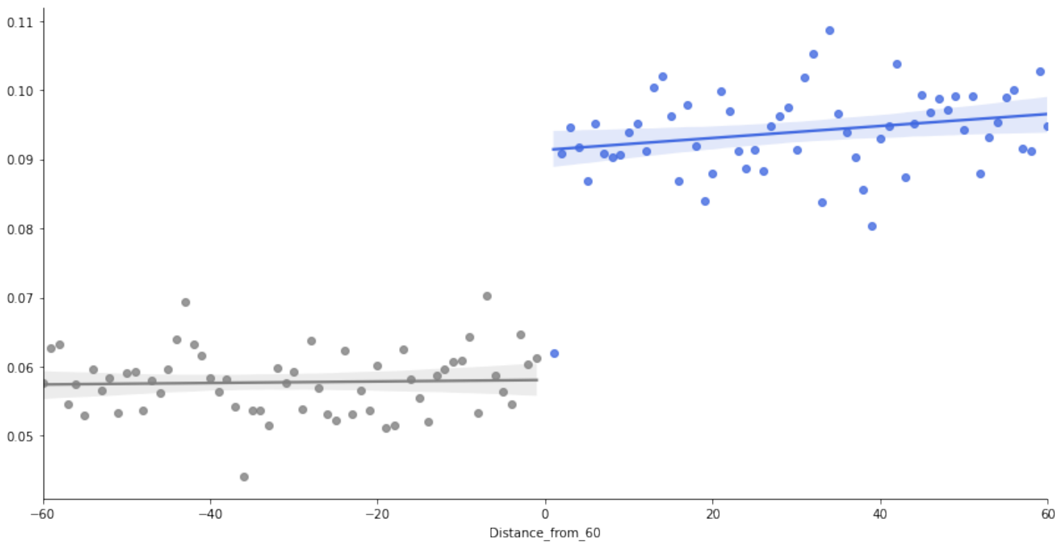
Analysis using the regression discontinuity method yielded statistically significant results for all doses that confirm the existing influence of financial motivation on vaccination. The magnitude of this effect varies across doses. The biggest influence the bonus had in the case of the booster dose of the vaccine and the lowest in the case of the second dose.
Referring to subsection **Local treatment effect (5.4.3)**, we will present two scenarios for individual dose, one with a constant impact of the bonus across age cohorts and another with a diminishing impact of the bonus.

6.1.1 Effect of the vaccination bonus on first dose uptake

The chosen form of the eligible population for the first dose is robust to previous developments in vaccination. Therefore, we do not have to apply a difference in difference approach to previous developments in vaccination. The difference in the vaccination of the age group over 60 and the control age group under 60 can be directly interpreted as a causal effect of the bonus.
The aforementioned bonus effect is visible in figure 6.1 as a jump between

individual regressions in which observations closer to the bonus limit, i.e. 60 years old by 31.12.2021, have a higher weight.

Figure 6.1: Effect of the incentive on the first dose uptake



Source: Author's visualization

Parameter	Estimate (SE)	P-value
Intercept	0.0597 (0.0-1)	<0.001
Discontinuity	**0.0323 (0.002)**	**<0.001**
Distance from 60|D=0	<0.001 (<0.001)	0.062
Distance from 60|D=1	<0.001 (<0.001)	0.907

Table 6.1: WLS regression results-First dose

It is clear from the graph, that people above the age of 60 were more prone to get the first dose than people below the border in the monitored period. The regression results confirm this statement, therefore we conclude that we observed a significant [1]impact of the bonus on vaccination with the first dose.

Implementation of the bonus was reflected in the **increase in vaccination rate by 3.23 (0.2) p.p.** (Table 6.1 coefficient - Discontinuity [2]) The base vaccination rate is 5.97 (0.1) p.p. The white test confirmed the heteroscedasticity. Reflecting on the fact we employed heteroscedasticity robust standard errors. The other confounding factors were not observed. The total vaccination rate with the first dose at the threshold of eligibility can be estimated at 1.2 p.p.
If we rely on the fact that there were 461 393 unvaccinated persons on the date of the bonus announcement: In the case of the first scenario, we receive around 14 903 people which were nudged by the incentive.
In the case of the second scenario we receive around 5 912 people who were nudged by the incentive.

6.1.2 Effect of the vaccination bonus on second dose uptake

The analysis of regression discontinuity indicates that the bonus significantly increased vaccination with the second dose at the threshold of eligibility in the group of seniors entitled to the second dose in the monitored period by 3.5 percentage points, from 74.7% to 78.2%. In the 60+ group, the bonus convinced to the second dose of an estimated 380 to 906 seniors, depending on the assumption that the effect weakened with age or remained constant. Considering the fact that in the 60-year-old age group, roughly 2.4% of the population was entitled to the second dose, the impact on the overall vaccination rate with the second dose can be estimated at 0.08 p.p.

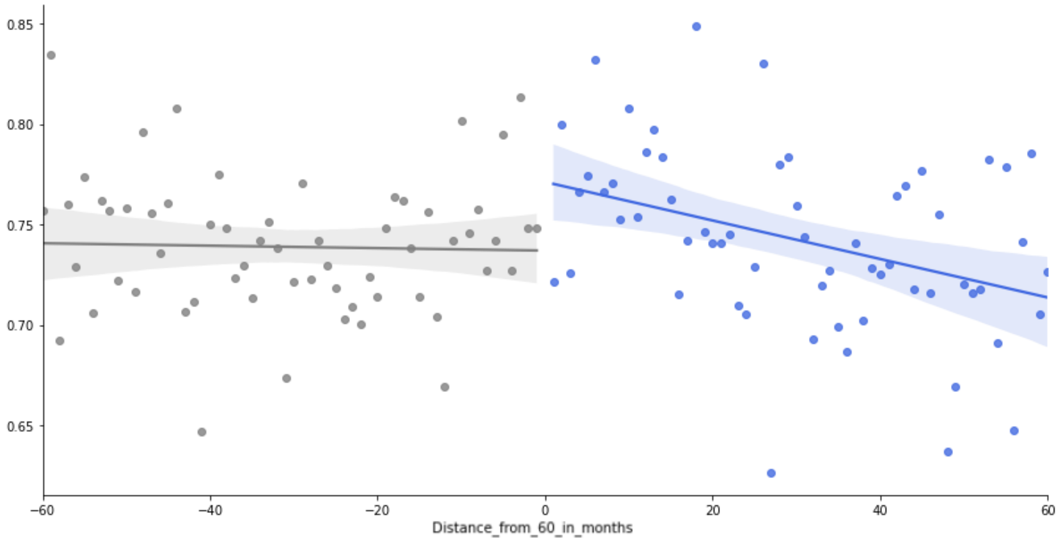
With a two-dose vaccine, the decision to vaccinate naturally includes both doses, so there is no obstacle leading to the decision to take only the first dose. The vast majority completed this type of dose without hesitation (any external motivation) and the overall revaccination with the second dose, regardless of age, is almost 100% in the population that received the first dose. On the other hand, for those who felt that even one dose would protect them sufficiently, or those who were discouraged by an adverse effect after the first dose

[1]By significant we mean that the p-value of the regression coefficient is significant at the 5% level of statistical significance ($\alpha = 0.05$). This applies unless otherwise stated .

[2]The causal effect of the intervention can be found under the same coefficient in table 6.2 and table6.3, the text refers to them indirectly.

of vaccination, the bonus could have nudged their decision, last but not least, the vaccination could have been delayed due to overcoming the disease in the period between first and second dose.

Figure 6.2: Effect of the incentive on the second dose uptake



Source: Author's computation

Parameter	Estimate (SE)	P-value
Intercept	0.7467 (0.01)	<0.001
Discontinuity	**0.0351 (0.013)**	**0.009**
Distance from 60|D=0	0.0004 (<0.001)	0.225
Distance from 60|D=1	-0.002 (<0.001)	<0.001

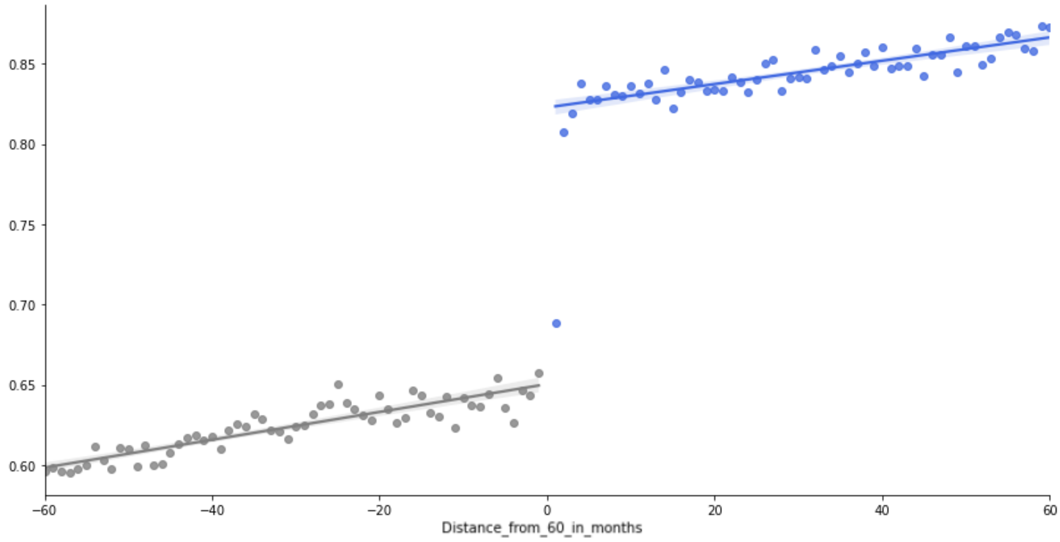
Table 6.2: WLS regression results-Second dose

6.1.3 Effect of the vaccination bonus on booster dose uptake

The development of vaccination in the neighbourhood of the border of entitlement to the vaccination bonus indicates that the bonus increased vaccination in the group of seniors entitled to a booster dose by 17.2 percentage points, from 65.2% to 82.4%. Given the fact that roughly 51% of the population in the 60-year-old age group was entitled to a booster dose from the announcement of the bonus to the end of January, the impact on the total vaccination rate with

a booster dose at the eligibility threshold can be estimated at 8.3 percentage points.
The vaccination bonus convinced 46,057 to 97,424 seniors to be vaccinated with a booster dose in the 60+ group, depending on whether the effect weakened with age or remained constant.

Figure 6.3: Effect of the incentive on the booster dose uptake



Source: Author's computation

Parameter	Estimate (SE)	P-value
Intercept	0.6520 (0.005)	<0.001
Discontinuity	**0.1722 (0.005)**	**<0.001**
Distance from 60|D=0	<0.001 (<0.001)	<0.001
Distance from 60|D=1	<-0.001 (<0.001)	0.356

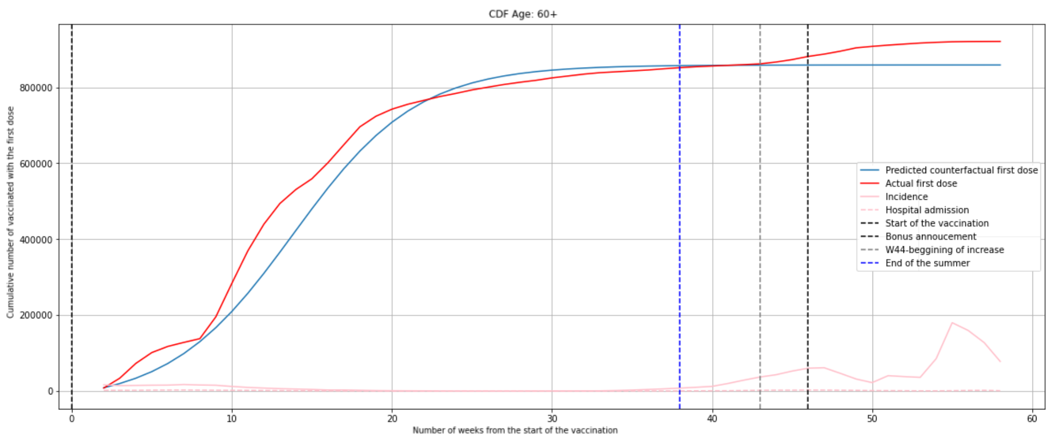
Table 6.3: WLS regression results-Booster dose

Due to the fact that the booster dose has the biggest impact within the measure, it is possible to find details about the regression results in Appendix A.1

6.2 Bass Diffusion model

We employed the Bass Diffusion model to confirm results from RDD on the weekly aggregated data. We applied the methodology only on the first doses since there was not enough data to calibrate the model in the case of booster doses. There were only four weeks before the bonus was introduced and to perform calibration few more weeks of observation were needed.

Figure 6.4: Predicted counterfactual first dose uptake by Bass diffusion model vs. real uptake in 60+ population

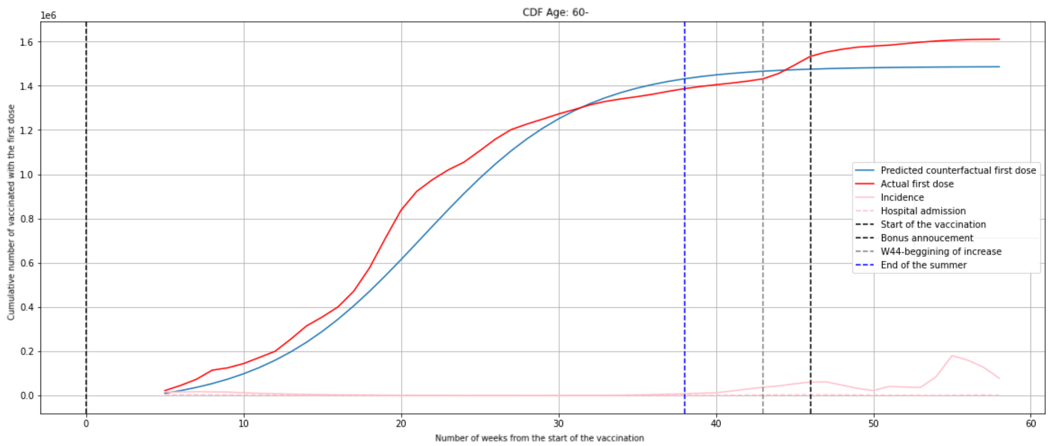


Source: Author's computation

Modelling vaccination with the second dose in this way contradicts the model's assumptions. With a two-dose vaccine, the decision to get vaccinated naturally includes both doses, and thus the second dose follows, with exceptions, the decision about the first dose. For this reason, we do not have any innovators or imitators here, and therefore the use of the model is meaningless.

As we can see in figure 6.5, the willingness to get vaccinated was growing even before the bonus was announced, mainly due to the worsening pandemic situation. We capture this growth at the end of the period during which we are trying to estimate the model parameters. Although an increase from week 44 is included in several recent observations, it is important to check this increase for the credibility of the results. Suppose there was an exogenous shock before week 44 that affected people's vaccination decisions across age categories. This shock could have been caused either by the epidemiological situation itself or by the measures that tried to respond to the deteriorating situation. During this period, various anti-pandemic measures were considered, which were originally intended for the unvaccinated group, which might have inclined some to vaccinate. Let's assume that this reaction to the worsened pandemic situation and to the introduction of measures was present in all age categories, then if we control the effect of an exogenous shock in the over-60 categories with a shock effect in the under the 60 groups, we will get the most accurate estimate of vaccination with this method. From the total number of immitators, we must subtract those imitators who postponed vaccination, but regardless of the situation, they could be vaccinated.

Figure 6.5: Predicted counterfactual first dose uptake by Bass diffusion model vs. real uptake in 60+ population



Source: Author's computation

By implementing the procedure of controlling the shock we obtain a very similar result to the regression discontinuity. Implementation of the bonus according to the Bass diffusion model was reflected in the increase in vaccination rate by 3.33 (0.28) p.p. which is reflected in 15 307 nudged people. The total vaccination rate with the first dose at the threshold of eligibility can be estimated at 1.21 p.p.

Since the result from RDD and Bass diffusion model are equal at the level of significance $\alpha = 0.05$ We will use the results from the RDD model in CBA. By RDD we model all three doses thus the results are more coherent. Besides, RDD allows us to present scenarios in greater granularity and therefore represents more accurate estimates of cost-benefit ratios.

6.3 CBA analysis

6.3.1 Benefits

In a scenario with the dominant Omikron variant, the **direct social benefits of vaccinating** one senior with one dose are estimated at €1,970 and with the second dose at €1,375 . Vaccination with a booster dose has an estimated social value of €1,252 (Table A.1).
The direct benefits of vaccination consist in the protection of the vaccinated person against a severe course of disease, hospitalization and death. The immediate social value of vaccination is therefore estimated as a reduction in the expected (average) costs of illness (hospitalization and death) in the target age group due to receiving another dose of vaccine (Table A.1, Table A.2). The calculation includes the fact that vaccines do not provide complete protection, but "only" a significant reduction in risk, as well as the fact that vaccine effectiveness decreases over time.

The indirect social benefits of vaccination during the winter of 2021/22 were estimated to be around €190 per person. Higher vaccination of the population brings indirect social benefits (externalities) in the form of higher economic growth due to lower morbidity among employees, a lower rate of social isolation and thus higher consumption, as well as due to shorter and less restrictive restrictions on the economy needed to slow down the spread of the virus.
According to the Bruegel think tank Oliu-Barton *et al.* (2022), the benefit of increasing vaccination coverage by 10% in OECD countries is on average approximately 0.52% of GDP. Oliu-Barton *et al.* (2022) did not measure how long the effect on GDP lasted.
Therefore, the calculation include the period during which the economy was limited after the announcement of the bonus on 11/26/2021. Counts the period up to 26.2.2022 [3]. The calculation of the benefit per vaccinated person was made on the assumption that it lasted two months.

[3]When the OTP OP OP+ regime was cancelled and the first phase of a significant easing of restrictions began: https://www.podnikajte.sk/zakonne-povinnosti-podnikatela/covid-opatrenia-od-26-2-2022- first-phase-of-release. As a result, it is probably a conservative estimate that overestimates the social benefits, since the study was done on data from a period when the Delta variant prevailed, which was more dangerous than Omikron and therefore required greater restrictions on the economy.

6.3.2 CBA

Omicron variant of the coronavirus

The bonus convinced an estimated 52,000 to 113,000 seniors who would not have been vaccinated without it, thus saving 211 to 461 lives. This estimate is based on the rate of death risk for the Omicron variant and the rate of protection provided by individual doses of the vaccine (Table A.1). The result depends on whether the impact of the bonus decreased with age (lower estimate, more likely scenario) or remained constant (higher estimate,less likely scenario). Nevertheless, due to the huge costs, the vaccination bonus was not, according to the results of the analysis, returnable from the point of view of quantifiable social welfare. The loss amounts to €74 to €168 million. The benefit-cost ratio is lower than 1 Table 6.4[4].

	Cost (mil. €)	Number of nudged	Benefits from nudged€	Benefits (mil. €)	Benefit-cost ratio
First dose	8,5	14 903	2 160	32,2	**3,77**
Second dose	10,7	906	1 565	1,4	**0,13**
Booster dose	228,9	97 424	1 442	140,5	**0,61**
Total	**248,1**	**113 233**	**1 537**	**174,1**	**0,70**

Table 6.4: Constant effect of the bonus

In a more realistic scenario, where the impact of the bonus gradually decreases with age, the benefits do not reach even a third of the costs incurred. In the case of a constant effect across the age groups of seniors, the benefits reach the level of more than two-thirds of the costs.

	Cost (mil. €)	Number of nudged	Benefit from nudged€	Benefits (mil. €)	Benefit-cost ratio
First dose	8,5	5 912	2 160	12,8	**1,50**
Second dose	10,7	380	1 565	0,6	**0,06**
Booster dose	228,9	46 057	1 442	66,4	**0,29**
Total	**248,1**	**52 349**	**1 524**	**79,8**	**0,32**

Table 6.5: Diminishing effect of the bonus

The benefits outweigh the costs only for the first dose. However, this is the

[4]The costs included in tables include the cost of vaccine substance and the administration of the vaccination (applies to all tables)

smallest part of the total expenses. Seniors who received their first dose after 26/11/2021 were paid €8.1 million, which is 3.3% of the total package. With a booster dose that makes up 92.3% of the entire package, the benefit-cost ratio is only 0.61, even in a more optimistic scenario. The effectiveness of vaccination support with the second dose, for which €10.6 million (4.3% of the package) went, turned out to be negligible.

Delta variant of the coronavirus

If the Delta variant of the virus would not be displaced by the Omikron variant, but the vaccination rate would develop at the same rate as in reality, the benefit-cost ratio of the bonus would increase significantly (Table 6.6). The reason is the fact that the probability of hospitalization and death is significantly higher in the case of Delta than in the case of Omikron, and thus also the direct social benefits of vaccination.

	Cost (mil. €)	Number of nudged	Benefits from nudged €	Benefits (mil. €)	Benefit-cost ratio
First dose	8,5	14 903	14 011	208,8	**24,48**
Second dose	10,7	906	4 336	3,9	**0,37**
Booster dose	228,9	97 424	1 608	156,7	**0,68**
Total	**248,1**	**113 233**	**3 263**	**369,4**	**1,49**

Table 6.6: Constant effect of the bonus

The assessment of the benefit of the bonus in all age groups of seniors in this scenario depends on the assumption of the evolution of the influence with increasing age. In a more realistic scenario, in which the influence of the bonus decreases with age, even with the Delta variant, the benefits would be more than a third lower than the costs. Conversely, in the case of a constant bonus effect, the benefits would exceed the costs by 49%.

	Cost (mil. €)	Number of nudged	Benefit from nudged€	Benefits (mil. €)	Benefit-cost ratio
First dose	8,5	5 912	14 011	82,8	**9,71**
Second dose	10,7	380	4336	1,6	**0,15**
Booster dose	228,9	46 057	1 608	74,1	**0,32**
Total	**248,1**	**52 349**	**3 029**	**158,6**	**0,64**

Table 6.7: Diminishing effect of the bonus

However, the calculation of this scenario is based on the **not very realistic** assumption that vaccination development would remain unchanged compared to the baseline scenario with the Omikron variant. One would expect that in the case of the continued dominance of the more dangerous Delta variant, or Omicron would have similar parameters to Delta, the overall vaccination rate would be higher and the sensitivity of decisions to financial motivations would be lower. This would lead to higher costs and lower benefits than in the above calculation. However, quantification of this deviation from the basic scenario is not possible based on the available information.

6.3.3 Effect on the bonus entitlement limit

By comparing people exactly at the limit of eligibility for the bonus, we get the most accurate possible estimate. For this reason, we present the CBA evaluation separately.

Even this comparison does not indicate cost-effectiveness in the scenario of the dominant Omicron variant. The benefits exceed the costs only in the case of the first dose, however, the costs for this group of recipients amounted to approximately €0.5 million. Within this group, the largest part of financial resources was withdrawn for the payment of incentives for booster benefits, approximately €10.9 million out of a total of €12.3 million, which roughly represents almost 89%.

As can be seen from Table 6.8 and Table 6.9, the benefit-cost ratio was, in the case of the first doses, above 1. The mentioned ratio was 1.68 and up to 16.3 in the case of the scenario with the dominant delta variant. In the case of second doses, the comparison of yields and costs is not favourable in any of the presented scenarios and is at a value of approximately 0.05, or 0.2 in the case of dominance of the delta variant. This means that only approximately 5% or 20% of the costs were returned to the state in the form of improved health of the population, saved public funds, or economic growth. In the case of the booster dose, this comparison is higher, but nevertheless, the costs did not exceed the benefits. Benefits were only approximately 40% of costs. In the case of the dominant variant Delta, this ratio increased by approximately 25 p.p. to 65%.

The overall assessment in the case of the Omicron variant of the coronavirus does not represent the cost-effectiveness of the vaccination bonus(Table 6.8). The costs are equal to €12.3 million . The benefit from the nudged population is estimated at roughly €5.1 million. Benefits, therefore, represent only 42% of costs.

	Cost (mil. €)	Number of nudged	Benefit from nudged€	Benefits (mil. €)	Benefit-cost ratio
First dose	0,5	843	969	0.8	**1.68**
Second dose	0.9	60	734	0.0	**0.05**
Booster dose	10.9	6 233	682	4.3	**0.39**
Total	**12.3**	**7 136**	**716**	**5.1**	**0.42**

Table 6.8: CBA on the threshold of entitlement to a bonus.Omicron Variant scenario

The overall assessment in the case of a hypothetical scenario with a dominant Delta variant of the coronavirus represents the cost-effectiveness of the vaccination bonus. (Table 6.9). In this scenario, the costs represent approximately €12.3 million and the returns are estimated at approximately €15.2 million, which means that the costs exceed the returns by approximately 24%.

	Cost (mil. €)	Number of nudged	Benefit from nudged€	Benefits (mil. €)	Benefit-cost ratio
First dose	0,5	843	9 417	7.9	**16.3**
Second dose	0.9	60	2 958	0.2	**0.2**
Booster dose	10.9	6 233	1 134	7.1	**0.65**
Total	**12.3**	**7 136**	**2 128**	**15.2**	**1.24**

Table 6.9: CBA on the threshold of entitlement to a bonus. Delta Variant scenario

Chapter 7

Conclusion

The vaccination bonus was paid to 847,000 seniors who were vaccinated at the end of 2021 and the beginning of 2022, at a total cost of 245 million euros. Of this, 92% went to seniors who completed the booster dose. At the bonus entitlement limit, we estimated the incentive effect by Regression discontinuity design analysis. The incentive had the greatest impact on booster dose uptake, approximately 8.3 p.p. Followed by the first doses, where the measure increased vaccination by approximately 1.2 p.p. We also observed a statistically significant effect with the second dose, where the effect of the vaccination bonus was estimated at approximately 0.08 p.p.

These results suggest that the bonus convinced 52,000 to 113,000 seniors who would not have been vaccinated without it, depending on whether the effect decreased with age or remained constant.The estimated number of hospitalizations averted was in range from 775 to 1 725. The number of saved lives can be estimated between 211 to 461 based on scenario selected.

The benefits of the vaccination bonus in the form of savings in health care costs, the value of protected life years and higher economic growth are lower than the realized costs. The overall loss will reach €74 to €168 million.
The benefits exceed the costs only in the case of a €200 bonus for unvaccinated seniors who received the first dose during the entitled period. However, this is the smallest part of the expenses, worth only €8.1 million. The benefits of the measure do not include deferred care costs or outpatient and follow-up care costs or the cost of sick leave. This leads to a slight underestimation of the benefits of the measure and to a worsening of the benefit-cost ratio. However, even after accounting for these costs, it cannot be expected that the measure will be cost effective.

Given the established ratio of benefits and costs, the payment of this health intervention from public funds is not justified.

The measure may have undesirable longer-term effects on prevention by creating the expectation of a financial incentive. People may neglect preventive measure in the future when such incentive is not offered. However, this effect is questionable, nevertheless, we support research in this area as well. Examining this psychological-sociological phenomenon can help in implementing measures of a similar nature.

Implications emerging based on this quasi-experiment:
In the beginning, it is necessary to answer a question like what are the factors of acceptance, or on the basis of what factors do people refuse vaccination? Is it possible to remove these obstacles with a financial incentive?
The question posed in this way can be answered by scientific literature or representative research in society.

If the answer is yes, then before launching a comprehensive measure, we recommend trying a smaller pilot program that would try several alternatives, from the point of view of alternatives to financial motivation, or a combination of them.
This pilot will help to choose the best possible solution and prevent the inefficient spending of public resources and social divisions created by the perception of unfairness by those not eligible.
We believe that the €300 reward was more generous than necessary in the case of the booster dose and people would have responded to a lower amount in a similar way. This assumption is based on the fact that these were not people who a priori refused vaccination. This group of people had already two doses of the vaccine, so it can be assumed that with appropriately chosen communication and a nudge in the form of a smaller financial incentive, they would be vaccinated again, aware of the private benefits resulting from vaccination. Such a generously introduced measure had the form of reward rather than a nudge. Considering the fact that no survey was conducted to confirm such a claim, it is only our guess. The mentioned effect could be verified with the proposed pilot.
It is necessary to think about the possible undesirable long-term effects on society and to respond to these effects as much as possible when creating policies. Last but not least, it is necessary to unify and prepare a methodology that would help evaluate individual interventions in the field of health. At the very

least, such a methodology should include the valuation of one year lived in full health as well as a methodology for adjusting its quality. In the case of ex-ante evaluation, it should contain a threshold of the benefit-cost ratio that the measure must exceed in order to be implemented.

In order to achieve cost efficiency, it is necessary to give space for discussion a constructive criticism by scientists and experts when designing the measure. On the other hand, policymakers should respond adequately to such a discussion. Otherwise, it can apper that the measure is designed primarily as a means of winning favor with voters. However, we admit that at the end of the day, the final decision lies in the hands of politicians as they are ultimately responsible to voters.

Finally, we bring several possible improvements that can raise this evaluation and suggestions for further research.
As we mentioned, we, unfortunately, could not include some aspects of the calculation of the benefits, so including them would make the estimate of the benefit-cost ratio even more accurate.
There is room for improvement even in the case of the methods used, the data we had at our disposal did not allow us to look at a more disaggregated level, by day of birth. This detail could bring more accurate estimates of the impact of the financial scheme on vaccination. On such data, it would be more appropriate to use polynomial functions to estimate the regression discontinuity. The selected control group may, due to the imperfections mentioned in the text, distort the results. By creating a suitable synthetic control group, the results obtained by us could be more robust.
We also mentioned a possible long-term adverse effect on future vaccinations, whether for COVID-19 or others diseases. It may therefore be interesting to investigate, for example, the revaccination with another booster in the population of bonus recipients for the third dose and compare the vaccination with this dose with other countries that have not introduced a similar measure.

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Appendix A

Tables and Figures

	60-69	70-79	80+	60+
First dose	**779**	**3 891**	**3 786**	**1 970**
Lower cost of hospitalization	32	83	78	54
Value of saved years of life	747	3 809	3 708	1 916
Second dose	**544**	**2 716**	**2 643**	**1 375**
Lower cost of hospitalization	22	58	54	38
Value of saved years of life	521	2 659	2 588	1 337
Booster dose	**492**	**2 480**	**2 414**	**1 252**
Lower cost of hospitalization	11	29	28	19
Value of saved years of life	480	2 451	2 386	1 233

Table A.1: Direct benefits of vaccination of one senior in the case of Omicron variant (EUR)

	60-69	70-79	80+	60+
First dose	**9 227**	**18 566**	**18 065**	**13 821**
Lower cost of hospitalization	128	331	312	217
Value of saved years of life	9 099	18 235	17 753	13 604
Second dose	**2 768**	**5 570**	**5 419**	**4 146**
Lower cost of hospitalization	39	99	93	65
Value of saved years of life	2 730	5 470	5 326	4 081
Booster dose	**944**	**1 912**	**1 858**	**1 418**
Lower cost of hospitalization	34	88	83	58
Value of saved years of life	910	1 823	1 775	1 360

Table A.2: Direct benefits of vaccination of one senior in the case of Delta variant (EUR)

	Prob. of hosp.	Cost of hosp.	Prob. of death	Lost years of life	Lost years adj. for qual.	PV of years of life lost	Total exp. costs
Non-vaccinated							
60-69	11,96%	1 431	2,47%	18	13	491 058	12 303
70-79	24,61%	1 793	7,54%	11	8	322 513	24 754
80+	28,79%	1 443	12,82%	6	4	184 587	24 086
Average	18,43%	1 570	5,59%	11	8	324 720	18 429
28+d after 1st dose							
60-69	2,99%	1 431	0,62%	18	13	491 058	3 076
70-79	6,15%	1 793	1,88%	11	8	322 513	6 189
80+	7,20%	1 443	3,21%	6	4	184 587	6 022
Average	4,61%	1 570	1,40%	11	8	324 720	4 607
0-3mts after 2nd dose							
60-69	0,30%	1 431	0,06%	18	13	491 058	308
70-79	0,62%	1 793	0,19%	11	8	322 513	619
80+	0,72%	1 443	0,32%	6	4	184 587	602
Average	0,46%	1 570	0,14%	11	8	324 720	461
25+W after the 2nd dose							
60-69	2,69%	1 431	0,25%	18	13	491 058	1 252
70-79	5,54%	1 793	0,75%	11	8	322 513	2 531
80+	6,48%	1 443	1,28%	6	4	184 587	2 461
Average	4,15%	1 570	0,56%	11	8	324 720	1 879
0-3 after booster dose							
60-69	0,30%	1 431	0,06%	18	13	491 058	308
70-79	0,62%	1 793	0,19%	11	8	322 513	619
80+	0,72%	1 443	0,32%	6	4	184 587	602
Average	0,46%	1 570	0,14%	11	8	324 720	461

Table A.3: Expected direct costs of the disease according to age and dose in the case of the Delta variant

$$F(0) = 0$$

$$\frac{f(t)}{1-F(t)} = p + qF(t)$$

$$\frac{\frac{\partial F}{\partial t}}{1-F} = p + qF$$

$$\frac{\partial F}{\partial t} = (p+qF)(1-F)$$

$$\frac{\partial F}{\partial t} = p + (q-p)F - qF^2$$

$$\int \frac{1}{p+(q-p)F-qF^2} dF = \int dt$$

$$\frac{ln(p+qF) - ln(1-F)}{p+q} = t + c$$

$$t = 0 \implies F(0) = 0 \implies c = \frac{ln(p)}{p+q}$$

$$F(t) = \frac{pe^{(p+q)t} - p}{e^{(p+q)t} + q}$$

Figure A.1: WLS regression result Booster doses

WLS Regression Results

Dep. Variable:	VR_3rd_dose_31_1_2022	R-squared:	0.992
Model:	WLS	Adj. R-squared:	0.992
Method:	Least Squares	F-statistic:	8317.
Date:	Tue, 27 Sep 2022	Prob (F-statistic):	3.37e-135
Time:	17:08:52	Log-Likelihood:	378.64
No. Observations:	120	AIC:	-749.3
Df Residuals:	116	BIC:	-738.1
Df Model:	3		
Covariance Type:	HC1		

	coef	std err	z	P>|z|	[0.025	0.975]
Intercept	0.6520	0.005	144.043	0.000	0.643	0.661
Bonus[T.áno]	0.1722	0.005	33.452	0.000	0.162	0.182
Distance_from_60_in_months	0.0009	0.000	5.999	0.000	0.001	0.001
Distance_from_60_in_months:Bonus[T.áno]	-0.0002	0.000	-0.923	0.356	-0.000	0.000

Omnibus:	53.059	Durbin-Watson:	1.994
Prob(Omnibus):	0.000	Jarque-Bera (JB):	433.234
Skew:	1.198	Prob(JB):	8.40e-95
Kurtosis:	11.995	Cond. No.	116.

Notes:
[1] Standard Errors are heteroscedasticity robust (HC1)

Source: Author's computation