THE FINANCIAL IMPACT OF SHINGLES VACCINE REIMBURSEMENT ON LITHUANIA'S BUDGET

A Thesis

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by

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Summary

Investment in public health has always been an important aspect for the improvement of a society's wellbeing and economic development of a country. Due to a recent increase in cases of vaccine-preventable diseases and the inevitable society's ageing, the national healthcare system in Lithuania is expected to face increasing financial pressure. One of the possible ways of reducing the financial burden of elderly treatment in Lithuania is vaccination against shingles virus. Therefore, the thesis will try to evaluate the financial impact of shingles vaccine funding on the country's budget if the state reimbursed it.

In order to achieve such aim, the first part of the thesis will examine the budget composition of the National Health Insurance Fund and will present the importance of shingles spread worldwide as well as in Lithuania. The second chapter will include the theoretical analysis on the economics of immunization, compare possible research methods and include a detailed description of the thesis research model. Finally, the last part will measure the financial costs of shingles treatment in Lithuania and compare it with the potential shingles vaccination scenario. By using economic modelling and scenario analysis methods, the thesis concludes that shingles vaccine reimbursement for all adults over 50 years-old is not an optimal financial decision. Other strategies, such as vaccinating a smaller part of the risk group or choosing to partially reimburse the vaccine, could bring more than 0.8 million EUR savings into the country's budget.

Keywords: budget-impact analysis, reimbursement, vaccination, shingles

Word count: 14862

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Introduction

Since 2016, Lithuania records positive general government sector's balance (Eurostat, 2020b), indicating effective management of the country's finances. Part of Lithuania's general government budget structure is formed by the National Health Insurance Fund (NHIF), which has been experiencing budget growth in recent years (NHIF, 2019). Naturally, this growth not only allows to increase financing for medicines, treatment services and salaries of the medical community, but also to expand the existing health programs, such as the National Immunoprophylaxis Programme. While the preventative children vaccination calendar's implementation in the programme is effective with more than 90% vaccination coverage, however, vaccination for adults and elderly remains insufficient, which is the main reason of the recent vaccine-preventable diseases outbreak (Ministry of Health, 2019). Consequently, as the incidence of these diseases increases, the more pressure is directed towards the national health system and distribution of budget funds.

One of the most relevant diseases of the elderly nowadays is shingles virus which can lie in people's nerve cells for many years without causing any symptoms (WHO, 2014b). The weakening of immune system, additional oncological or HIV diseases, as well as rising global stress levels, trigger the reactivation of virus most commonly for people over 50 years-old (Gershon et al., 2015; Harpaz, Leung, Brown, & Zhou, 2015). The older is the adult, the more he is likely to develop complications that will be treated at hospitals, such as long-lasting nerve pain, blindness, hearing problems and in rare cases, the disease can become fatal (Gershon et al., 2015). As most of the societies are ageing, including Lithuania, the change in the demographic situation will naturally lead to increasing incidence rates of the shingles virus, thus there will be a more significant part of society experiencing complications, whose treatment will be covered by the National Health Insurance Fund.

Consequently, it is not only essential to evaluate current financial costs of treating patients with the active incidence of shingles, but also to reconsider the preventative measure's – vaccination – impact if the state funded it. Vaccination is expected to improve general society's wellbeing, enhance immunity towards infectious diseases and minimize financial burden on the Lithuania's healthcare system. Therefore:

Problem being investigated throughout the paper: how could shingles vaccine funding contribute to reducing the disease's financial burden on the country's budget?

Aim of the thesis: to determine the financial impact of shingles vaccine reimbursement on Lithuania's budget.

Objectives:

1. Examine the composition of the National Health Insurance Fund's (NHIF) budget and the allocation of funds;
2. Analyse current shingles spread and tendencies globally as well as in Lithuania;
3. Analyse existing theoretical literature on the economics of immunization;
4. Compare possible research models and describe a chosen research method;
5. Measure the financial costs of shingles treatment in Lithuania;
6. Evaluate the financial implications of shingles vaccine's reimbursement on Lithuania's budget.

Research methods: in order to calculate treatment and potential prevention costs from the National Health Insurance Fund's perspective, a budget impact model is developed using Microsoft® Excel 365. The expected treatment focus costs are compared with a prevention focus, including both scenario and break-even analyses. The time frame chosen is five years and results are provided as the net present value, comparing both treatment and prevention focus as projects to minimize costs.

As there is no publicly available pharmacoeconomic analysis on shingles disease treatment in Lithuania, this research could be useful for the Ministry of Health of the Republic of Lithuania as well as for the Centre for Communicable Diseases and AIDS by providing in-depth analysis how preventing this disease would benefit the society. As well, it could encourage collecting and publishing more extensive shingles disease incidence data in Lithuania. The analysis provides the forecast of future costs by choosing to prevent or treat the disease, thus it allows to compare different strategies and creates a better understanding of the expected results for the Government. Moreover, this research can also be valuable for the National Health Insurance Fund and the Ministry of Finance of the Republic of Lithuania to re-evaluate current budget structure and its appropriations for different areas of the health sector. Finally, it is expected that the research will create the benefit for patients and the overall pharmaceutical industry in Lithuania by increasing awareness of the shingles disease.

1. Situation Analysis

The first chapter of this thesis focuses on providing the general environment analysis where the research problem exists. Firstly, the National Health Insurance Fund budget is reviewed to understand how the funds for the health system were distributed in the period 2016-2020. Then, the analysis of vaccination coverage in Lithuania provides a clear understanding of the Government's and society's position towards the prevention of the diseases. Moreover, the paper overviews shingles spread by explaining the importance of the disease and a possible preventative measure - vaccination. Finally, the last subsection includes the analysis of shingles treatment and prevention in Lithuania.

1.1. Lithuanian Healthcare System and Budget

Effective management of a healthcare system, from the point of view of budget funding and appropriations, is a continual country's necessity. It allows increasing the general well-being of society by guaranteeing high-quality care, ensuring affordability of medicines and expanding capital investment into the newest medical devices. According to the Organisation for Economic Co-operation and Development (OECD, 2018), since the renewal of Lithuania's independence in the late twentieth century, the country was able to build a remarkably stable and modern healthcare system. The main institutions remain the Ministry of Health of the Republic of Lithuania and the National Health Insurance Fund (NHIF), governed by the Ministry of Health, which are responsible for formulating health-related policies and regulations in the country (OECD & European Observatory on Health Systems and Policies, 2019). In 1996, the legislation of the compulsory health insurance was passed, where the automatic health coverage for children, students, the unemployed and pensioners was provided, meaning that the rest of the population became entitled to making statutory contributions in order to be eligible for free care (OECD, 2018). Nowadays, these statutory contributions compile a central part of the National Health Insurance Fund revenues in the yearly budget. Thus, they are important to be analysed in the time perspective.

1.1.1. National Health Insurance Fund revenues. The Law on Health Insurance in Lithuania states that an economically active person employed on a contract shall pay 6.98% of a person's income (other employment categories face an adjusted tariff, for example, percentage can be applied on their minimum monthly earnings) (The Law on Health Insurance, 2014, as cited by the NHIF, 2020a). Contributions to the NHIF from payrolls in total accounted for approximately 69%-70% of the overall Fund's revenues in the period of 2016-2020, as it is shown in Figure 1.

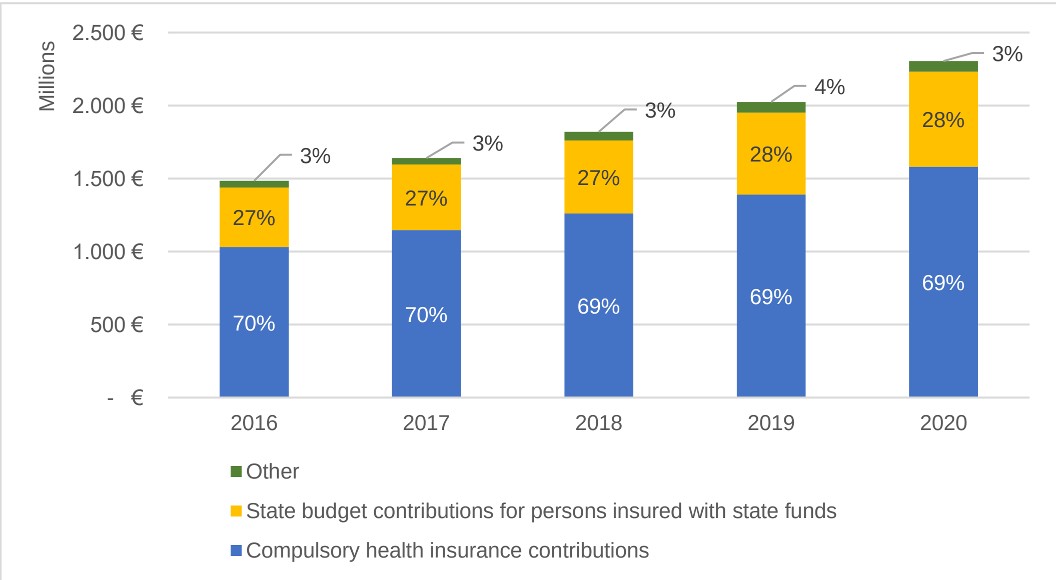


Figure 1. Revenue composition of the National Health Insurance Fund 2016-2020. Created using the data from "Biudžeto vykdymo ataskaitų rinkiniai" by the National Health Insurance Fund, 2020b. The data for 2016-2019 represents budget execution, while the data for 2020 – the budget. Percentages provided are rounded to the nearest unit.

However, a slight decrease of these revenues as a share of total NHIF income can be noticeable since 2018 alongside with a small increase in assignations from the Republic of Lithuania national budget for the persons insured with state funds (children up to 18 years old, students, unemployed people and pensioners over 64 years, depending on gender). The biggest economically inactive group of population in Lithuania are individuals over 65 years (almost 20% of the total population in 2019), which size in terms of the total population is increasing every year of around 0.12%-0.33% percentage points (Eurostat, 2020a). As the ageing process in Europe is inevitable and a considerable shrink in the working population (15-64 year olds) is expected reaching just a bit more than 55% of the total population in Lithuania in 2070 (European Commission, 2018), there are no doubts that assignations from the national budget will have to make up a much more significant part of the NHIF budget in order for the healthcare system to remain effective in the long-term. One of the possible ways to support the NHIF budget is to allocate a higher share of the national Government's revenues. However, the optimisation and revision of NHIF budget expenditures are essential as well as ensuring a well-functioning health system in Lithuania.

1.1.2. National Health Insurance Fund expenditures. Budget appropriations of the National Health Insurance Fund include several areas of activity, ranging from the expenditures for the personal health care services, medicines, health programs and rehabilitation to the functioning of the NHIF. The budget expenditures of 2020 of the National Health Insurance Fund are decomposed in Figure 2.

The biggest share of the total budgeted expenditures of the NHIF in the year 2020 is formed towards personal health care services. These services include primary inpatient (mainly hospitalization) and outpatient care (mostly visits to general practitioners and other healthcare professionals), medical nursing services, etc. and are planned to account to 65% of total expenditures, or approximately to 1,510 million EUR. The second most crucial expenditure area is medicines and medical aids, which is expected to amount to more than 360 million EUR or 16% of total expenditures. Since 2018, the NHIF included an additional area of appropriations – part of the available funds is allocated to the National Health Insurance Fund's reserves. Such decision allows planning future balance of funds and the potentials risks more effectively. These reserves are expected to account to 9% of total expenditures in 2020. Finally, health programs make up a relatively significant part of the budget, including expenditures to a number of preventative programs as well as the National Immunoprophylaxis Programme’s funding. The NHIF has planned to spend around 63 million EUR, or 6% of total expenditures, to support these programs.

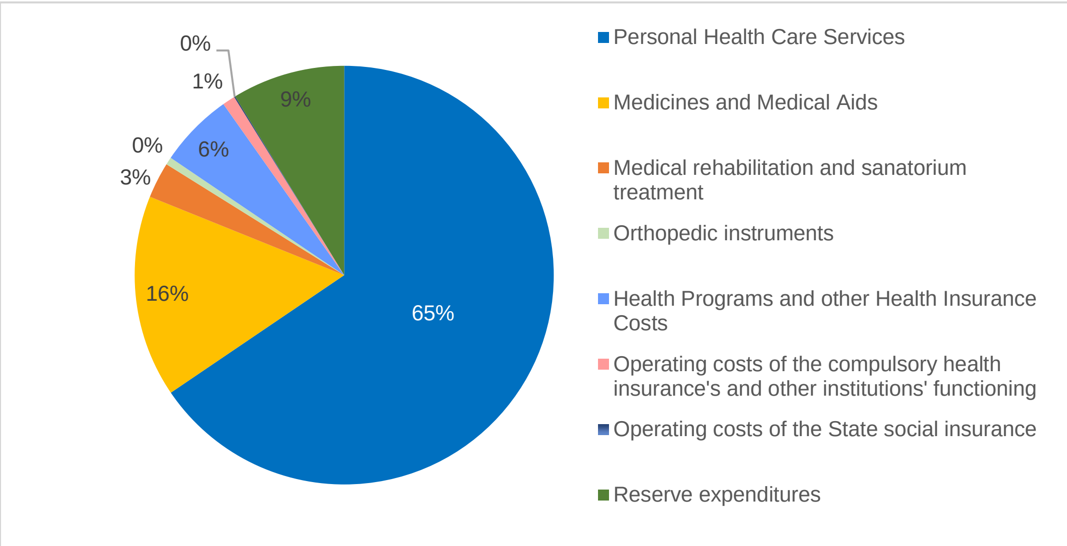


Figure 2. Composition of the National Health Insurance Fund budget expenditures 2020. Created using the data from “Biudžeto vykdymo ataskaitų rinkiniai” by the National Health Insurance Fund, 2020b.

Furthermore, after the analysis of the composition of the National Health Insurance Fund in 2020, it is important to compare how the budget’s execution was changing between 2016 and 2020. It can be noticed in Figure 3 that since 2016 the expenditures of the NHIF increased by 56% - from 1,474 to 2,305 million EUR. In fact, the expenditures towards personal health care services were significantly increasing in the analysed period, which raises a question what actions should be taken in order to reduce general societies’ morbidity, thus people would need to visit physicians, be hospitalized or seek other medical aid less frequently. As a consequence, from the NHIF budget‘s point of view, decreased morbidity would allow to spend less for the personal health care services, therefore, the higher allocation to other healthcare system areas might become potential.

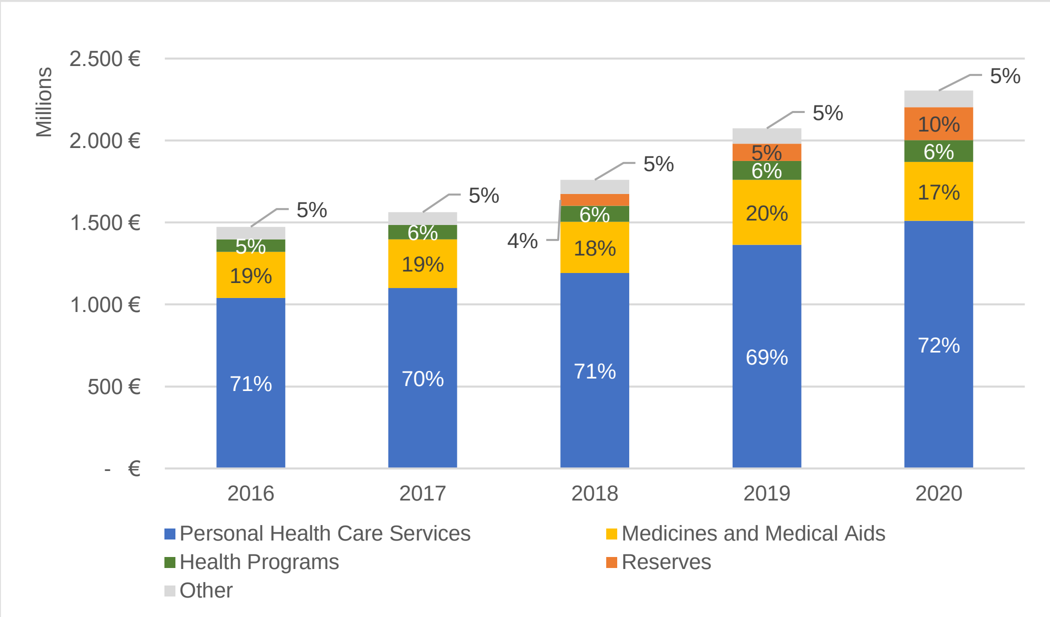


Figure 3. Expenditures of the National Health Insurance Fund in 2016-2020. Created using the data from "Biudžeto vykdymo ataskaitų rinkiniai" by the National Health Insurance Fund, 2020b. The data for 2016-2019 represents budget execution, while the data for 2020 – the budget.

As an example, expenditures towards health programs, which would contribute to the improvement of public health, were not that significantly increasing since 2016. Figure 3 shows that spending on preventative programs made up around 5%-6% of total assignations. What is even more critical, that the National Immunoprophylaxis Programme's – as a part of the health programs' in Lithuania to manage, reduce morbidity and outbreaks of communicable diseases through vaccination – a share of total expenditures has been even decreasing (from 0.62% in 2017 to 0.59% in 2019 of total spending). In comparison to the European Union, Lithuania spent 0.9 percentage points less than the EU on average in 2017 for the preventative programs' implementation, and it is highly relatable to the fact that mortality rate from vaccine-preventable diseases in Lithuania is among the highest in the EU (OECD & European Observatory on Health Systems and Policies, 2019). On the other hand, not only the appropriations of the NHIF budget seem questionable nowadays, but also the overall Government's position to healthcare spending. The study provided by the OECD and the European Observatory on Health Systems and Policies (2019) indicates that "Lithuania's spending on health care is among the lowest in the EU", more specifically, it is the fifth-lowest (p.10). Therefore, taking into account these significant differences between spent amounts on treatment and preventative programs and in general low healthcare spending, it is evident that the approach of the Government, Ministry of Health and the NHIF to the long-term wellbeing of the society and effective allocation of funds should be reconsidered.

1.2. Vaccination Coverage in Lithuania

The overview of current Lithuania's stance towards vaccination as an effective preventative measure to increase societies' wellbeing is provided to understand how the Government forms its position through the national vaccine-preventable diseases programme as well as the society's response to the programme implementation.

1.2.1. National Immunoprophylaxis Programme. The immunization coverage rate, as a percentage of given vaccine doses out of total target group, can express a general population's position towards vaccination as a way to immunize and prevent communicable diseases. According to the National Immunoprophylaxis Programme for 2019-2023 (Ministry of Health, 2019), insufficient vaccination coverage for the past few years has significantly contributed to increasing communicable diseases' incidence rates in Lithuania and is caused by several factors. Due to limited reliable information that would be easily accessible for the society, misleading articles provoking controversial discussions in the media and misunderstanding of the societal benefits of vaccination by both society and medical community, the confidence in vaccines is continuously decreasing (Ministry of Health, 2019). Moreover, as the morbidity of some infectious diseases has outstandingly decreased, the society started questioning the need of vaccination, which induces the movements of anti-vaccination groups promoting public distrust (Ministry of Health, 2019). According to the European Vaccine Action Plan for 2015-2020 by the World Health Organization (WHO, 2014a), it is essential to reach vaccination coverage goals in order to keep incidence rates of these diseases low. This way, the role of vaccination to prevent morbidity, save lives and prolong life expectancy would keep its significance, and at the same time it would contribute to the social and economic development of the country.

1.2.2. Immunization rates. It is important to note that in general vaccination against infectious diseases is not mandatory in Lithuania and immunization coverage rates are substantially different for children and adult target groups. One of the reasons might be that Lithuania's immunization calendar is intended for children vaccination with clearly set coverage goals, while adults remain the group which the state has set the goal to only keep increasing immunization for (Ministry of Health, 2019). For example, vaccination coverage in 2019 was 96.6% and 96.3% for new-born tuberculosis and hepatitis B vaccination, respectively (Centre for Communicable Diseases and AIDS, 2020). On the other hand, even if measles vaccination coverage (children of 2 years) might seem sufficient with the rate of 92.1% in 2019 (Centre for Communicable Diseases and AIDS, 2020) it does not satisfy the target of 94% recommended by the World Health Organization, indicating the possible reason of measles outbreak in the past few years (OECD & European Observatory on Health Systems and Policies, 2019). Immunization for one of the most critical diseases - pneumococcal infection - that is particularly risky for adults over 65 years old, coverage is not even tracked, the only official information available is the number of people vaccinated in the risk group – 13587 adults in 2019 (Centre for Communicable Diseases and AIDS, 2020). One of the provisions of the WHO is to increase seasonal influenza coverage and keep it around 75%. However, the reality reveals that only 13% of people over 65 years-old that are eligible for a free vaccination are vaccinated against influenza, while the European Union's average remains around 44% in 2019 (OECD & European Observatory on Health Systems and Policies, 2019). In fact, since influenza vaccine's reimbursement in 2007 (Ministry of

Health, 2020), vaccination coverage has not increased significantly – every year it varies from 9% to 15% for adults over 65 years-old, leading to a fact that immunization rates for adults are, in fact, extremely low. As a result, mortality from influenza is an increase facing consequence of nowadays Lithuania (Centre for Communicable Diseases and AIDS, 2020). Thus, there are no doubts that much more focus should be dedicated to adult vaccination and prevention of such disease. Finally, receiving a varicella vaccine from chickenpox can reduce the risk of shingles reactivation in the future (the relationship between these two diseases is explained in the next section) (CDC, 2019a), but the immunity is acquired for 10-20 years, and a person becomes prone to the infection's reactivation (CDC, 2019b). However, chickenpox vaccine in Lithuania is not funded by the Government to any age group, which leads to low immunization rates, thus, much higher probability to develop shingles in the future (Centre for Communicable Diseases and AIDS, 2020).

Taking everything into account, the differences between children and adult vaccination exist, which are mainly impacted by the fact that adult vaccination is not a clear priority for the state. Consequently, the analysis of vaccination coverage in Lithuania provides a clear view that much more focus on preventing diseases for adults should be dedicated. Therefore, one of the emerging infections' worldwide – shingles virus – importance and prevention is analysed in the following section as a way to increase the adult society's wellbeing with a positive impact on the healthcare budget in Lithuania.

1.3. Global Epidemiology of Shingles

To understand the growing importance of shingles virus, the general information of the infection is provided, followed by its prevalence worldwide and the causation provoking the virus. Finally, the most effective preventative measure – vaccination – is overviewed.

1.3.1. Shingles disease. Shingles (or herpes zoster, HZ) is being caused by an identical varicella zoster virus which firstly causes chickenpox – highly contagious infection, that usually children get infected of (Reich, Psomadakis, & Buka, 2016) and is identified with red itchy spots appearing all over the body (NHS, 2017). Once a person gets infected with chickenpox, the virus stays in a human's body and can lie in nerve cells without any symptoms until its reactivation, which causes shingles – a painful, itchy rash that usually forms around nerves (WHO, 2014b). It is essential to mention that it is not possible to catch shingles from a person who is ill with chickenpox, however, it can happen vice versa - a person can get infected with chickenpox from someone with shingles (NHS, 2017). Naturally, the higher is the number of shingles virus incidence worldwide, the higher the risk is to get infected with the first form of varicella virus if no preventative measures are taken. Consequently, the more people are carrying the deactivated varicella virus, the higher part of the society is likely to face its reactivation.

1.3.2. Prevalence and complications. When it comes to the spread of herpes zoster virus in Europe, the lifetime risk of an individual is around 24%-30%, thus one out of four people is expected to develop shingles during his life (Pinchinat, Cebrian-Cuenca, Bricout, & Johnson, 2013). Studies show that HZ for people aged 50 years and more occurs approximately for two-thirds (Yawn et al., 2007). Finally, if an individual is aged 85 years or more, the risk increases to 1 in 2 people to develop the disease (Schmader, 2001). In addition to this, the disease can also lead to a number of complications. For example, post-herpetic neuralgia (PHN), long-term pain of nerves (CDC, 2019c), is estimated to occur for 22% of patients (WHO, 2014c), leading to "several months of treatment and loss of quality life" (Pinchinat et al., 2013, p.2). Another complication with a likelihood of 15% is HZ ophthalmicus, which if untreated, can lead to visual impairment or even blindness (WHO, 2014c). Very rarely, shingles can lead to hearing problems or encephalitis (CDC, 2019c) and 7-25 out of 100,000 cases can be fatal (WHO, 2014c).

Nevertheless, studies show that herpes zoster spread is different among the regions and countries. One of the reasons why these differences appear is that high-income countries invest in collecting data of varicella incidence rates, while most of the low and middle-income countries do not track such data, which leads only to assumption-based researches performed in those countries (Hussey et al., 2016). Reasons why data is limited also depend on a society's propensity to either attend medical appointments or choose self-treatment (Yawn & Gilden, 2013). As an example, there is very limited summarized information on shingles and overall varicella virus burden in Africa region due to the limited amount of cases reported (Hussey et al., 2016). Similar data limitations are noticeable in Asia and Latin America regions, while, in comparison, there are more than 130 studies about the shingles spread in North America, Europe and Asia-Pacific (Zorzoli et al., 2018). On the other hand, depending on the quality of studies, the differences in prevalence are mostly noticeable in Asia-Pacific region, where the incidence rates reach to 3-10/1000 person-years (reported in Australia, Taiwan, South Korea, Japan), while in North America and Europe about 3-5/1000 person-years (Yang et al., 2019). However, taking into account the estimates of 2018, there will be a quarter of population globally aged over 60 years, whereas the population of 80-year-old will treble in 2050 (excluding African region) (Zorzoli et al., 2018). Therefore, we might expect much more focused priority in collecting shingles virus-related data and quality researches worldwide.

1.3.3. Reactivation. Another important aspect of the analysis of the virus spread is when and how it reactivates during a person's lifetime. One of the most significant factors that lead to the risk of developing shingles is the age of 50 years and the older a person is, the more likely he is to develop the disease (Gershon et al., 2015). Besides, older people usually have a weaker immune system and chronic illnesses that provoke the infection, and it is also highly relatable to chemotherapy which is used to treat cancer and HIV infection (Gershon et al., 2015). The hypothesis of stress-related reactivation of the virus is also supported by studies (Schmader, George, Burchett, Hamilton, & Pieper, 1998; Harpaz, Leung, Brown, & Zhou, 2015). Although the global stress levels have been increasing for the past few years, the pandemic COVID-19 disease in the year of 2020 has contributed significantly to the causation of stressful emotions (CDC, 2020a). Thus, the importance of this factor is likely to be much stronger nowadays than a few years ago. On the other hand, risk factors can be unrelated to a person’s health, taken medication or lifestyle, but can depend on gender and even ethnicity: studies show that being a white female is a strong factor that increases the risk of shingles reactivation (Thomas & Hall, 2004). By overviewing the main causes of shingles, it becomes clear that it can be provoked by many factors, as well as be dependent and independent on a person’s healthiness.

To conclude, even if shingles is not the most life-threatening infection, there are no doubts about its prevalence worldwide, the need to lower morbidity and painful burden for the elderly. Also, it is important to analyse how the preventative measure – vaccination – would help to reduce the disease incidence.

1.3.4. Prevention. Vaccination is the best way to prevent developing severe complications of shingles. Currently, there are two vaccines available for HZ prevention – “Zostavax”, Zoster vaccine live developed by Merck (Merck Sharp & Dohme Corp., n.d.) and “Shingrix”, a non-live adjuvanted vaccine developed by GlaxoSmithKline (GlaxoSmithKline plc, 2018). The latter vaccine is being recommended by the Advisory Committee on Immunization Practices in the United States since 2017 and is considered to be effective by more than 90% in preventing shingles and post-herpetic neuralgia (CDC, 2018a). In Europe, both of these vaccines are registered, however, “Zostavax” is not supplied to the region (National Public Health Centre under the Ministry of Health, 2019). Furthermore, an adjuvant added in the vaccine “Shingrix” is the ingredient which creates a robust immune response (CDC, 2018b) that is much harder to be evoked in the elderly people otherwise (Esposito et al., 2018). Thus, the vaccine “Shingrix”, as a preventative measure against herpes zoster, will be further considered in this paper as it is expected to provide the most effective prevention.

Although the risk group of shingles reactivation are people over 50 years old, studies show that funded vaccination of shingles is not necessarily covering the entire risk group. For example, the Australian National Shingles Vaccination Program has reimbursed the vaccine “Zostavax” for the adults aged 70-79 years, as the routine vaccination is “expected to obtain the greatest benefits against shingles and its complication” (Australian Government Department of Health, n.d., p.2). In Ontario, Canada, for example, the vaccine “Shingrix” is funded since 2016 for elderly at 65-70 years old (Ontario Ministry of Health and Long-Term Care, n.d.). Being introduced in 2013 and adjusted in 2017, the shingles vaccination programme in the United Kingdom provides free vaccination for patients aged 70 years or 78 (Public Health England, 2018). Finally, the recommendation by STIKO (Standing Committee on Vaccination) in 2018 December was passed to reimburse the vaccine for people over 60 years-old in Germany (Siedler et al., 2019). Taking into account the differences in recommendations among the countries, it leads to a conclusion that there is no one single decision for which age group shingles vaccine should be funded.

1.4. Shingles Morbidity in Lithuania

According to the European Centre for Disease Prevention and Control (2011), there was no surveillance system for herpes zoster until 2010 in Lithuania. In order to receive shingles morbidity data for the period 2016-2019, a specific request was made to the Institute of Hygiene as currently the data is not being publicly provided. The officially registered cases of shingles morbidity in Lithuania for the period 2016-2019 are summarized in Figure 4.

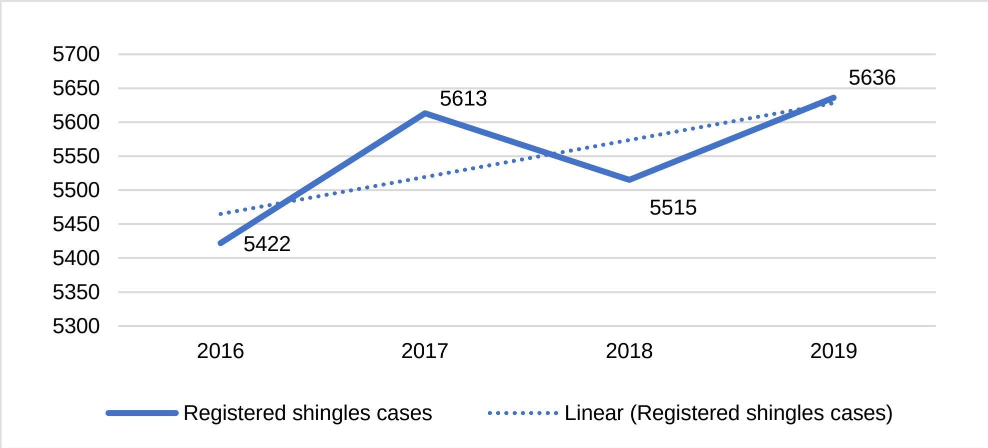


Figure 4. The official shingles morbidity in 2016-2019. Created using the data from the Institute of Hygiene, personal communication, October 30, 2020.

The number of officially registered shingles cases was slightly fluctuating in 2016-2019 and approximately amounted to 5,547 cases every year. Nevertheless, a growing linear trend can be undoubtedly noticed, indicating that more and more people will develop this disease in the future. It is important to mention that such data include cases by both outpatient and inpatient health care services. Thus, it does not allow to create a more detailed picture of shingles morbidity in Lithuania, since it is not available to be analysed by gender or age group or only by visits at physicians or hospitalizations. In addition to this, there is no official study or report on the Government's position towards shingles treatment and prevention in Lithuania. Therefore, it is extremely important that such position would be formed as it would raise public awareness for the disease and would allow considering the allocation of budget resources for the prevention and treatment of the disease.

Currently, there is only one possibility to vaccinate against shingles (vaccine "Shingrix") at the price of 190 EUR in the private market in Lithuania (Endemik, 2020). In order for immunization to be acquired, two injections with an interval of two to six months have to be received by an individual (GlaxoSmithKline plc., n.d.), therefore, in total it costs 380 EUR. Since an average monthly salary in Lithuania amounts to net 889 EUR (Ministry of Social Security and Labour, 2020), the price of the vaccine makes up around 21.4% of an individual’s monthly income. However, this statement is only applicable to individuals who are older than 50 years (approximately 42% of the total population) but are still active in the labour market. When an individual becomes a pensioner (in 2020, the retirement age in Lithuania is 64 and 63-years for male and female, respectively, and is expected to increase and reach 65-years in the year 2025 (Sodra, 2020a)), it is practically impossible to afford a vaccine as it amounts to nearly 50% of an average pension per month in Lithuania in 2020 (Ministry of Social Security and Labour, 2020). Naturally, the current private market vaccination opportunity cannot be easily obtainable for most of the elderly society members, meaning that other solutions, such as the vaccine’s funding, should be considered and compared to the expected treatment costs. Therefore, other chapters in the paper will review the existing literature on the models of shingles treatment costs’ evaluation and will estimate the financial burden on Lithuania’s healthcare system.

2. Theoretical Justification and Research Methods

The second chapter of this paper considers the theoretical background on the potential economic implications if the preventative measure – vaccination – is chosen to reduce shingles morbidity. Therefore, this chapter firstly focuses on the theoretical analysis of the economics of immunization. Secondly, in order to create a research model which would test shingles vaccination funding impact on Lithuania's budget, possible research methods on a vaccine's reimbursement are analysed, and components for the model analysis are selected. Finally, the detailed explanation of the paper's research method is provided, which is further developed in the third chapter.

2.1. Economics of Immunization

At all times, public health has been an important aspect of every society. Since such epidemics as the European Black Death, caused by the bubonic plague in 1347, people have started to recognize that every individual's health is strongly affected by the healthiness of other society members' (Smith, Woodward, Acharya, Beaglehole, & Drager, 2004). Due to emerging globalization in the twentieth century, the interconnectedness of health has accelerated the transmission of communicable diseases (Smith et al., 2004). Naturally, the question arises, whether individuals or Governments should take the responsibility to prevent the global spread of such diseases.

In order to identify the role of Government in the control of vaccine-preventable diseases, it is important to analyse prevention as a good from the perspective of the Global Public Good concept (GPG). A public good, in general, is defined by the rivalry in consumption and excludability (Kaul, Grunberg, & Stern, 1999). Immunization, as the process of becoming resistant to a disease through vaccination (WHO, n.d.), can be considered a rival good, since in order to acquire it, the specific vaccine is needed for a person. Therefore, the number of vaccines manufactured decreases as people get vaccinated.

Similarly, immunization can be excluded from someone who cannot pay for a vaccine. Thus, it is excludable from individuals having lower financial capabilities (Kaul et al., 1999). Consequently, if immunization is neither non-rival nor non-excludable, it might be stated that immunity is not a public good.

However, externalities arising from the gained immunity should be taken into account before such a conclusion is made. A robust positive externality can be considered a situation when a person, who has not received a vaccine, avoids the infection due to the fact that a sufficient number of individuals in a society has developed immunity. Such a concept, in theory, is described as herd immunity, when protection is created indirectly through a vaccine’s effect on a disease transmission (Fine, Eames, & Heymann, 2011). Although there are several definitions of this concept, this paper considers a viewpoint that “not everyone in a population needs to be immunized to eliminate disease” (John & Samuel, 2000, p.601). In other terms, even if the vaccine coverage is significantly less than 100%, it might be enough to prevent a disease’s transmission in a society (John & Samuel, 2000). Therefore, the more people get vaccinated against a particular infection, the stronger direct effect of immunity is created, which leads to indirect benefits of vaccination. It means that immunization as a good can be, in fact, considered non-rival, as the benefit of herd immunity received does not limit other individuals to experience such benefit. Finally, immunity, then, is non-excludable, as even if some individuals are excluded from receiving it, the socially sub-optimal exclusion is formed by the external benefits of herd immunity (Smith et al., 2004). Thus, the positive externality associated with herd immunity is what makes immunization to be a public good.

Furthermore, it can be argued that immunity is not only a public good for a nation, but for the world as well: if Country A can reduce a disease prevalence, Country B is expected to benefit from this reduction (Smith & MacKellar, 2007). It is especially true for diseases that are easily transmitted by humans, animals or products in trade (Smith & MacKellar, 2007).

On the other hand, such diseases as malaria are only endemic in specific geographic areas, and control benefits are limited, thus much less than global. However, other infections such as varicella zoster virus, leading to chickenpox and the reactivation of shingles, are spread globally (Sengupta & Breuer, 2009) (for this disease specifically, the decrease in shingles cases would mean a reduction in chickenpox morbidity – such relationship is described in section *1.3.1. Shingles disease*). This leads to a conclusion that immunity can be considered a global public good for a specific sub-set of communicable diseases. For infections that are important at a global level, the "collective action at the international level" has to be ensured, but since there is no global government, the leading strategical players are national governments, which should provide funding for the control of communicable diseases (Smith et al., 2004, p.272).

Even if national Governments should support immunization against particular vaccine-preventable diseases, the private market provision of vaccines is prevalent in many countries. A study by DeRoeck (2004) showed that private sector's delivery of vaccines creates a "public demand for a vaccine before it is introduced into the public sector" (p.328) and creates an opportunity for individuals with higher income to receive a vaccine that is not yet available in the public sector, or receive vaccination service with higher quality. However, as the private sector mainly includes profit-seeking organizations, they are unable to ensure a high vaccination coverage due to the price that is not affordable for a significant share of the society (Levin & Kaddar, 2011), which is precisely the reason of the private market failure. In addition to this, as part of the society is not able to become immunized due to vaccination costs, the problem of free-riding appears, as individuals receive the benefit of the control of a communicable disease without having to pay for it (Ibuka, Li, Vietri, Chapman, & Galvani, 2014). Therefore, a private sector in vaccines provision is often viewed as a "gap filler" to provide immunization services when they are limited to public market (Levin & Kaddar, 2011) or have higher estimated benefits than if being provided by the Government.

The estimation of perceived benefits or minimized costs that are expected to appear if the Government is responsible for a vaccine's funding involves the analysis of health, social and economic implications. The latter – economic – consequences are usually measured through budget impact or cost-effectiveness models (Rodrigues & Plotkin, 2020). If the estimated benefits exceed the expected costs or the costs are significantly reduced, then the Government plays an essential role in funding immunization, as a public good, to society.

All in all, immunization against specific, globally significant communicable diseases is a desirable target of every society due to positive externality of herd immunity, which makes immunization a global public good. Since sufficient coverage resulting in indirect vaccination benefits is not likely to be reached through the private sector, Governments are incentivized to fund vaccines in the public market. Thus, it is important to overview the researches on shingles vaccine provision in the public market and introduce what potential components could be used to evaluate the shingles vaccine reimbursement project in Lithuania.

2.2. Empirical Research Methods

Although there is a number of cost-effectiveness analyses (CEA) performed on the topic of a vaccine's funding, Carvalho, Jit, Cox, Yoong and Hutubessy (2017) summarized that most of the published economic evaluations do not perform a budget impact analysis (BIA) due to confidentiality and publicity issues. According to the Principles of Good Practice for Budget Impact Analysis by Mauskopf et al. (2007), the main difference between these types of researches is while "CEA evaluates the costs and outcomes of alternative technologies over a specified time horizon to estimate their economic efficiency, BIA addresses the financial stream of consequences related to the uptake and diffusion of technologies to assess their affordability" (p.337). Thus, even if there are many similar components included in both CEA and BIA researches, the final answer received can lead to different results and interpretations. For example, CEAs include the estimation of a vaccine's efficacy (Brisson, Pellisier, Camden, Quach, & De Wals, 2008), the number of people required to vaccinate in order to prevent one case (Annemans, Bresse, Gobbo, & Papageorgiou, 2010) and provide an outcome as a cost of quality-adjusted life-year, which in other words means how much does it cost to gain one more life-year for a person (Ultsch et al., 2013). Clearly, such estimations and results would not provide this thesis with an answer to the raised aim, therefore, a more detailed look is taken at the models of budget impact analysis. However, it is important to point out that decisions cannot be based only on the budget impact analysis – it should be performed complementary to CEA (Mauskopf et al., 2007).

The potential budget impact analysis framework is provided by Mauskopf et al. (2007) in Principles of Good Practice for Budget Impact Analysis (Appendix A, Figure 1A). The primary purpose of the budget impact model, according to this research, is to estimate the financial consequences by adopting a new drug, therapy or vaccine to treat or prevent a specific health condition – "new environment" - and compare it with a "current environment". Such summarized view to a budget impact analysis is useful to understand the process of estimating the population included in the analysis and, by taking into account different factors, arrive at the expected cost of illness (Appendix A, Figure 1A). However, such good practice model is not specific to a vaccine's funding scenario, therefore, it is useful to analyse how this model is implemented in actual researches. For example, one of the studies performed in Mexico (Graham et al., 2019) evaluated the potential budget impact of chickenpox vaccination inclusion in the national immunization program by applying the model as shown in Figure 5.

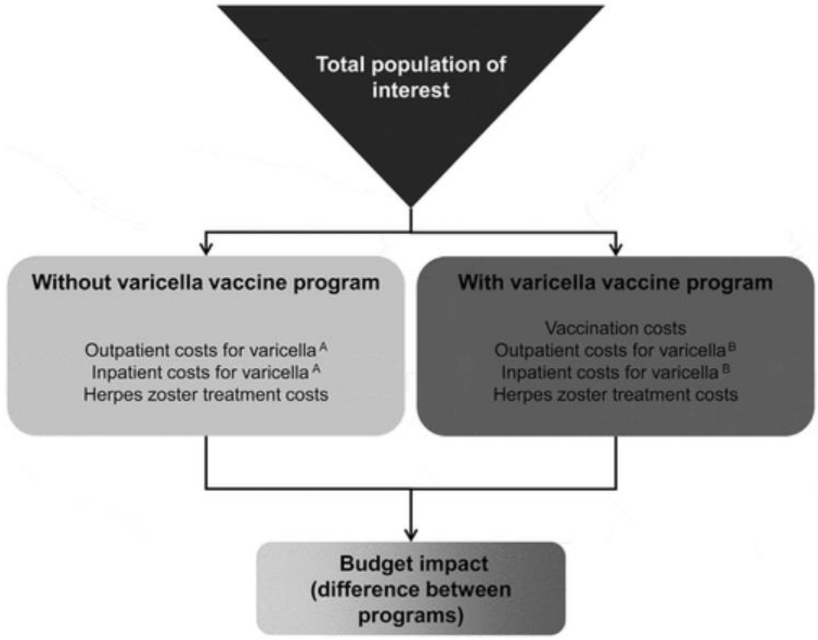


Figure 5. Budget impact structure. From "Budget impact analysis of multiple varicella vaccination strategies: a Mexico perspective" by Graham et al., 2019.

The structure presented in Figure 5 clearly shows that a population of interest, or, in other words, the target group, is first of all identified to be included in the analysis. Then the analysis is divided into two sections: "without vaccination" (regular treatment of a disease) and "with vaccination" (prevention costs plus treatment of patients who have not received the vaccine but have developed the disease). In both scenarios, outpatient and inpatient costs are evaluated, which include hospitalization and visits at physicians, respectively. Furthermore, vaccination costs, included in "with vaccination" scenario, are significant as they should not offset this expected budget-saving coming from the reduction in outpatient and inpatient costs. When all of the costs are summed in each scenario, the difference between the two programs – the budget impact – is calculated. If the scenario of regular care is expected to be more costly, then the vaccination program should be introduced, if less – it is more beneficial for a country's budget to continue usual care of a disease.

Another study performed in the United States by McLaughlin, McGinnis, Tan, Mercatante and Fortuna (2015) thoroughly evaluated the financial and economic burden of the shingles disease and provided a simplified cost model formula of the virus implications on the country‘s budget:

$$TC = No.\ of\ persons * IR * (MC\ per\ case + nMC\ per\ case)$$

where TC are estimated total costs, No. of persons – number of people in the target group or a population of interest in a specific year, IR – estimated incidence rate, MC per case – estimated medical costs of a shingles case and nMC per case – non-medical costs of a shingles case. Such formula is useful to note as it shows that not only direct medical costs (outpatient and inpatient costs) should be considered to be included in the analysis. Non-medical or indirect treatment costs were derived in the research by including lost productivity data (McLaughlin et al., 2015), which can be evaluated as sick-leave benefits paid. Another budget impact research in Germany, although conducted for the rotavirus vaccination program, similarly defined indirect costs as sick-leave benefits, assuming that a disease's treatment costs are also associated with the fact that a person might not be able to work for a particular period of time (Karmann, Jurack & Lukas, 2015).

To conclude, after the review of possible research methods, it was found that the research model of this thesis should be based on the framework of a budget impact analysis, as the aimed research result is the expected financial consequences of both scenarios – regular care (treatment) and prevention of shingles disease. The further section describes the selected research model in detail.

2.3. Research Model

The overall research model is set using Microsoft® Excel 365 software, which was selected due to its flexibility to forecast and evaluate different scenarios. The model is divided into two sub-models, which the associated costs are estimated for:

- Treatment focus: includes estimated costs of usual care of shingles in Lithuania, refers to "no vaccination".

- Prevention focus: includes estimated vaccination against shingles costs plus the remaining estimated usual care for individuals that will not receive the vaccine, refers to "with vaccination".

Both sub-models are considered as cost minimization projects to be analysed in a five years' period timeframe of 2021-2025. Such time frame is selected due to the fact that it corresponds to the period of high "Shingrix" vaccine efficacy (discussed further in section *2.3.4.1. Adjusted shingles morbidity*), meaning that the analysis for a longer period of time (e.g. ten years) might lead to incorrect model assumptions, while a shorter period (e.g. three years) would not allow evaluating an impact of vaccination on morbidity. As presented in section *2.2. Empirical Research Methods*, the first step in a budget impact analysis is to identify the population of interest included in the analysis.

2.3.1. Population of interest. The analysis in section *1.3.4. Prevention* showed that there is no single decision which age group should receive a funded shingles vaccine. In addition to this, different economic evaluations include various age groups which the vaccine's reimbursement was found to be cost-effective for (Chiyaka et al., 2019). Therefore, it was decided to include a whole risk group – population aged 50 years and over – into the base case scenario. Consequently, the term "population" in this paper will, first of all, refer to all people older than 50 years who are permanently resident in Lithuania. Regardless of the results of the base case model, the scenario analysis, then, would allow estimating how the change in vaccinated population size would change the decision to continue usual care of shingles or to reimburse.

2.3.2. Shingles morbidity. As discussed in section *1.4. Shingles Morbidity in Lithuania,* although the data on registered shingles cases in Lithuania was obtained, it is not available to be analysed by gender or age group or by visits at physicians or hospitalizations. Therefore, the model will include the registered shingles cases as a reference point and compare them with the expected shingles cases. Expected shingles cases at a time *t* ($ExpHZ_t$), then, are derived by multiplying shingles incidence rate (IR), taken from another cost-effectiveness or budget impact research on shingles, with the population size estimate in a specific year ($Population_{est,t}$):

$$ExpHZ_t = IR * Population_{est,t} \qquad (1)$$

In addition to this, different morbidity rates are specific to age groups, thus populations‘ and morbidity data is divided into eight groups: 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, >=85 and the gender split is applied. As the most common complication of shingles is post-herpetic neuralgia (PHN) and the incidence of it can be reduced by receiving the vaccine “Shingrix“ (GlaxoSmithKline plc, 2020a), the number of total PHN cases are estimated by multiplying the expected shingles cases ($ExpHZ_t$) with the expected percentage of the population who will develop such complication ($Rate_{PHN}$):

$$ExpPHN_t = ExpHZ_t * Rate_{PHN} \qquad (2)$$

Moreover, the segregation between one and three-month duration PHN cases will be made, since it is expected that costs associated with treatment for three-month PHN duration will be higher. Furthermore, it is believed that treatment costs are different for patients experiencing various levels of pain, thus, by applying an expected percentage, the number of patients experiencing “No pain”, “Mild pain”, “Moderate pain” and “Severe pain” will be found. Although shingles can reoccur a second time, studies show that time between episodes can vary from 96 days to 10 years (Yawn, Wollan, Kurland, Sauver, & Saddier, 2011). Therefore, it is assumed that over a five years period shingles will not reoccur in order not to overcomplicate the model. Finally, having no data on shingles-specific mortality in Lithuania, the mortality level is set to zero as it is being supported by experts' opinions (Annemans et al., 2010).

2.3.3. "No vaccination" sub-model. In this sub-model, the previously described shingles morbidity outputs are used to determine the associated costs of shingles treatment for the period of 2021-2025. Treatment costs are separated into direct medical and indirect costs.

***2.3.3.1. Direct medical costs*.** Direct costs included in the research model are received by adding inpatient and outpatient costs. Inpatient costs, or hospitalization, is considered an important aspect of shingles and PHN treatment as it is the most expensive among all costs (Institute of Hygiene, 2014) and can be prevented with early outpatient treatment. The formula includes an average duration treatment price (*Price(inpatient)*) for an infectious disease multiplied with an estimated number of patients hospitalized for a specific length of stay (*Total Stay*). It is assumed that all necessary medical devices, medical examination and nursing as well as required drugs are included in the average treatment price.

$$Inpatient\ Costs\ (IC) = Price(inpatient) * Total\ Stay \qquad (3)$$

In addition to inpatient costs, outpatient services include visits at primary care physicians in order to consult for an uncomplicated treatment at home of a disease. A physician might prescribe medicines, such as acyclovir, famciclovir or valacyclovir (CDC, 2019d). However, such drugs are currently not compensated in Lithuania, thus they are not included in the analysis. Outpatient costs, then, consist only of the visit price at a physician (*Price(outpatient)*) multiplied with an estimated number of patients' visits (*Total visits*).

$$Outpatient\ Costs\ (OC) = Price(outpatient) * Total\ visits \qquad (4)$$

2.3.3.2. Indirect costs. The model includes only one type of indirect costs – sickness benefits paid for the period of incapacity to work. Such costs are applicable only to age groups which are still active in the job market. As sickness benefits calculations are highly dependent on a specific country included in the analysis (e.g. according to the Lithuanian laws, sickness benefits for the first 2 calendar days of illness is paid by the employer (Sodra, 2020b)), it was decided to use the "Sickness benefit calculator" provided by Sodra (2020c) to arrive at the expected gross value of sickness benefits. The gross value is then adjusted to local taxes, and the net sick-leave costs are summed into total (*SC*).

Then, the total treatment costs are calculated as follows:

$$Treatment\ \ Costs\ (TC) = IC + OC + SC \quad (5)$$

where *IC* is *Inpatient Costs*, *OC – Outpatient Costs* and SC – *Sick-leave Costs*.

Finally, the net present value (NPV) of treatment focus in the upcoming five years is, then, the sum of expected treatment focus costs (TC_T) and discounted at a rate *i:*

$$NPV\ of\ treatment = \frac{-TC_{T,1}}{(1+i)^1} + \frac{-TC_{T,2}}{(1+i)^2} + \cdots + \frac{-TC_{T,5}}{(1+i)^5} \qquad (6)$$

2.3.4. "With vaccination" sub-model. This sub-model is expected to consist of both treatment costs described in the previous section and as well be affected by costs arising from vaccination. In addition to this, as part of the vaccinated population will not develop shingles, shingles morbidity calculations will be adjusted.

2.3.4.1. Adjusted shingles morbidity. First of all, the selection of expected shingles vaccination coverage has to be made, assuming that it will be increasing in the period 2021-2025 as more and more people become aware of the free vaccination possibility. As the efficacy of the vaccine "Shingrix" is between 91.4%-97.4% (GlaxoSmithKline plc, 2020b), the model assumes that even if some patients develop the disease, it will lead to minimal treatment costs, thus are not significant for making the decision of the vaccine's reimbursement. As the vaccine's "Shingrix" protection is still effective by more than 85% for at least four years, it is assumed that a vaccinated person will not develop shingles in the analysed period 2021-2025. In order to reach such high vaccine's efficacy, two vaccine shots, administered in a 2-6 month interval, are needed (Shingrix, 2018). Since there is no officially confirmed data of a one-shot efficacy, the model will also assume that each patient will receive two vaccine shots in the analysed period. Then, the formula used to calculate the number of people vaccinated against shingles in the first year (*t*) is the expected vaccine coverage rate (*Rate*) times the population size estimate in the first year ($Population_{est,t}$):

$$Vaccinated\ group_t\ (VG_t) = Rate_t * Population_{est,t} \quad (7)$$

In the following years, the changes in vaccination coverage rate and population needed to vaccinate to reach the coverage are expected. Thus, the vaccinated group from the previous year is excluded from the potential vaccination group:

$$VG_{t+1} = (Rate_{t+1} * Population_{est,t+1}) - VG_t \quad (8)$$

2.3.4.2. Prevention costs. Although part of the population is expected to become immunized, another part will still develop shingles and will be treated in the same way as described in section *2.3.3. "No vaccination" sub-model.* Such costs form a part of the total prevention focus scenario but need to be adjusted for costs arising from populations' vaccination – vaccine purchase and administration costs.

The most significant part of the new scenario costs is expected to be formed by the vaccine price – or in other words, the price that the manufacturer, GlaxoSmithKline, will agree to sell the products to the state. Thus, total vaccine purchase costs for each year are calculated as follows:

$$Vaccine\ Purchase\ Costs\ (VPC) = Vaccine\ Price\ (VP) * Vaccinated\ group\ (VG) \quad (9)$$

Besides, the implementation of shingles vaccination is expected to require an additional workload for health care professionals (HCPs). Therefore, the formula to calculate total vaccine administration costs for each year include medical service price (*MSC*) multiplied by the number of people vaccinated (*VG*) times two (since both vaccine shots are administered, two visits at an HCP are required):

$$Administration\ Costs\ (AC) = MSC * VG * 2 \quad (10)$$

Taking all the costs described into account, the formula for total prevention focus costs can be derived by adding treatment costs (TC_P), vaccine purchase costs (*VPC*) and administration costs (*AC*):

$$Prevention\ costs\ (PC) = TC_P + VPC + AC \quad (11)$$

2.3.4.3. Prevention benefits. Using the health benefit framework by Barnighausen et al. (2011), the research includes the potential expected preventative focus benefits on the country's budget. Although such benefits are not expected to be received as an additional income, however, they are identified as budget savings which lower the expected costs when switching from treatment to prevention focus. If the treatment costs in prevention focus (TC_P) are less than treatment focus costs (TC_T), it is believed that the positive difference can be treated as a benefit for the country, therefore:

$$Prevention\ benefits\ (PB) = Tsavings = TC_T - TC_P \quad (12)$$

The NPV of such project is, then, the discounted difference between estimated benefits and costs, where *PB* is prevention benefits, *PC* is prevention costs and *i* is a selected discount rate, thus:

$$NPV\ of\ prevention = \frac{PB_1 - PC_1}{(1+i)^1} + \frac{PB_2 - PC_2}{(1+i)^2} + \cdots + \frac{PB_5 - PC_5}{(1+i)^5} \qquad (13)$$

The net present value of both treatment and prevention focus is not assumed to be positive – the expected goal of the model is finding the cost minimizing scenario. If the NPV of prevention is less than the NPV of treatment focus, then it is financially viable for the state to reimburse the vaccination project in Lithuania.

2.3.5. Social discount rate. The inclusion of a discount rate in the net present value calculations allows to assume economic growth, thus a wealthier future society, and to pull all future benefits and costs into a common present value metric. Since both treatment and prevention focus scenarios are considered as the Government's projects, the discount rate applied is called the social discount rate (SDR), since the choice of SDR can affect the policy changes – thus, the whole society wellbeing. Kazlauskienė (2015) summarized that there is a "lack of researches of SDR determination" in Lithuania (p.465), leading to a need to analyse the researches performed in other countries. For example, it is recommended to apply a 3.5% SDR for 0-35-year projects in the United Kingdom, 3-4.3% in Germany, 5% in Italy, 4-8% in France, though the general guidance from the European Commission is to use 5% SDR (Kazlauskienė, 2015). Another point of view to look at SDR is to narrow it to health-specific projects. According to Haacker, Hallet and Atun (2020), most of the analyses apply a discount rate of 3%, which is generally established as a global health project standard. Since health and immunization can be considered as global public goods (see *2.1. Economics of Immunization*), this research will assume a 3% SDR in a basic model and will account to uncertainty by changing the selected discount rate in the scenario analysis.

In general, the expected goal of the model is to find if preventing shingles disease in Lithuania less costly to the state than treating it. However, due to specific selection of a population of interest made in the base case scenario (section *2.3.1. Population of interest*), the results received can be different than expected – high vaccination costs can offset the expected budget savings from treatment. Nevertheless, no matter what outcome is received, the scenario analysis is performed to account for the changes by, first of all, adjusting the vaccine price in the basic scenario model, changing the population of interest and accounting for uncertainty by changing the discount rate. The model will also test if a partial 50% vaccine price reimbursement is a considerable option for Lithuania's case.

3. Empirical Research

The third chapter of this thesis is based on the methodology provided in the previous part of the paper and is intended to answer the problem investigated: how could the vaccine's reimbursement contribute to reducing shingles financial burden on the Lithuania's budget?

3.1. Epidemiology

3.1.1. HZ incidence. In order to calculate the impact of shingles treatment in Lithuania, the research, first of all, will account for morbidity results. Naturally, the more there are people who develop a specific disease, the higher the total costs are for a country's budget. Based on the assumptions provided in section *2.3.2. Shingles morbidity*, the incidence rates of herpes zoster will be used from Gauthier, Breuer, Carrington, Martin and Remy (2009) research in the United Kingdom (Appendix B, Table 3B). Different morbidity rates are provided in the study, based on age and gender, thus population and morbidity data are classified into eight age groups 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84 and >=85 as well as are accounted for the gender split. By using the data on Lithuania's demographics for the period 2016-2020 and applying the excel formula *trend*, the forecast on population is produced for the period 2021-2025 (Appendix B, Table 1B-2B). It shows that Lithuania's working population (up to 65 years old) is expected to form approximately half of the total population over 50 years with the biggest age group of 55-64. The forecasted population data is then used to calculate the expected morbidity cases by age and gender. Total shingles incidences in Lithuania are estimated by using equation (1) and are provided with the comparison of the forecasted registered shingles cases in Table 1.

	2021	*2022*	*2023*	*2024*	*2025*
Expected cases	***6,308***	***6,331***	***6,354***	***6,377***	***6,400***
Female	*4,315*	*4,324*	*4,334*	*4,344*	*4,354*
Male	*1,993*	*2,006*	*2,020*	*2,033*	*2,047*
Registered cases	*5,632*	*5,652*	*5,673*	*5,694*	*5,714*
Difference	*676*	*678*	*681*	*683*	*686*

Table 1. The expected shingles morbidity versus the registered cases in 2021-2025. Created using the HZ incidence rates from Gauthier et al., 2009 and forecasting the officially registered cases from the Institute of Hygiene, personal communication, October 30, 2020.

The table shows that, based on the applied incidence rates, herpes zoster morbidity in Lithuania is estimated to be around 6,300 cases in 2021 and increase by nearly 100 cases in 2025, which translates into an expected average year-on-year growth of 0.4%. Morbidity by gender split shows that twice as many female than male is projected to develop the disease. For both genders, the incidence of HZ increases with age and is particularly risky for age groups of 75-79 and 80-84 (6.3 male, 7.7 female and 6.4 male, 7.8 female patients per 1,000 people, respectively) (Appendix B, Table 3B). By looking at the past few years data of the expected and registered shingles cases, it was found that approximately 10% of patients developed a very mild form of the disease, thus they have not received medical treatment, and such cases were not officially registered. In contrary, 90% of shingles cases are expected to be officially registered in the period 2016-2019. Therefore, the number of future registered shingles cases is forecasted by applying the same logic and proportion (the year 2020 were forecasted as well). Such differences between expected and registered shingles cases are assumed to be possible and valid, leading to a conclusion that further calculations will be based on the expected herpes zoster incidence data.

3.1.2. PHN incidence. The number of PHN cases for both one month and three-months duration is calculated by multiplying the number of HZ patients in a particular age group with the respective PHN proportion rates from Gauthier et al. (2009), based on the equation (2) (Appendix B, Table 4B). The results (Appendix B, Table 5B) indicate that, on average, every year there will be 66% out of total cases that will develop PHN of one-month duration. From the budget impact point of view, it already leads to a conclusion that even if a part of patients is expected to develop such complication, more of them will develop it for a shorter duration, leading to a shorter treatment and lower treatment costs.

3.1.3. Pain split for HZ and PHN. Another perspective to look at the expected herpes zoster and post-herpetic neuralgia cases is to classify them into four different pain level categories: “No pain”, “Mild pain”, “Moderate pain” and “Severe pain”. The rates for classification applied can be found in Appendix B, Table 6B. Most of the HZ patients are expected to feel mild pain during their course of the disease (37% of total patients), however, as a patient becomes older than 70 years, there is a higher likelihood that he will feel moderate and severe pain. In other words, there are expected 16% severe shingles cases in total, out of which half is composed by the patients older than 70 years old. A different situation can be noticed for patients who might develop the complication of PHN. Younger patients (below 69-year old) are expected to mostly feel either mild or severe pain, while 67% of the older ones – to suffer from a severe course of the complication. The number of severe pain PHN patients in both age groups account to 60% of total PHN cases, which allows concluding that the severity of the disease significantly increases if a patient develops the complication of PHN.

Taking everything into account, segregation of herpes zoster incidence by age group, gender, pain level as well as PHN incidence are important to create an expected overall picture of morbidity and severity of shingles disease. Finally, it also facilitates treatment and prevention focus calculations to evaluate the impact of shingles disease morbidity on Lithuania’s budget.

3.2. Base Case Scenario

3.2.1. Treatment focus. This part of the empirical research is based on the model described in section *2.3.3. "No vaccination" sub-model.* It is important to mention, that an epidemiological forecast described in section *3.1. Epidemiology* is fully applicable to the analysis of treatment focus since it was assumed that no measures will be taken to reduce shingles morbidity.

3.2.1.1. Inpatient costs. Hospitalization due to shingles is calculated for both general herpes zoster patients (with no or other complications) and those who have developed post-herpetic neuralgia. HZ and PHN hospitalization rates are based on the experienced pain level and provided in Appendix C, Table 1C. Inpatient treatment costs were specifically requested and received from the National Health Security Fund (personal communication, November 26, 2020) and are provided in Appendix C, Table 2C. In order to calculate shingles hospitalization costs, the cost of 869.40 EUR is attributed to patients with PHN, whereas an average cost of other diagnoses is calculated to arrive at the expected average duration herpes zoster treatment cost – 861.68 EUR. It is assumed that such costs include all necessary medication needed during the hospital stay. According to the Act No. V-1486 by the Ministry of Health (2011), an average treatment duration of a viral disease is four days, thus provided costs are adjusted to receive an average one-day "bed" price. Finally, the mean length of hospital stay in days for both HZ and PHN patients are provided in Appendix C, Table 3C. Total inpatient costs are calculated by using the equation (3) and provided in Table 2.

3.2.1.2. Outpatient costs. As described previously, outpatient costs include visits at primary care physicians that patients consult regarding the mild form of a disease. In order to evaluate the number of patients who will visit their physicians, it was decided to use the forecasted registered shingles cases and, by subtracting the number of expected hospitalized cases (as they are assumed to be a part of registered cases), to arrive at the estimate of primary care visits. A visit price for a primary healthcare service is different for all age groups in Lithuania, and the prices are only available as a yearly "patient price": 62.06 EUR and 77.94 EUR for the age groups 50-65 and over 65 years old, respectively (NHIF, 2020c). According to the National Health Security Fund (NHIF, 2020d), patients over 50 years-old usually visit general practitioners six times in a year, meaning that one visit prices for both age groups are divided accordingly. Since there are different statistics of how many visits to a general practitioner can be expected by one patient due to shingles (at least one visit per case (Ultsch et al., 2013); 1.4 visits per case (Gauthier et al., 2009); 2.4 visits per case (Stein et al., 2009)), it was decided to account for two visits: the first to evaluate a patient's health and prescribe medicine for treatment and the second visit to assess if the patient's health is improving. Total outpatient costs are calculated by using the equation (4) and summarized in Table 2.

3.2.1.3. Sick-leave costs. The research model assumes that such costs are only applicable to age groups of 50-54, 55-59 and 60-64 since others will be retired (presented in section *1.4. Shingles Morbidity in Lithuania*). The number of days lost from work and the proportion of patients are summarized in Appendix C, Table 4C. Sickness benefits are calculated by using the "Sickness benefit calculator" provided by Sodra (2020c), assuming that each hospital stay begins on Monday. The benefits are calculated based on the average monthly gross salary of 1,398.5 EUR in Lithuania in 2020 (Ministry of Social Security and Labour, 2020). Since the calculator provides sickness benefits in the form of gross payment, they are adjusted to local taxes using "Workplace calculator" by Sodra (2020d). Sickness benefits are summarized in Table 2.

	2021	***2022***	***2023***	***2024***	***2025***
Inpatient costs	*540,379 €*	*542,142 €*	*543,905 €*	*545,669 €*	*547,432 €*
Outpatient costs	*123,027 €*	*123,464 €*	*123,902 €*	*124,339 €*	*124,776 €*
Sick-leave costs	*237,348 €*	*238,965 €*	*240,582 €*	*242,199 €*	*243,816 €*
Treatment costs	***900,754 €***	***904,572 €***	***908,389 €***	***912,207 €***	***916,025 €***

Table 2. Treatment costs.

Inpatient costs are expected to amount to 540.4 thousand EUR in 2021 and increase by 7 thousand EUR in 2025 (yearly 0.3% increase). In general, the hospitalization costs' importance during the course of the disease and its treatment is easily noticeable, as inpatient costs are more than four times higher than primary health care costs, which on average are expected to amount to 123.9 thousand EUR, translating into a 0.4% increase every year. The most significant primary outpatient care burden for the healthcare system is estimated to come from the patient visits of the age group over 65 years-old, mainly due to a 26% higher one primary outpatient visit price and higher morbidity than of the other age group. Indirect costs of shingles treatment – sickness benefits - are expected to amount to 237-243 thousand EUR in the period 2021-2025. Such costs are mainly driven by the patients experiencing severe pain, as they are expected to be incapable to work for a longer period of time (11 and 19 days for HZ and PHN patients, respectively) and the net amount of sickness benefit is expected to be more than 300 EUR per case.

In order to calculate the net present value of total treatment focus costs, first of all, all treatment costs are added using formula (5) and, by using the discount rate of 3% (selection is described in section *2.3.5. Social discount rate)* and the formula of NPV (6) for treatment focus scenario, the net present value is calculated.

Total:	**2021**	**2022**	**2023**	**2024**	**2025**
4,159,124 €	874,518 €	852,645 €	831,305 €	810,484 €	790,171 €

Table 3. The net present value of treatment focus costs.

The NPV of 4.2 million EUR indicates that the Government is expected to spend such amount of the country's budget in five year's period to treat shingles in Lithuania. The present value of treatment costs every year is expected to amount approximately to 832 thousand EUR, out of which around 612 thousand EUR are formed by direct medical costs (inpatient and outpatient). If yearly medical costs would be compared to an expected NHIF budget spending on personal health care services, it would translate into a 0.04% ratio in the year 2020 (NHIF, 2020b). However, even if such spending might seem not a significant part of the budget, potential savings could come from the prevention focus scenario.

3.2.2. Prevention focus. This section is based on the model described in part *2.3.4. "With vaccination" sub-model.* The epidemiological forecast described in section *3.1. Epidemiology* is applicable from a logical sequence point of view, however, the preventative measure is expected to decrease overall shingles morbidity, therefore it is important to analyse its effect in detail.

3.2.2.1. Vaccination coverage. The analysis showed that data on adult vaccination coverage for infectious diseases is relatively low or even not collected in Lithuania. Naturally, it is very doubtful that a new vaccine's – "Shingrix" – introduction in the market will cover a significant share of the population in the first five years. In comparison, an economic evaluation performed in Italy assumed that vaccination coverage would be 20% in the first year, 35% the second, and reach 50% in the following years (Boccalini et al., 2017). In addition, the shingles vaccination program in England also shows a 44% coverage for patients aged 70 years (Public Health England, 2018). Such rates are unlikely to be reached in Lithuania, therefore, it was decided to build a base case scenario by considering the coverage target rates that were set out in the United States. The initiative of "Healthy People 2020" defines the vaccination against shingles target of 30% to be reached in 12 years period for the age group over 60 years (ODPHP, 2020). Immunization rates were 2% and 6.7% in the first and second year, accordingly, of the vaccine's introduction in the market, and the coverage was expected to increase by 23.3% in 12 years period (ODPHP, 2020). Since the base case scenario model accounts for the projection of five years period and a bigger population, it is assumed that immunization of people over 50 years-old will be 3% in the first year, reaching 15% in the year 2025 (15% target means the number of people who have received the vaccine any time in five year's period divided by the number of people aged 50 years and more). Although the expected immunization coverage might seem to be low, however, the analysed period coincides with the period of possible vaccination against COVID-19 virus, which, with no doubts, would be the main focus of the state. The number of vaccines to be received by male and female is assumed to be proportional to the number of people in a particular age group compared to the total population. The vaccinated part of the population is calculated by using the equation (7) for the first year and equation (8) for the following years.

Prevention focus in the base case scenario is expected to prevent more than 181 thousand people over 50 years of developing shingles in five year's period. Morbidity is expected to decrease by more than 2800 patients. Consequently, there would be 200 less hospitalizations, less visits to general practitioners by more than 4600 and less days spent on sick leave by around 400 days in total. However, it is now important to analyse how the implementation of the preventative measure would impact shingles treatment costs.

3.2.2.2. Regular treatment. Such costs, extensively discussed in section *3.2.1. Treatment focus*, constitute part of the expected prevention focus costs, however, the more people are vaccinated against HZ, the lower treatment costs should be. In order to evaluate treatment costs in prevention focus and compare it with the treatment scenario, the costs are provided in the Table 4.

	Treatment focus			***Prevention focus***		
	Inpatient	***Outpatient***	***Sick-leave***	***Inpatient***	***Outpatient***	***Sick-leave***
2021	*540,379 €*	*123,027 €*	*237,348 €*	*524,488 €*	*119,400 €*	*230,249 €*
2022	*542,142 €*	*123,464 €*	*238,965 €*	*510,265 €*	*116,189 €*	*224,725 €*
2023	*543,905 €*	*123,902 €*	*240,582 €*	*495,947 €*	*112,956 €*	*219,158 €*
2024	*545,669 €*	*124,339 €*	*242,199 €*	*481,535 €*	*109,701 €*	*213,549 €*
2025	*547,432 €*	*124,776 €*	*243,816 €*	*467,027 €*	*106,425 €*	*207,898 €*
Total:		***4,541,946 €***			***4,139,510 €***	

Table 4. Treatment costs under treatment and prevention focus.

When comparing treatment costs (not discounted, at nominal value) under prevention scenario with the costs that the state is expected to incur either way, the savings of more than 400 thousand EUR are expected in total for the period 2021-2025. Hospitalization savings, in fact, would make up 60% of total savings (around 240 thousand EUR), while outpatient and sick-leave costs 14% (around 54 thousand EUR) and 27% (around 106 thousand EUR), respectively. However, a moderate prevention focus impact is expected due to conservative vaccination coverage projections and could be higher if, for example, 30% of the population in the year 2025 would be vaccinated. Nevertheless, even if at low vaccination levels, there are no doubts in the decrease of treatment costs, thus it is now essential to look at how these savings are adjusted by increased costs related to vaccination implementation.

3.2.2.3. Vaccination costs. According to the estimates presented in section *3.2.2.1. Vaccination coverage,* the number of people over 50 years should compile approximately 36.2 thousand vaccinations every year. Since two vaccine shots are needed, and the model assumes that every patient will receive both of them in order to acquire the immunity, this already allows indicating that vaccine purchase costs will be a significant factor determining total prevention focus costs. As mentioned before, the current vaccine price in the private market is 190 EUR (Endemik, 2020). However, it is 50% higher than in the United States private market (CDC, 2020b). It is expected that the vaccine's price should decrease due to price competition if the vaccine is being supplied directly to Lithuania's market and provided more widely in private clinics. If other high-price (over 80 EUR in Lithuania's private sector) vaccines are compared, it is found that private market vaccine prices in the US are 19% higher than in Lithuania (CDC, 2020b), which allows to arrive at the expected "Shingrix" private market price (104.98 EUR) if it were more widely supplied in Lithuania (Appendix C, Table 5C). Such price difference (between current 190 EUR and 105 EUR) can be logically reasoned by the estimates in Germany and STIKO recommendations' paper – the price of a dose was assumed to be 84 EUR in the private market (Siedler et al., 2019). Then, the vaccines in Lithuania, which cost more than 80 EUR in the private market, are found to be 43 EUR cheaper in public clinics (Appendix C, Table 6C), which allows to estimate "Shingrix" vaccine price – 62 EUR. Vaccine purchase costs for each year are calculated with the equation (9).

In addition to this, the medical service price for injecting a vaccine per patient in Lithuania is 4.82 EUR (visit at a general practitioner for appointment and injection by a nurse) (NHIF, 2020c). However, a part of the vaccinated group, which is over 65 years old, can receive both influenza and herpes zoster vaccines at the same time. Thus, costs for such age groups are shared, therefore divided by two. The formula used to calculate administration costs is (10).

	2021	***2022***	***2023***	***2024***	***2025***
Vaccine Purchase	*4,366,282 €*	*4,392,384 €*	*4,418,487 €*	*4,444,589 €*	*4,470,692 €*
Administration	*138,977 €*	*139,807 €*	*140,638 €*	*141,469 €*	*142,300 €*
Total:	***4,505,259 €***	***4,532,192 €***	***4,559,125 €***	***4,586,059 €***	***4,612,992 €***

Table 5. Vaccine purchase and administration costs.

At the vaccine price of 62 EUR, vaccine purchase costs each year are expected to amount to on average 4.4 million EUR, while administration costs – around 141 thousand

EUR. Total prevention focus costs are received by adding prevention scenario treatment costs with vaccine purchase costs and administrations costs, as per equation (11).

3.2.2.4. Budget impact analysis. Firstly, prevention scenario benefits are added to the total prevention focus costs which are the observed savings between treatment costs in both scenarios, refer to equation (12). Then, the net present value of the prevention focus using formula (13) is calculated at the selected 3% discount rate and the results are summarized alongside with the comparison to treatment focus in Table 6.

	Total	**2021**	**2022**	**2023**	**2024**	**2025**
Treatment focus costs	**4,159 €**	875 €	853 €	831 €	810 €	790 €
Prevention focus costs	**20,511 €**	4,348 €	4,222 €	4,099 €	3,979 €	3,863 €

Table 6. The net present value of both prevention and treatment focus costs, base case scenario, in thousands.

The comparison of the net present value for both scenarios clearly shows that, under given conditions, it is not financially viable to choose prevention focus and vaccinate all age groups over 50-years old against shingles in Lithuania. If it is assumed that the planned budget expenditures towards the National Immunoprophylaxis Programme in Lithuania in 2020 are the same as in the upcoming year 2021, this would mean that prevention focus scenario would account to approximately 34% of the Programme's total assignations each year. Therefore, such scenario of the vaccine's reimbursement is not financially bearable, as it would have to reduce expenditures towards other health programs, and it can be concluded that it should not be implemented in Lithuania. However, it is useful to analyse how changing different variables would affect the current decision to continue usual care of shingles or to reimburse.

3.3. Scenario Analysis

3.3.1. Adjusting the base case scenario. Although the base case scenario resulted in the decision to take usual care of shingles, the scenario analysis allows assessing which factors made the most significant impact. Two variables are distinguished to be free varying in the model – the discount rate and the vaccine price. As the vaccine price per one-shot is 62 EUR and medical service price is only 4.82 EUR per visit (such price is not adjusted for cost-sharing for influenza vaccination), it is clear that significantly increased costs in the prevention focus are driven by the vaccine price, which, first of all, should be adjusted in order to break-even. It is found that if "Shingrix" vaccine price decreased to 11.88 EUR per one-shot, treatment and prevention focus costs would be equal and, from a financial perspective, there would be no difference either to take usual care of shingles or to reimburse the vaccine. Nevertheless, although optimal, the situation shows that such vaccine price of 11.88 EUR is not attainable in the public market – currently, only the influenza vaccine costs around 9 EUR per shot, whereas chickenpox – around 36 EUR (Centro Poliklinika, 2020), therefore, it is expected that shingles vaccine price will not decrease below 36 EUR as in practice (CDC, 2020b). Even if the discount rate decreased, savings in prevention focus would be minimal and insignificant at such vaccine price.

Therefore, it can be concluded that even if free-varying model components were changed, the scenario to reimburse the vaccine for all age groups over 50 years-old is not attainable from the vaccine price perspective. It leads to a fact that other model components might be adjusted, or in other words, how the change in population size, eligible for vaccination, would impact the decision to fund the vaccine or take usual care of shingles in Lithuania.

3.3.2. Changing population of interest. As discussed in section *2.3.1. Population of interest*, since there is no single decision which age group should be eligible for free vaccination, it was decided to include a whole risk group into the base case scenario model. However, as both the base case scenario and the adjusted base case scenario were not favourable to the implementation of the preventative measure, it is now essential to evaluate the impact received by the change in the vaccinated population size. Thus, further modelling for vaccination is divided into such sizes of the population: over 50 years-old, over 55 years-old, over 60 years-old, over 65 years-old, over 70 years-old, over 75 years-old, over 80 years-old and over 85 years-old. Moreover, as the highest morbidity is visible for the age groups of 70-74, 75-79 and 80-84 years-old, and the incidence increases with older age (Appendix B, Table 3B), it was also decided to include a wider age group of 70-84 and a narrower one of 75-84 years where the incidence of the disease is the highest. In any scenario, treatment costs are calculated for all patients over 50 years-old, however, the vaccine is, then, only funded for a particular age group (e.g. over 65 years-old). The analysis is performed at a 3% discount rate by lowering the price by 5 EUR. If the price was lowered by more than 5 EUR, scenarios of positive prevention focus impact might not be highlighted. On the contrary, if the price was lowered by less than 5 EUR, many scenarios would be presented that would bring no additional value in finding a cost-effective decision. The results are summarized in Appendix D, Table 1D.

The Table 1D shows that HZ immunization results as a favourable impact of 1.1 million EUR on the country's budget if the vaccine is reimbursed for people over 80 years-old at the most expected price of 62 EUR. If the price could be reduced by 10 EUR or 25 EUR, then vaccination against shingles would be a positive investment with 0.1 million savings in the age group over 75 years-old or over 70 years-old, respectively. However, it is noticeable that the selection of eligible age group for vaccination and potential budget savings is highly dependent on the vaccine price. The practices in other countries show a possibility to reimburse the vaccine partially by 50% (Pavlopoulu, Michail, Samoli, Tsiftis, & Tsoumakas, 2013; McHugh, Browne, O'Neill, & Kearny, 2015; Braeckman et al., 2011; Silins & Szkultecka-Debek, 2017). Therefore, the reimbursement decision dependency on price could be reduced by choosing this alternative when a patient partially contributes to receiving a vaccine. In order to conclude which of the scenarios provide the highest benefits for the country, measures of the break-even point price, cost-effectiveness ratio and the maximum NPV savings at the possible partial reimbursement price are introduced and summarized in Table 7.

			Savings		
Age group	***Price at break-even***	***CER at break-even***	***50% reimbursed on price 62 EUR, at 3%, mEUR***	***50% reimbursed on price 62 EUR, at 5%, mEUR***	***50% reimbursed on price 62 EUR, at 1%, mEUR***
Over 80y	*83.85 €*	*153 €*	*2.6 €*	*2.5 €*	*2.8 €*
Over 75y	*53.80 €*	*105 €*	*1.8 €*	*1.7 €*	*1.9 €*
Over 70y	*38.04 €*	*71 €*	*0.8 €*	*0.7 €*	*0.8 €*
75-84	*76.95 €*	*140 €*	*2.5 €*	*2.3 €*	*2.6 €*
70-84	*48.37 €*	*89 €*	*1.5 €*	*1.4 €*	*1.6 €*

Table 7. Comparison of different scenarios at break-even price, cost-effectiveness ratio and potential savings of partial reimbursement.

If alternative scenarios were compared only from a price at the break-even point of view, then there are no doubts that the state should choose to fund the vaccine fully for all individuals over 80 years-old or in the age group of 75-84. This means that even if the expected price was 62 EUR, the scenario to vaccine all people aged 80 years would result in 1.1 million EUR savings, as mentioned before, while the scenario of 75-84 years – in 0.8 million EUR savings. However, it is important to take into account the indicator of cost-effectiveness (calculated by dividing vaccine purchase and administration costs by the number of prevented cases – this translates into an additional cost per prevented case), which shows that such two scenarios produce the highest cost per patient prevented, thus are not cost-effective. If there were a possibility to reimburse the vaccine partially by 50% (meaning that a patient would be paying 31 EUR for one shot and the state would be reimbursing another 31 EUR) than the most cost-effective reimbursement decision would be for people over 70 years, all the other factors being equal. The cost-effectiveness ratio of 71 EUR per one prevented shingles case indicates that a critical amount of people could be vaccinated, of which more than 60 thousand people at risk could be prevented at the lowest vaccination costs when compared to other scenarios. A potential partial reimbursement could bring around 0.8 million EUR savings. On the other hand, another cost-effective decision would be to fund the vaccine for the age group of 70-84, where HZ incidence rates are the highest – in this scenario, 47 thousand people would be vaccinated with budget savings of around 1.5 million EUR with partial vaccine reimbursement. The change in the discount rate is not expected to affect such conclusions significantly.

The analysis of adjusted age groups eligible for free vaccination allows concluding that in Lithuania, as well as in other countries, immunization program is not necessarily a budget-saving project for all age groups at the risk of developing shingles. The research found several scenarios where the project of the vaccine's full or partial reimbursement could minimize budget expenditures towards shingles treatment, leading to the conclusion that such scenarios are price sensitive in order to bring budget savings.

3.4. Recommendations

There are several recommendations that could be associated with this thesis. First of all, the model does not assume changes in vaccination coverage and the possibility that a person might not receive the second vaccine shot. It was noticed that if the component of vaccination coverage is considered to be free-varying, too many scenarios, assuming changes in population size and vaccine price, are possible, leading to a much more complex analysis and complicated interpretation of results. Thus, such variation is considered to be out of the scope of this bachelor thesis. If the vaccine price was known, then future researches could potentially assume changes in vaccination coverage. As well, the decision to include both vaccine shots allowed to assume a full vaccine's efficacy and exclude shingles reactivation after vaccination. In reality, part of the vaccinated group might not receive the second shot, thus future researches could adjust the model for this limitation. Secondly, although the positive externalities of immunization were extensively discussed in the theoretical part, they were not included in the model due to the specificity of the disease. The decrease in shingles morbidity does not directly impact transmission of shingles to other people – the disease can only be transmitted to people who have never had varicella zoster virus, which would occur as chickenpox for the first time. Thus, in order to evaluate possible prevention benefits, coming from decreased chickenpox morbidity, it would require to analyse a different course of the disease, which would have significantly different treatment costs. As such evaluation is considered to be out of the scope for this bachelor thesis, it was not included in the model. Nevertheless, future researches should include these potential benefits as they would decrease prevention costs, which were found to be high in the model. Moreover, the model assumed proportional vaccination coverage rates among the population – the more there are people in a particular age and gender group, the more there will be people of that age and gender who will receive a vaccine. Such proportional calculations were assumed as data on adults' propensity to vaccinate at different ages in Lithuania was not obtained. If such data were collected and accessible in the future, further researches could include a more accurate distribution of vaccination among age and gender groups. Finally, due to limited data on shingles morbidity in Lithuania, the model used herpes zoster incidence rates from researches in other countries – although such practice is widely used and acceptable (Ultsch et al., 2011; de Boer et al., 2013), it would be more accurate to use data received from the official state agencies. Currently, the data on total shingles cases registered was obtained, however, if other researches were performed in the future, the official agencies might then be able to provide a more extensive data on shingles in Lithuania.

Conclusions

1. The analysis of the National Health Insurance Fund's (NHIF) budget composition revealed that assignations from the national budget for persons insured with state funds are increasing, leading to a need to revise and optimize budget expenditures. While inpatient and outpatient care form 65% of the total NHIF spending and health programs only 6%, it raises a question how the budget resources should be allocated so that morbidity from preventable diseases would decrease, leading to potential savings from primary health care services and economic development of the country.

2. As adult vaccination coverage from preventable diseases is overlooked in Lithuania, one of the emerging infection's – shingles virus – importance and prevention is analysed as the way to increase society's wellbeing with a positive impact on the healthcare budget. Although the mortality from shingles is low or in some cases even not observed, there are no doubts of the disease's painful burden on a person's quality of life. The analysis showed there is very limited data on shingles morbidity in Lithuania.

3. Even though it can be argued that a person's health is a private matter, however, due to the interconnectedness of health in the global environment, the transmission of communicable diseases has accelerated. Since there are positive externalities arising from vaccination, which are both non-rival and non-excludable, and the private market fails to ensure high vaccination coverage, the key players in prevention are Governments, which should provide funding to minimize morbidity from preventable diseases.

4. After the comparison of possible research models, it was found that budget impact analysis type model is preferred over cost-effectiveness due to the fact that the latter model would not produce the expected financial consequences of choosing to fund the vaccine or continue usual care of shingles. It was decided to compare two sub-models of "no

vaccination" and "with vaccination" by including both direct medical and indirect costs. The aim of the overall model was finding the cost-minimizing scenario.

5. When evaluating the financial impact of shingles treatment in Lithuania, it was found that the infection's treatment has a moderate financial impact on the country's economy and account to yearly costs of approximately 0.8 million EUR. These costs are mainly driven by hospitalization (60%) and sickness benefits (26%), while visits at primary healthcare specialists are estimated to impact costs the least (14%).

6. By including vaccine purchase and administration costs in order to evaluate total prevention focus impact on potential budget savings, it was found that it is not financially optimal to reimburse the vaccine for all age group over 50 years. At the "Shingrix" vaccine price of 62 EUR, it is concluded that the estimated vaccine purchase costs are too high to produce budget savings and vaccine's funding would lead to even higher budget expenditures (additional 4 million every year) towards shingles treatment and prevention.

7. However, the scenario analysis showed that the change in the size of population eligible for free vaccination is an important factor which determines whether the switch to prevention focus is beneficial for the country from a financial perspective. In addition to this, different results in scenario analysis showed a high model dependency on the vaccine price changes. Therefore, a potential partial vaccine reimbursement solution was introduced. It was found that full reimbursement at the vaccine price of 62 EUR for the age groups of over 80 years-old and 75-84 years is expected to provide budget savings of 1.1 million EUR and 0.8 million EUR, respectively. In order to vaccinate more society members, a price should significantly decrease, or a partial 50% vaccine reimbursement should be introduced. In such scenarios, it would be cost-effective to vaccinate all individuals over 70 years or the age group of 70-84 years-old, with potential budget savings of 0.8 or 1.5 million EUR, respectively.

References

Annemans, L., Bresse, X., Gobbo, C., & Papageorgiou, M. (2010). Health economic evaluation of a vaccine for the prevention of herpes zoster (shingles) and post-herpetic neuralgia in adults in Belgium. *Journal of Medical Economics, 13*(3), 537-551. doi:10.3111/13696998.2010.502854

Antėja Laboratorija. (2020). *Skiepai.* Retrieved from: https://anteja.lt/skiepai

Australian Government Department of Health. (n.d.). *The National Shingles Vaccination Program*. Retrieved from: https://www.health.gov.au/sites/default/files/shingles-provider-fs.pdf

Barnighausen, T., Bloom, D. E., Canning, D., Friedman, A., Levine, O. S., O'Brien, J., Privor-Dumm, L., & Walker, D. (2011). Rethinking the benefits and costs of childhood vaccination: The example of the Haemophilus influenzae type b vaccine. *Vaccine, 29*(13), 2371-2380. doi:10.1016/j.vaccine.2010.11.090

Boccalini, S., Alicino, C., Martinelli, D., Bechini, A., Tiscione, E., Pellizzari, B., Prato, R., Icardi, G., Iannazzo, S., & Bonanni, P. (2017). Clinical and economic impact of herpes zoster vaccination in elderly in Italy. *Human vaccines & immunotherapeutics*, *13*(2), 405-41. doi:10.1080/21645515.2017.1264832

Braeckman, T., Van Herck, K., Raes, M., Vergison, A., Sabbe, M., & Van Damme, P. (2011). Rotavirus vaccines in Belgium: policy and impact. *The Pediatric infectious disease journal*, *30*(1), S21-S24. doi:10.1097/INF.0b013e3181fefc51

Brisson, M., Pellissier, J. M., Camden, S., Quach, C., & De Wals, P. (2008). The potential cost-effectiveness of vaccination against herpes zoster and post-herpetic neuralgia. *Human Vaccines, 4,* 238-245. doi:10.4161/hv.4.3.5686

Carvalho, N., Jit, M., Cox, S., Yoong, J., & Hutubessy, R. C. W. (2017). Capturing Budget Impact Considerations Within Economic Evaluations: A Systematic Review of

Economic Evaluations of Rotavirus Vaccine in Low- and Middle-Income Countries and a Proposed Assessment Framework. *Pharmacoeconomics, 36*. doi:10.1007/s40273-017-0569-2

Centers for Disease Control and Prevention (CDC). (2018a). *Shingles Vaccination.* Retrieved from: https://www.cdc.gov/vaccines/vpd/shingles/public/shingrix/index.html

Centers for Disease Control and Prevention (CDC). (2018b). *Get the new shingles vaccine if you are 50 or older.* Retrieved from: https://www.cdc.gov/shingles/downloads/shingles-factsheet-adults.pdf

Centers for Disease Control and Prevention (CDC). (2019a). *Shingles (Herpes Zoster). Clinical Overview.* Retrieved from: https://www.cdc.gov/shingles/hcp/clinical-overview.html

Centers for Disease Control and Prevention (CDC). (2019b). *About the Varicella Vaccine*. Retrieved from: https://www.cdc.gov/vaccines/vpd/varicella/hcp/about-vaccine.html

Centers for Disease Control and Prevention (CDC). (2019c). *Complications of Shingles.* Retrieved from: https://www.cdc.gov/shingles/about/ complications.html

Centers for Disease Control and Prevention (CDC). (2019d). *Treating Shingles*. Retrieved from: https://www.cdc.gov/shingles/about/treatment.html

Centers for Disease Control and Prevention (CDC). (2020a). *Coping with Stress*. Retrieved from: https://www.cdc.gov/coronavirus/2019-ncov/daily-life-coping/managing-stress-anxiety.html

Centers for Disease Control and Prevention (CDC). (2020b). *CDC Vaccine Price List*. Retrieved from: https://www.cdc.gov/vaccines/programs/vfc/awardees/vaccine-management/price-list/index.html

Centre for Communicable Diseases and AIDS. (2020). *Sergamumo užkrečiamosiomis ligomis Lietuvoje 2019m. apžvalga*. Retrieved from: http://www.ulac.lt/lt/sergamumo-uzkreciamosiomis-ligomis-apzvalgos

Centro Poliklinika. (2020). *Vakcinos.* Retrieved from: https://www.pylimas.lt/paslaugos/mokamos-paslaugos/vakcinos

Chiyaka, E. T., Nghiem, V. T., Zhang, L., Deshpande, A., Mullen, P. D., & Le, P. (2019). Cost-effectiveness of herpes zoster vaccination: a systematic review. *PharmacoEconomics*, *37*(2), 169-200. doi:10.1007/s40273-018-0735-1

de Boer, P. T., Pouwels, K. B., Cox, J. M., Hak, E., Wilschut, J. C., & Postma, M. J. (2013). Cost-effectiveness of vaccination of the elderly against herpes zoster in The Netherlands. *Vaccine*, *31*(9), 1276-1283. doi:10.1016/j.vaccine.2012.12.067

DeRoeck, D. (2004). The Importance of Engaging Policy-makers at the Outset to Guide Research on and Introduction of Vaccines: The Use of Policy-maker Surveys. *Journal of Health, Population and Nutrition, 22*(3), 322-330. Retrieved from: http://www.jstor.org/stable/23499147

Endemik. (2020). *Skiepų kainos Vilniaus klinikoje*. Retrieved from: https://endemik.lt/skiepu-ir-imunoprofilaktikos-kainos/skiepu-kainos-vilniaus-klinikoje/

European Centre for Disease Prevention and Control. (2011). *Surveillance of Varicella and Herpes Zoster in Europe.* Retrieved from: https://www.ecdc.europa.eu/sites/default/files/media/en/publications/Publications/varicella_zoster_report_2009_euvacnet.pdf

European Commission. (2018). *The 2018 Ageing Report*. Retrieved from: https://ec.europa.eu/info/sites/info/files/economy-finance/ip079_en.pdf

Eurostat. (2020a). Population on 1 January by age group, sex and country of birth [MIGR_POP3CTB]. Retrieved from: https://ec.europa.eu/eurostat/databrowser/view/MIGR_POP3CTB__custom_20717/default/table?lang=en

Eurostat. (2020b). General government deficit (-) and surplus (+) - annual data [TEINA200]. Retrieved from: https://ec.europa.eu/eurostat/databrowser/view/teina200/default/table?lang=en

Esposito, S., Principi, N., Rezza, G., Bonanni, P., Gavazzi, G., Beyer, I., Sulzner, M., Celentano, L. P., Prymula, R., Rappagliosi, A., Sevilla, J., Poland, G., & WAidid-EVASG Panel on vaccination of 50+. (2018). Vaccination of 50+ adults to promote healthy ageing in Europe: The way forward. *Vaccine, 36*(39), 5819–5824. doi: 10.1016/j.vaccine.2018.08.041

Fine, P., Eames, K., & Heymann, D. L. (2011). “Herd immunity”: a rough guide. *Clinical infectious diseases*, *52*(7), 911-916. doi:10.1093/cid/cir007

Gauthier, A., Breuer, J., Carrington, D., Martin, M., & Remy, V. (2009). Epidemiology and cost of herpes zoster and post-herpetic neuralgia in the United Kingdom. *Epidemiology & Infection*, *137*(1), 38-47. doi:10.1017/S0950268808000678

Gershon, A. A., Breuer, J., Cohen J. I., Cohr, R. J, Gershon, M. D., Gilden, D., Grose, C., Hambleton, S., Kennedy, P. G. E., Oxman, M. N., Seward, J. F., & Yamanishi, K. (2015). Varicella zoster virus infection. *Nature Reviews Disease Primers, 1*(1). doi: 10.1038/nrdp.2015.16

GlaxoSmithKline plc. (2018). *Shingrix approved in Europe and Japan for the prevention of shingles in adults aged 50 and over.* Retrieved from: https://www.gsk.com/en-gb/media/press-releases/shingrix-approved-in-europe-and-japan-for-the-prevention-of-shingles-in-adults-aged-50-and-over/

GlaxoSmithKline plc. (2020a). *SHINGRIX demonstrated an effect on postherpetic neuralgia (PHN).* Retrieved from: https://gskpro.com/en-ca/products/shingrix/efficacy-data/phn/

GlaxoSmithKline plc. (2020b). *Shingrix Efficacy*. Retrieved from: https://gskpro.com/en-us/products/shingrix/efficacy/

GlaxoSmithKline plc. (n.d). *Package leaflet: Information for the user*. Herpes Zoster vaccine. Retrieved from: https://endemik.lt/wp-content/uploads/2018/09/Shingrix-informacinis-pakuotes-lapelis.pdf

Graham, J., Wolfson, L. J., Kyle, J., Bolde-Villarreal, C. P., Guarneros-DeRegil, D. B., Monsanto, H., Pillsbury, M., Talbird, S., & Daniels, V. J. (2019). Budget impact analysis of multiple varicella vaccination strategies: a Mexico perspective. *Human vaccines & immunotherapeutics*, *16*(4), 886-894. doi:10.1080/21645515.2019. 1672491

Haacker, M., Hallett, T. B., & Atun, R. (2019). On discount rates for economic evaluations in global health. *Health Policy and Planning, 35*(1), 107-114. doi: 10.1093/heapol/czz127

Harpaz, R., Leung, J. W., Brown, C. J., & Zhou, F. J. (2015). Psychological stress as a trigger for herpes zoster: might the conventional wisdom be wrong?. *Clinical Infectious Diseases*, *60*(5), 781-785. doi:10.1093/cid/ciu889

Hussey, H. S., Abdullahi, L. H., Collins, J. E., Muloiwa, R., Hussey, G. D., & Kagina, B. M. (2016). Varicella zoster virus-associated morbidity and mortality in Africa: a systematic review protocol. *BMJ open*, *6*(4). doi:10.1136/bmjopen-2015-010213

Ibuka, Y., Li, M., Vietri, J., Chapman, G. B., & Galvani, A. P. (2014). Free-riding behavior in vaccination decisions: an experimental study. *PloS one*, *9*(3). doi:10.1371/journal.pone.0087164

Institute of Hygiene. (2014). Išvengiamos hospitalizacijos. *Visuomenės Sveikatos Netolygumai, 4*(8). Retrieved from: http://hi.lt/uploads/pdf/padaliniai/BAS/VSN8_isvengiamos_hospitalizacijos.pdf

John, T. J., & Samuel, R. (2000). Herd immunity and herd effect: new insights and definitions. *European Journal of Epidemiology, 16*(7), 601–606. doi: 10.1023/a:1007626510002

Karmann, A., Jurack, A., & Lukas, D. (2015). Recommendation of rotavirus vaccination and herd effect: a budget impact analysis based on German health insurance data. *The European Journal of Health Economics, 16*(7), 719-731. doi:10.1007/s10198-014-0624-2

Kaul, I., Grungberg, I., & Stern, M. A. (1999). *Global public goods: international cooperation in the 21st century*. New York: Oxford University Press.

Kazlauskienė, V. (2015). Social discount rate: theoretical models and their application in assessment of public investment projects. *International scientific conference of Economics and Management, ICEM, 1*(1). Retrieved from: http://158.129.0.26/index.php/icem/article/view/1880

Levin, A., & Kaddar, M. (2011). Role of the private sector in the provision of immunization services in low- and middle-income countries. *Health Policy and Planning*, *26*(1), i4-i12. doi:10.1093/heapol/czr037

Mauskopf, J. A., Sullivan, S. D., Annemans, L., Caro, J., Mullins, C. D., Nuijten, M., Orlewska, E., Watkins, J., & Trueman, P. (2007). Principles of Good Practice for Budget Impact Analysis: Report of the ISPOR Task Force on Good Research Practices – Budget Impact Analysis. *Value Health*, *17*, 5-14. doi:10.1111/j.1524-4733.2007.00187.x

McHugh, S. M., Browne, J., O'Neill, C., & Kearney, P. M. (2015). The influence of partial public reimbursement on vaccination uptake in the older population: a cross-sectional study. *BMC Public Health*, *15*(1). doi:10.1186/s12889-015-1356-7

McLaughlin, J. M., McGinnis, J. J., Tan, L., Mercatante, A, & Fortuna, J. (2015). Estimated Human and Economic Burden of Four Major Adult Vaccine-Preventable Diseases in the United States. *The Journal of Primary Prevention, 36*(1), 259-273. doi:10.1007/s10935-015-0394-3

MediCa klinika. (2020). *Paslaugų kainynas*. Retrieved from: https://www.medicaklinika.lt/paslaugu-kainynas/72

Medicinos Diagnostiskos ir Gydymo Centras. (2020). *Skiepai.* Retrieved from: https://www.medcentras.lt/paslaugos-ir-kainos/skiepai/

Merck Sharp & Dohme Corp. (n.d.). *Highlights of Prescribing Information.* Retrieved from: https://www.merck.com/product/usa/pi_circulars/z/zostavax/zostavax_pi2.pdf

Ministry of Health of the Republic of Lithuania. (2011). *Dėl Giminingų diagnozių grupių sąrašo, normatyvinės gydymo trukmės ir giminingų diagnozių grupėms priskiriamų kainų koeficientų sąrašo bei bazinės aktyviojo gydymo atvejo kainos tvirtinimo pakeitimo (Nr. V-1118).* Retrieved from: https://www.e-tar.lt/portal/en/legalAct/a30bfde0afbd11e5b12fbb7dc920ee2c

Ministry of Health of the Republic of Lithuania. (2019). *Dėl Nacionalinės Imunoprofilaktikos 2019-2023 metų programos partvirtinimo.* Retrieved from: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/a88940c123b911e9b246d9cc49389932

Ministry of Health of the Republic of Lithuania. (2020). *Gripas.* Retrieved from: https://sam.lrv.lt/lt/veiklos-sritys/visuomenes-sveikatos-prieziura/uzkreciamuju-ligu-valdymas/gripas

Ministry of Social Security and Labour. (2020). *Pagrindiniai socialiniai rodikliai.* Retrieved from: https://socmin.lrv.lt/lt/veiklos-sritys/socialine-statistika/pagrindiniai-socialiniai-rodikliai

National Health Insurance Fund (NHIF). (2019). *Augantis PSDF biudžetas kitąmet sudarys € 2.3 milijardus eurų*. Retrieved from: http://www.vlk.lt/naujienos/Puslapiai/Augantis-PSDF-biud%C5%BEetas-kit%C4%85met-sudarys-2,3-milijardus-eur%C5%B3.aspx

National Health Insurance Fund (NHIF). (2020a). *Compulsory health insurance contributions*. Retrieved from: http://www.vlk.lt/sites/en/health-insurance-in-Lithuania/compulsory-health-insurance-contributions

National Health Insurance Fund (NHIF). (2020b). *Biudžeto vykdymo ataskaitų rinkiniai*. Retrieved from: http://www.vlk.lt/veikla/biudzeto-vykdymo-ataskaitu-rinkiniai/Puslapiai/default.aspx

National Health Insurance Fund (NHIF). (2020c). *Sveikatos priežiūros paslaugų bazinės kainos.* Retrieved from: http://www.vlk.lt/veikla/veiklos-sritys/sveikatos-prieziuros-paslaugu-bazines-kainos

National Health Insurance Fund (NHIF). (2020d). *Ataskaita apie 2019 metų teritorinių ligonių kasų ir asmens sveikatos priežiūros įstaigų sutarčių dėl asmens sveikatos priežiūros paslaugų vykdymą.* Retrieved from: http://www.vlk.lt/veikla/veiklos-sritys/sutarciu-sudarymas/duomenysapiesutsudarirvykd/Documents/0717%202019%20sut%20vykd%20ataskaita.pdf

National Health Service (NHS). (2017). *Chickenpox*. Retrieved from: https://www.nhs.uk/conditions/chickenpox/

National Public Health Center under the Ministry of Health. (2019). *Lietuvoje ir Europos sąjungoje registruotų ir užkrečiamųjų ligų profilaktikai naudojamų vakcinų/imunoglobulinų sąrašas.* Retrieved from: https://nvsc.lrv.lt/uploads/nvsc/documents/files/Vakcinu%20sarasas%20internetui_%20%202019-06-17.pdf

Organization for Economic Co-operation and Development (OECD). (2018). *Reviews of Health Systems: Lithuania 2018*. Retrieved from: https://www.oecd.org/health/health-systems/OECD-Reviews-of-Health-Systems-Lithuania-2018-Assessment-and-Recommendations.pdf

Organization for Economic Co-operation and Development (OECD), & European Observatory on Health Systems and Policies. (2019). *Lithuania: Country Health Profile 2019, State of Health in the EU, OECD Publishing, Paris/European Observatory on Health Systems and Policies, Brussels*. Retrieved from: https://ec.europa.eu/health/sites/health/files/state/docs/2019_chp_lt_english.pdf

Office of Disease Prevention and Health Promotion (ODPHP). (2020). *Healthy People 2020*. Retrieved from: https://www.healthypeople.gov/node/4673/data_details

Official Statistics Portal. (2020). *Resident population by sex and age at the beginning of the year.* Retrieved from: https://osp.stat.gov.lt/statistiniu-rodikliu-analize?hash=a924b9a6-9877-4c14-9acd-e4b3ae7255ed#/

Ontario Ministry of Health and Long-Term Care. (n.d.). *Transition to Publicly Funded Shingrix® Vaccine for Ontario's Shingles (Herpes Zoster) Immunization Program: Information for Health Care Providers.* Retrieved from: http://www.health.gov.on.ca/en/pro/programs/immunization/docs/shingles_hcp_qa_en.pdf

Pavlopoulou, I. D., Michail, K. A., Samoli, E., Tsiftis, G., & Tsoumakas, K. (2013). Immunization coverage and predictive factors for complete and age-appropriate vaccination among preschoolers in Athens, Greece: a cross-sectional study. *BMC public health*, *13*(1). doi:10.1186/1471-2458-13-908

Pinchinat, S., Cebrián-Cuenca, A. M., Bricout, H., & Johnson, R. W. (2013). Similar herpes zoster incidence across Europe: results from a systematic literature review. *BMC infectious diseases, 13*(1), 1-10. doi:10.1186/1471-2334-13-170

Public Health England. (2018). *Herpes zoster (shingles) immunisation programme 2017 to 2018: evaluation report.* Retrieved from: https://assets.publishing.service.gov.uk/

government/uploads/system/uploads/attachment_data/file/758888/hpr4218_shngls_vc.pdf

Reich, D., Psomadakis, C. E., & Buka, B. (2016). Shingles. *Top 50 Dermatology Case Studies for Primary Care,* 281-287. doi:10.1007/978-3-319-18627-6_42

Rodrigues, C. M. C., Plotkin, S. A. (2020). Impact of Vaccines; Health, Economic and Social Perspectives. *Frontiers in Microbiology*. doi:10.3389/fmicb.2020.01526

Schmader, K. (2001). Herpes zoster in older adults. *Clinical infectious diseases: an official publication of the Infectious Diseases Society of America*, *32*(10), 1481–1486. doi:10.1086/320169

Schmader, K., George, L. K., Burchett, B. M., Hamilton, J. D., & Pieper, C. F. (1998). Race and stress in the incidence of herpes zoster in older adults. *Journal of the American Geriatrics Society*, *46*(8), 973-977. doi:10.1111/j.1532-5415.1998.tb02751.x

Sengupta, N., & Breuer, J. (2009). A Global Perspective of the Epidemiology and Burden of Varicella-Zoster Virus. *Current Pediatric Reviews, 5*(4), 207-228. doi:10.2174/157339609791317315

Shingrix. (2018). *Frequently asked questions*. Retrieved from: https://www.shingrix.com/shingrix-faqs.html

Siedler, A., Koch, J., Garbe, E., Hengel, H., von Kries, R., Ledig, T., Mertens, T., Zepp, F., & Überla, K. (2019). Background paper to the decision to recommend the vaccination with the inactivated herpes zoster subunit vaccine. *Bundesgesundheitsblatt-Gesundheitsforschung-Gesundheitsschutz*, *62*(3), 352-376. doi:10.1007/s00103-019-02882-5

Silins, J., & Szkultecka-Dębek, M. (2017). Drug policy in Latvia. *Value in health regional issues*, *13*, 73-78. doi:10.1016/j.vhri.2017.08.006

Smith, R. D., & MacKellar, L. (2007). Global public goods and the global health agenda: problems, priorities and potential. *Globalization and Health*, *3*(9). doi:10.1186/1744-8603-3

Smith, R., Woodward, D., Acharya, A., Beaglehole, R., & Drager, N. (2004). Communicable disease control: a ‘Global Public Good’ perspective. *Health Policy and Planning*, *19*(5), 271-278. doi:10.1093/heapol/czh032

Sodra. (2020a). *Retirement age table.* Retrieved from: https://www.sodra.lt/en/retirement-age-table

Sodra. (2020b). *Ligos išmoka (Ligos socialinis draudimas).* Retrieved from: https://socmin.lrv.lt/lt/veiklos-sritys/socialinis-draudimas/socialinio-draudimo-ismokos/valstybinio-socialinio-draudimo-ismokos/ligos-ismoka-ligos-socialinis-draudimas

Sodra. (2020c). *Sickness benefit calculators.* Retrieved from: https://www.sodra.lt/en/calculators/sickness_benefit_calculator#step1

Sodra. (2020d). *Workplace calculator*. Retrieved from: https://www.sodra.lt/en/calculators/workplace_calculator

Stein, A. N., Britt, H., Harrison, C., Conway, E. L., Cunningham, A., & MacIntyre, C. R. (2009). Herpes zoster burden of illness and health care resource utilisation in the Australian population aged 50 years and older. *Vaccine*, *27*(4), 520-529. doi: 10.1016/j.vaccine.2008.11.012

Thomas, S. L., & Hall, A. J. (2004). What does epidemiology tell us about risk factors for herpes zoster?. *The Lancet infectious diseases*, *4*(1), 26-33. doi:10.1016/S1473-3099(03)00857-0

Ultsch, B., Siedler, A., Rieck, T., Reinhold, T., Krause, G., & Wichmann, O. (2011). Herpes zoster in Germany: quantifying the burden of disease. *BMC infectious diseases*, *11*(1). doi:10.1186/1471-2334-11-173

Ultsch, B., Weidemann, F., Reinhold, T., Siedler, A., Krause, G., & Wichmann, O. (2013). Health economic evaluation of vaccination strategies for the prevention of herpes zoster and postherpetic neuralgia in Germany. *BMC health services research*, *13*(1). Retrieved from: http://www.biomedcentral.com/1472-6963/13/359

World Health Organization (WHO). (2014a). *European Vaccine Action Plan 2015-2020*. Retrieved from: https://www.euro.who.int/_data/assets/pdf_file/0007/255679/WHO_EVAP_ UK_v30_WEBx.pdf

World Health Organization (WHO). (2014b). Varicella. Retrieved from: https://www.who.int/biologicals/vaccines/varicella/en/

World Health Organization (WHO). (2014c). *Varicella and Herpes Zoster vaccines: WHO position paper.* Retrieved from: https://www.who.int/immunization/position_papers/WHO_pp_varicella_herpes_zoster_june2014_presentation.pdf

World Health Organization (WHO). (n.d.). *Vaccines and immunization.* Retrieved from: https://www.who.int/health-topics/vaccines-and-immunization#tab=tab_1

Yang, F., Yu, S., Fan, B., Liu, B., Chen, Y. X., Kudel, I., Concialdi, K., DiBonaventura, M., Hopps, M., Hlavacek, P., Cappelleri, J. C., Sadosky, A., Parsons, B., & Udall, M. (2019). The Epidemiology of Herpes Zoster and Postherpetic Neuralgia in China: Results from a Cross-Sectional Study. *Pain and Therapy, 8,* 249-259. doi: 10.1007/s40122-019-0127-z

Yawn, B. P., & Gilden, D. (2013). The global epidemiology of herpes zoster. *Neurology, 81*(10), 928–930. doi:10.1212/wnl.0b013e3182a3516e

Yawn, B. P., Saddier, P., Wollan, P. C., St Sauver, J. L., Kurland, M. J., & Sy, L. S. (2007). A population-based study of the incidence and complication rates of herpes zoster before zoster vaccine introduction. *Mayo Clinic proceedings*, *82*(11), 1341–1349. doi:10.4065/82.11.1341

Yawn, B. P., Wollan, P. C., Kurland, M. J., Sauver, J. L. S., & Saddier, P. (2011). Herpes zoster recurrences more frequent than previously reported. *Mayo Clinic Proceedings, 86*(2), 88-93. doi:10.4065/mcp.2010.0618

Zorzoli, E., Pica, F., Masetti, G., Franco, E., Volpi, A., & Gabutti, G. (2018). Herpes zoster in frail elderly patients: prevalence, impact, management, and preventive strategies. *Aging Clinical and Experimental Research, 30*(7), 693–702. doi:10.1007/s40520-018-0956-3

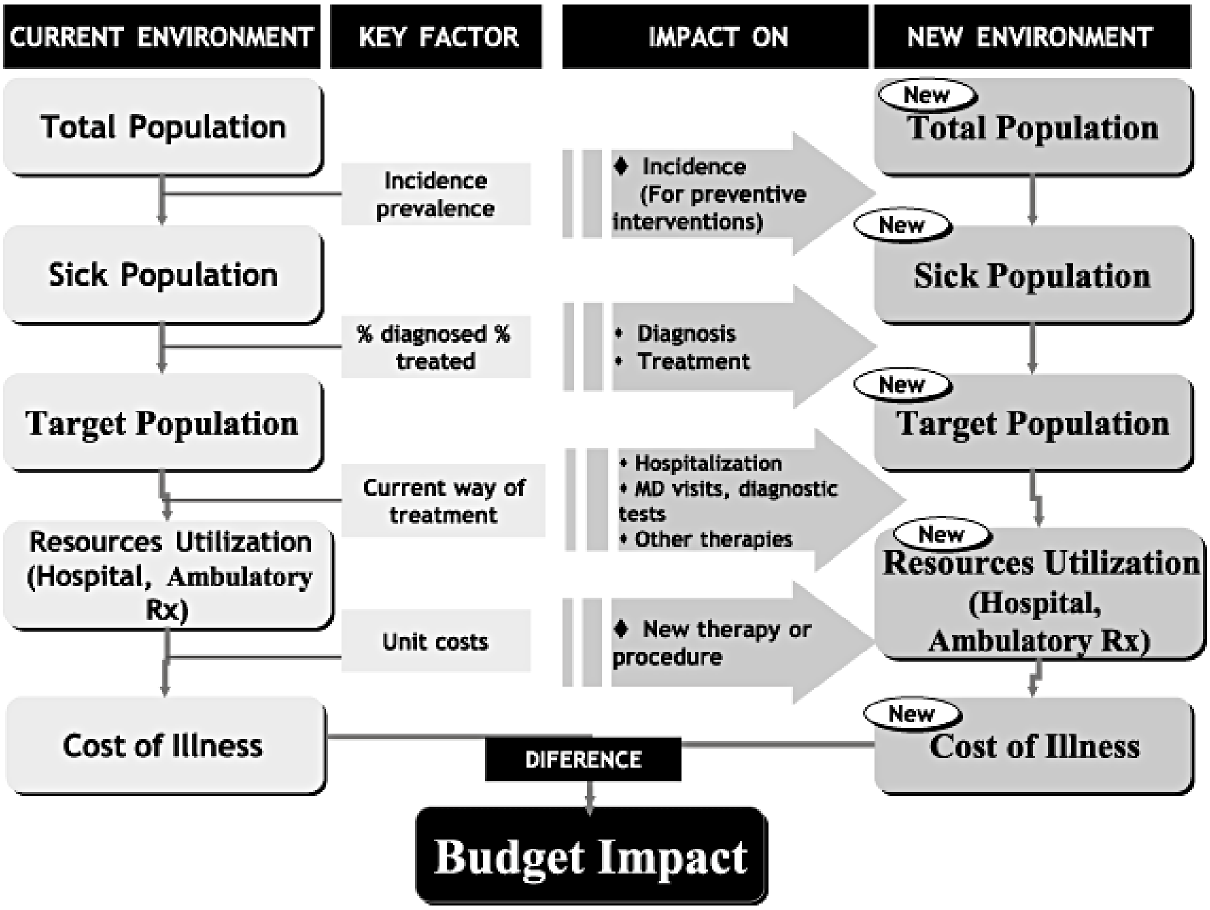
Appendices

Appendix A

Empirical research methods

Figure 1A

Budget impact analysis framework



Note. The figure is taken from “Principles of Good Practice for Budget Impact Analysis: Report of the ISPOR Task Force on Good Research Practices—Budget Impact Analysis” by Mauskopf et al., 2007 (doi:10.1111/j.1524-4733.2007.00187.x).

Appendix B

Epidemiology

Table 1B

Population projections - male

	2021	2022	2023	2024	2025
50-54	92,834	90,841	88,849	86,856	84,864
55-59	102,298	102,821	103,344	103,867	104,390
60-64	87,974	91,184	94,394	97,604	100,814
65-69	63,920	65,002	66,085	67,167	68,249
70-74	43,791	43,507	43,223	42,939	42,654
75-79	35,609	34,753	33,896	33,040	32,183
80-84	26,654	26,997	27,341	27,685	28,029
>=85	18,587	19,155	19,724	20,293	20,862
Total	**471,666**	**474,261**	**476,855**	**479,449**	**482,044**

Note. The data was adapted from “Resident population by sex and age at the beginning of the year” by Official Statistics Portal, 2020 (https://osp.stat.gov.lt/ statistiniu-rodikliu-analize?hash=a924b9a6-9877-4c14-9acd-e4b3ae7255ed#/). By using the excel formula *trend*, the forecast for such data was produced for the period 2021-2025.

Table 2B

Population projections - female

	2021	**2022**	**2023**	**2024**	**2025**
50-54	*101,391*	*98,467*	*95,543*	*92,619*	*89,695*
55-59	*118,740*	*118,286*	*117,832*	*117,378*	*116,924*
60-64	*113,229*	*116,575*	*119,921*	*123,266*	*126,612*
65-69	*94,700*	*95,642*	*96,584*	*97,526*	*98,468*
70-74	*76,753*	*75,892*	*75,031*	*74,171*	*73,310*
75-79	*74,351*	*72,937*	*71,522*	*70,108*	*68,693*
80-84	*65,093*	*65,815*	*66,537*	*67,258*	*67,980*
>=85	*57,810*	*59,367*	*60,924*	*62,482*	*64,039*
Total	***702,066***	***702,979***	***703,894***	***704,808***	***705,722***

Note. The data was adapted from "Resident population by sex and age at the beginning of the year" by Official Statistics Portal, 2020 (https://osp.stat.gov.lt/ statistiniu-rodikliu-analize?hash=a924b9a6-9877-4c14-9acd-e4b3ae7255ed#/). By using the excel formula *trend*, the forecast for such data was produced for the period 2021-2025.

Table 3B

Herpes zoster incidence rates by age group

HZ incidence (per 1,000 people)	***Male***	***Female***
50-54	*2.5*	*4.4*
55-59	*3.2*	*5.0*
60-64	*4.0*	*5.8*
65-69	*5.2*	*6.7*
70-74	*5.8*	*6.8*
75-79	*6.3*	*7.7*
80-84	*6.4*	*7.8*
>=85	*5.4*	*6.6*

Note. The data was adapted from “Epidemiology and cost of herpes zoster and post-herpetic neuralgia in the United Kingdom” by Gauthier et al., 2009 (doi:10.1017/S0950268808000678).

Table 4B

Post-herpetic neuralgia proportion per herpes zoster case

PHN proportion per HZ case, %	***1-month***	***3-months***
50-54	*14%*	*8%*
55-59	*19%*	*10%*
60-64	*22%*	*11%*
65-69	*27%*	*13%*
70-74	*30%*	*15%*
75-79	*36%*	*18%*
80-84	*39%*	*21%*
>=85	*35%*	*19%*

Note. The data was adapted from “Epidemiology and cost of herpes zoster and post-herpetic neuralgia in the United Kingdom” by Gauthier et al., 2009 (doi:10.1017/S0950268808000678). Post-herpetic neuralgia is divided into two definitions: patients experiencing one or three-months pain.

Table 5B

Total shingles cases with post-herpetic neuralgia

	2021	***2022***	***2023***	***2024***	***2025***
Total	***2,567***	***2,578***	***2,589***	***2,600***	***2,611***
1-month	*1,698*	*1,705*	*1,712*	*1,719*	*1,726*
3-month	*870*	*873*	*877*	*881*	*884*

Note. The data was adapted from "Epidemiology and cost of herpes zoster and post-herpetic neuralgia in the United Kingdom" by Gauthier et al., 2009 (doi:10.1017/S0950268808000678).

Table 6B

Pain split for herpes zoster and post-herpetic neuralgia patients

	HZ	***PHN***
<=69Y		
No pain	*27%*	*0%*
Mild pain	*41%*	*42%*
Moderate pain	*18%*	*9%*
Severe pain	*14%*	*49%*
>=70Y		
No pain	*26%*	*0%*
Mild pain	*32%*	*17%*
Moderate pain	*23%*	*16%*
Severe pain	*19%*	*67%*

Note. The data was adapted from “Health economic evaluation of a vaccine for the prevention of herpes zoster (shingles) and post-herpetic neuralgia in adults in Belgium” by Annemans et al., 2010 (doi:10.3111/13696998.2010.502854).

Appendix C

Healthcare resource use

Table 1C

Herpes zoster and post-herpetic neuralgia hospitalization rates

	HZ	***PHN***
No pain	*0.11%*	*0.00%*
Mild pain	*0.22%*	*0.42%*
Moderate pain	*8.33%*	*2.33%*
Severe pain	*15.56%*	*11.75%*

Note. The data was adapted from "Health economic evaluation of a vaccine for the prevention of herpes zoster (shingles) and post-herpetic neuralgia in adults in Belgium" by Annemans et al., 2010 (doi:10.3111/13696998.2010.502854).

Table 2C

Shingles hospitalization costs

Diagnosis	***Treatment cost***
B02.0 Zoster encephalitis	*1,519.15 €*
B02.1 Zoster meningitis	*794.13 €*
B02.2 Zoster with other nervous system involvement	*869.40 €*
B02.3 Zoster ocular	*677.17 €*
B02.7 Zoster generalisatus	*735.65 €*
B02.8 Zoster with other complications	*699.88 €*
B02.9 Zoster without complication	*744.12 €*

Note. The data was received and adapted from the National Health Security Fund, personal communication, November 26, 2020. Treatment costs here are average costs for an average treatment duration.

Table 3C

Mean length of hospital stay (days)

	HZ	***PHN***
No pain	*3*	*0*
Mild pain	*3*	*4.5*
Moderate pain	*4.67*	*6.75*
Severe pain	*6.29*	*6.44*

Note. The data was adapted from “Health economic evaluation of a vaccine for the prevention of herpes zoster (shingles) and post-herpetic neuralgia in adults in Belgium” by Annemans et al., 2010 (doi:10.3111/13696998.2010.502854).

Table 4C

Days lost from work

		Days lost from work	***Proportion of patients %***
HZ	*No pain*	*6*	*4.4%*
	Mild pain	*6*	*12.5%*
	Moderate pain	*6*	*39.4%*
	Severe pain	*11*	*78.8%*
PHN	*No pain*	*0*	*0.0%*
	Mild pain	*6*	*9.2%*
	Moderate pain	*11*	*33.3%*
	Severe pain	*19*	*52.6%*

Note. The data was adapted from "Health economic evaluation of a vaccine for the prevention of herpes zoster (shingles) and post-herpetic neuralgia in adults in Belgium" by Annemans et al., 2010 (doi:10.3111/13696998.2010.502854).

Table 5C

Comparison of private market vaccines' prices in Lithuania and the U.S.

Vaccine	***U.S. Private sector cost/dose, EUR***	***LT Private sector cost/dose, EUR***	***U.S. Private vs. LT Private sector, %***
Gardasil	*188.74 €*	*164.00 €*	*15%*
Trumenba	*124.12 €*	*118.00 €*	*5%*
Bexsero	*147.83 €*	*114.75 €*	*29%*
Rotarix	*103.00 €*	*80.48 €*	*28%*
AVERAGE			*19%*
Shingrix	*125.21 €*	***104.98 €***	

Note. The data was adapted from "Vakcinos" by Centro Poliklinika, 2020 (https://www.pylimas.lt/ paslaugos/mokamos-paslaugos/vakcinos) and "CDC Vaccine Price List" by CDC, 2020b (https://www.cdc.gov/vaccines/ programs/vfc/awardees/vaccine-management/price-list/index.html). The private market vaccine price of 104.98 EUR in Lithuania is calculated by applying the average percentage difference between the United States and Lithuania's vaccine prices.

Table 6C

Comparison of private and public market vaccines' prices in Lithuania

Vaccine	*LT Private sector cost/dose, EUR*	*LT Public sector cost/dose, EUR*	*Private vs Public sector, EUR*
Gardasil	*164.00 €*	*109.10 €*	*54.90 €*
Trumenba	*118.00 €*	*77.19 €*	*40.81 €*
Bexsero	*114.75 €*	*79.42 €*	*35.33 €*
Rotarix	*80.48 €*	*55.08 €*	*25.40 €*
Cervarix	*139.27 €*	*81.68 €*	*57.59 €*
AVERAGE			*42.80 €*
Shingrix	*104.98 €*	***62.17 €***	

Note. The data was adapted from "Vakcinos" by Centro Poliklinika, 2020 (https://www.pylimas.lt/ paslaugos/mokamos-paslaugos/vakcinos), "Skiepai" by Antėja Laboratorija, 2020 (https://anteja.lt/skiepai), "Skiepai" by Medicinos Diagnostikos ir Gydymo Centras, 2020 (https://www.medcentras.lt/paslaugos-ir-kainos/skiepai/skiepai-gimdos-kaklelio-vezio-prevencijai/) and "Paslaugų kainynas" by MediCa Klinika, 2020 (https://www.medicaklinika.lt/paslaugu-kainynas/72). The public market vaccine price of 62 EUR in Lithuania is calculated by deducting the average difference between private and public sector other vaccines' prices in monetary terms from the private sector's "Shingrix" vaccine price.

Appendix D

Sensitivity analysis

Table 1D

Prevention focus savings at different vaccine prices, in million EUR

Age group	***62 EUR***	***57 EUR***	***52 EUR***	***47 EUR***	***42 EUR***	***37 EUR***
Over 50y	*-16.4*	*-14.7*	*-13.1*	*-11.5*	*-9.8*	*-8.2*
Over 55y	*-13.3*	*-11.9*	*-10.5*	*-9.1*	*-7.7*	*-6.3*
Over 60y	*-9.4*	*-8.3*	*-7.2*	*-6.2*	*-5.1*	*-4.0*
Over 65y	*-5.5*	*-4.7*	*-3.9*	*-3.2*	*-2.4*	*-1.6*
Over 70y	*-2.6*	*-2.1*	*-1.5*	*-1.0*	*-0.4*	***0.1***
Over 75y	*-0.6*	*-0.2*	***0.1***	***0.5***	***0.9***	***1.3***
Over 80y	***1.1***	***1.3***	***1.6***	***1.8***	***2.1***	***2.3***
Over 85y	***2.7***	***2.8***	***2.9***	***3.1***	***3.2***	***3.3***
75-84	***0.8***	***1.1***	***1.4***	***1.6***	***1.9***	***2.2***
70-84	*-1.2*	*-0.7*	*-0.3*	***0.1***	***0.5***	***1.0***

Note. The data represents potential savings (treatment versus prevention scenario) for different age groups if price of the vaccine “Shingrix” would be decreasing by 5 EUR. Potential costs or savings represent treatment and prevention costs for all population over 50 years-old by selecting the age group eligible for free vaccination.