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Published in:
Expert Review of Pharmacoeconomics and Outcomes Research

DOI:
10.1080/14737167.2024.2306811

Expert Review of Pharmacoeconomics & Outcomes Research

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/ierp20

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To cite this article: Nikos Kotsopoulos, André Bento-Abreu, Goran Bencina & Mark P. Connolly (2024) Fiscal analysis of the pediatric immunization program in Belgium applying a lifetime government perspective framework, Expert Review of Pharmacoeconomics & Outcomes Research, 24:3, 437-445, DOI: 10.1080/14737167.2024.2306811

To link to this article: https://doi.org/10.1080/14737167.2024.2306811

EXPERT REVIEW OF PHARMACOECONOMICS & OUTCOMES RESEARCH
2024, VOL. 24, NO. 3, 437–445
https://doi.org/10.1080/14737167.2024.2306811

ORIGINAL RESEARCH

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Fiscal analysis of the pediatric immunization program in Belgium applying a lifetime government perspective framework

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ABSTRACT

Objectives: A public economic framework was used to explore lifetime government costs and benefits in relation to the Pediatric Immunization Program (PIP) in Belgium based on cases and deaths averted.

Methods: To estimate changes in net government revenue, we developed a decision-analytic model that quantifies lifetime tax revenues and transfers based on changes in morbidity and mortality arising from Belgium's Pediatric Immunization Program (PIP). The model considered differences in incidence rates with vaccines included in Belgium's PIP: compared with the pre-vaccine era. Changes in deaths and comorbid conditions attributed to PIP on the Belgium 2020 birth cohort were used to estimate gross lifetime earnings changes, tax revenue gains attributed to averted morbidity and mortality avoidance, disability transfer cost savings, and averted special education costs associated with each vaccine.

Results: Vaccinating a single birth cohort according to the PIP gives rise to fiscal gains of €56 million in averted tax revenue loss, €8 million disability savings, and €6 million special education cost-savings. Based on the costs of implementing the PIP, we estimate the fiscal benefit–cost ratio (fBCR) of €2.2 investment return for the government from every €1 invested excluding longevity costs.

Conclusions: Reducing vaccine-preventable conditions generates tax revenue for the government, providing fiscal justification for sustained immunization investments.

ARTICLE HISTORY
Received 20 November 2023
Accepted 3 January 2024

KEYWORDS
Fiscal analysis; infectious diseases; national immunization program; pediatric; vaccination; taxes

1. Introduction

Vaccines are considered one of the most impactful public health interventions to have been introduced in the last 100 years, responsible for saving countless lives and reducing the spread of infectious diseases, thereby reducing significantly untold suffering and the use of health-care resources [1,2]. Vaccines are known to be an economically efficient health-care intervention, often shown to be either cost-saving or cost-effective [3]. Despite the wide range of benefits attributed to vaccines, and economic gains to be achieved from reducing infectious conditions [4], Pediatric Immunization Program (PIP) can often be under-resourced and vulnerable to budget cuts [5]. This can be particularly concerning in the future if vaccination budgets do not keep pace with the introduction of new vaccines to treat other conditions [6].

Across Europe and globally, the vaccines included in PIPs and available for tax finance public funding can vary across countries, as well as the number of doses that are recommended for the same vaccine. Furthermore, in some cases vaccines can be recommended, but not publicly funded or not recommended and not funded [7]. The decision of whether to recommend and fund a new vaccine can be governed by a range of factors including budget limitations [8] which can contribute to differences in vaccine availability across countries. When viewed in the context of national healthcare spending, vaccines represent a small proportion of annual health-care budgets with an estimated median spend of 0.3%, and per capita and spending can vary across countries which likely reflects many factors, with the number of vaccines included in PIPs just one of the important factors [9,10]. The consequence of these varied decisions results in inconsistent availability of vaccines across countries [7], which is one of the factors underpinning calls by the European Commission to establish harmonized and sustainable vaccination policies [11].

Across Europe and many other countries, cost-effectiveness analysis has been introduced to evaluate whether vaccines represent an efficient use of public funds. This can be especially important for vaccines due to the upfront public expenditure required and the necessary ongoing commitment to fund programs annually. The conventional approach when using economics to evaluate the value of vaccines normally takes into consideration direct health-care costs applying a health service perspective [8]. A recent review of HTA assessments of vaccines in

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/14737167.2024.2306811.

Article highlights

- Population health can influence government accounts based on changes in work activity attributed to morbidity and mortality. Consequently, improvements in health or prevention of health events and infectious diseases can have positive fiscal impact for government.
- We explore this in relation to investments in the National Pediatric Immunization Program (PIP) for childhood vaccination in Belgium. We investigate how the PIP program in Belgium has reduced many common infections experienced by children and how this in turn impacts on the government accounts.
- The modeling framework translates health outcomes and resulting impact on work activity into tax revenue. When the population is healthy and able to work, the government benefits from this in terms of direct and indirect taxes collected. Similarly, by preventing diseases the government can reduce expenditure from health costs and disability costs that arise for people with permanent disabilities that arise from some infectious conditions experienced by children.
- We find that the Belgian government has a fiscal gain from the PIP based on lifetime future net tax gains achieved by preventing infectious diseases with vaccines. For each €1 spent on childhood immunization the government gains €2.2 in lifetime net tax gains
- There are many reasons for continuing to fund childhood immunization programs due to improvements in morbidity and mortality. The findings here provide a fiscal justification for continued commitments to vaccination programs.

developed countries identified that roughly half of the broader value components including productivity of patients and caregivers, cost off-sets that occur outside of the health service, prevention of antimicrobial resistance and macroeconomic influences were not taken into consideration with respect to vaccines [12]. Because vaccines have wide-reaching societal and economic implications, many researchers argue that a broader perspective should be applied when evaluating vaccines in order to capture the full range of benefits [13].

To capture the broader range of cost off-sets and fiscal gains associated with vaccination, we apply an accepted public economic framework used by governments to the PIP in Belgium. The framework is based on the generational accounting methodology also used by the European Commission and other governments for evaluating policy changes and fiscal sustainability [14]. In the context of vaccines, we apply this framework to evaluate how changing morbidity and mortality in the pediatric birth cohort associated with the PIP influences future lifetime work-force activity, which can be translated into tax revenue and social welfare costs for the Belgian government. The analysis described here can help to fulfill the aims of sustainable vaccination policy by understanding how historical changes to rates of infectious diseases in children have influenced government public accounts. Furthermore, applying a fiscal analysis which considers costs and benefits across a range of government budgets can inform the access environment and address sustainability issues. This is especially important in light of the introduction of new vaccines in the future that require funding commitments such as RSV, as well as helping governments prioritize increasing vaccine coverage rates of existing programs that have declined during and after the COVID-19 pandemic [15].

2. Methods

The fiscal analysis described here applied a previously reported decision analytic model developed to estimate the health economic impact of routine childhood vaccination programs in Belgium [16]. The study by Carrico et al. employed a decision-analytic model to project infectious cases and deaths and related health-care costs without immunization compared to implementing the full PIP for Belgium to the 2018 birth cohort [16]. For comparison, the Carrico et al. study used historical incidence data from published studies applied to the Belgian population and compared with the current incidence data for each condition obtained from the European Centre for Disease Prevention and Control. Interested readers are referred to the original model for more information [16]. The present analysis focused on six vaccines routinely administered from birth through age 10 years in Belgium: hexavalent (DTaP-IPV-HepB-Hib), DTaP-IPV, MMR, PCV, rotavirus, and meningococcal-type C vaccine [16]. Data on the effect of hepatitis B (HepB) vaccine on the incidence of the infection were excluded from the analysis due to surveillance limitations. The fiscal analytic framework applied, converted the public health benefit of immunization to fiscal gains following the ISPOR Good Practices for Outcomes Research recommendations for Economic Analysis of Vaccination Programs [17].

A birth cohort's lifetime (117,800 births in 2020) was simulated to firstly estimate the public health impact of vaccine-preventable conditions part of the PIP with and without vaccination. Subsequently, the benefits of vaccination, that is, reduced short-term and long-term morbidity and mortality, were translated into fiscal consequences for the Belgian government. Specifically, the fiscal consequences modeled were a) averted loss of tax revenue resulting from preventing deaths. Preventing deaths results in more productive life years from the birth cohort and lifetime earnings, which in turn, generate tax revenues; b) averted loss of tax revenue from preventing general and cognitive disabilities. The latter are known to negatively affect an individual's ability to work and thus their ability to generate earnings and pay taxes; c) averted transfer costs. Transfer costs pertain to disability benefits and excess costs for special education. These costs are incurred by individuals with long-term disabilities and can be prevented with vaccination. The sum of these fiscal consequences reflects the cross-sectorial impact of the public healthcare investment expressed in terms of future taxes and transfers [17]. The fiscal consequences of averted morbidity and mortality from vaccinations were then compared with the costs of public investments for implementing the PIP schedule.

Capturing the long-term complications is critical for public economic assessments of health as the fiscal consequences of each disease depend on the incidence of long-term disability in the birth cohort. The present analysis utilized the modeled long-term complications/sequelae and the associated annual direct costs, including the length of each long-term complication, and complication-related mortality rates produced by the analysis of Carrico et al., (2023) [16]. The findings on long-term sequelae from Carrico et al. have been summarized in the Supplemental Material. To convert public health events to fiscal consequences, evidence from the published literature was employed. Based on findings from the published literature, the following long-term health outcomes are known to result in fiscally relevant impacts: learning disabilities and cognitive impairment; Long-term cognitive impairment and learning disability resulting from encephalitis; hearing loss; disability from epilepsy; Permanent paralysis; renal failure and neurological defects; mortality from pediatric vaccine-preventable infections.

To identify the fiscal consequences related to long-term sequalae, a targeted literature review was conducted, in April 2023, in PubMed and Google Scholar aiming to find studies reporting the consequences of long-term sequalae on employment, in people with disabilities associated with vaccine-preventable diseases in Belgium (see Supplementary Material for summary of literature search and discussing the impact on employment). We identified from the literature search, the relative measures of impact for long-term outcome included in the analysis (e.g. hearing loss, permanent paralysis, cognitive impairment, epilepsy, and renal failure), and thus, the likely impact on future employment-related earnings losses in individuals with these conditions. In turn, labor market transitions were translated from the government perspective into lost fiscal revenue. Studies identified that translated long-term sequelae to fiscal losses are summarized in Table 1.

Additionally, for each vaccine-preventable condition and long-term complication, the fiscal costs were estimated based on transfer payments due to disability status. The underlying assumption applied in the model was that children with permanent disabilities attributed to infectious conditions would have increased dependency on public benefits due to reduced labor market activity. In adulthood, disability was associated with higher lifetime transfer costs due to lower levels of employment, and reduced lifetime earnings. Hence, the longevity gains from vaccinations raise total expected lifetime wages and lifetime tax revenues. Finally, our analysis considers the fiscal costs of vaccine-induced longevity, i.e. health-care costs and pension costs arising from increases in life expectancy. Table 1 shows the data used to capture the fiscal consequences of vaccine-preventable disease and the corresponding costs.

Official sources were used to obtain age-specific earnings and labor force participation rates [20,33]. The tax revenue consists of both direct and indirect tax levies on individuals. Direct taxes were estimated based on the average national tax burden on income [18,19]. Moreover, disability transfer cost-savings and averted special education costs associated with the number of prevented disability cases were estimated. To account for future government obligations due to vaccine-induced excess longevity, we estimate the fiscal consequences of longevity by taking into consideration the cost of pensions, for those 67 years of age and older [25] and unrelated health-care costs [34]. Direct health-care costs and published vaccinations costs were obtained from the analysis of Carrico et al., (2023) where costs of vaccine acquisition, administration, and treatment of adverse events were estimated at €93 million, which is the cost of implementing the PIP in Belgium [16].

The present analysis quantified the lifetime present value of gross earnings gains and tax revenue gains (i.e. averted gross earnings loss and averted tax revenue loss) attributed to reductions in morbidity and mortality from the PIP. To estimate the fiscal consequences from investments in the implementation of PIP, we generated fiscal benefit-cost ratios (fBCRs) based on the fiscal benefits arising from reducing excess vaccine-preventable morbidity and mortality. For the analysis, fiscal benefits include those from averted tax losses, reduced disability costs, special education cost-savings and vaccine-preventable disease-related health-care cost-savings; excess longevity costs include future unrelated health-care costs and pension costs associated with increased life expectancy. Future costs and wages were inflated at 0.7% and 1.1% annually, respectively, with cost and wage inflation rates based on the geometric mean of the last decade [35,36]. The present values of fiscal consequences were calculated using a discounting rate of 3% over the lifetime of the vaccinated and unvaccinated

Table 1. Data inputs for the calculation of fiscal consequences.

Parameter	Value	Source
Indirect tax burden (taxes based on consumption e.g. sales tax, VAT)	21.0%	[18]
Direct tax burden (captures taxation of wages and social insurances)	52.0%	[19]
Disposable income as % of gross income (portion of income spent on consumable products and services that are subject to indirect taxes i.e. VAT)	59.0%	[20]
Annual disability cost (adults <65 years of age)†	€15,250.89	[21]
Annual disability cost (<18 years of age, children/adolescents)	€5,373.73	[22]
Duration of adolescent disability benefits payments (years receiving benefit)	19	w.a.
Excess annual educational costs per pupil with cognitive disability‡	€38,983	[23]
Starting age of special educational needs (years of age)	5	[24]
Duration of special education (number of years receiving special education)	18	[24]
Average annual old-age state pension (adults ≥67 years of age)	€19,808.04	[25]
Reduction (loss) of economic activity for individuals with any disability (measles, polio, meningitis C)	33.79%	[26]
Reduction (loss) of earnings for individuals with cognitive disability(applies to Hib, rubella)	33.79%	[26]
Reduction (loss) of earnings for individuals with hearing loss (applies to Hib, pneumococcal, meningitis C)	25.6%	[27]
Reduction of economic activity for individuals with hearing loss (Hib, pneumococcal, meningitis C)	29.2%	[28]
Epilepsy-related loss of economic activity (applies to meningitis C)	12.7%	[29]
Renal failure-related loss of activity (applies to meningitis C)	28.0%	[30]
Major paralysis: Reduction (loss) of economic activity. (applies to polio)	100%	wa
Neurological defect-related loss of economic activity (applies to meningitis C)	0.0%	[31]
Amputation-related loss of economic activity (applies to meningitis C)	0.0%	[32]

Note: wa: working assumption; †This represents the amount of income support paid by government annually to support a disabled person. ‡applied to every year of schooling for the proportion of children that became cognitively impaired due to infectious conditions.

cohorts. The ratios for estimating fiscal benefit cost ratios are described below. **fBCR excluding longevity**: [tax revenue tax gain + disability costs-savings + health-care costs-savings]: [PIP costs]

$$fBCR_{excl.\,longevity} = \sum_{t=0}^{t=101} \beta(t)_j \times \left(\gamma(t)_j + \delta(t)_{j+} + \varepsilon(t)_j\right) \times (1+r)^{-t} \div [N_j \times \sum_{j=1}^{j=13} VC(t)_j \times (1+r)^{-t}]$$

fBCR including longevity: [tax revenue gain + disability costs-savings + health-care costs-savings]: [PIP costs + excess old age pension costs + excess unrelated health-care costs]

$$fBCR_{incl.\,longevity} = \sum_{t=0}^{t=101} \beta_j(t) \times \left(\gamma_j(t) + \delta_j(t) + \varepsilon(t)_j\right) \times (1+r)^{-t} \div [N_j \times \sum_{j=1}^{j=11} VC_j(t) \times (1+r)^{-t} + S_j \times \sum_{t=0}^{t=101} [P(t) + E(t)] \times (1+r)^{-t}]$$

Where,

t: Time from vaccination (year of age)
β: prevented cases
γ: tax revenue gain
δ: disability cost-savings
ε: healthcare cost savings
r: discounting rate
j: type of vaccine j = 1–11
N: vaccinated population
VC: total cost per vaccination
P: old age pension costs
S: excess survival
E: unrelated health-care costs

2.1. Sensitivity analysis

To test the model's sensitivity, we applied plausible ranges for the model's parameters including discount rate, inflationary measures i.e. CPI, wage growth rates, and vaccine acquisition costs. This deterministic one-way sensitivity analysis aims to evaluate the sensitivity of the base case results on the fBCR with and without the effect of longevity. The variation applied in the sensitivity analysis is reported in the Supplement.

3. Results

3.1. Base case

Fiscal projections were based on the number of vaccine-preventable infections experienced by the cohort, as previously reported [16]. This entailed capturing earnings losses from 248,765 infectious cases averted, 383 deaths prevented, and 34 disability cases avoided over the lifetime of the cohort.

The projected earnings loss (societal perspective) averted from immunizing the 2020 birth cohort ($N = 117{,}800$) was €87 million over the projected lifetime. Moreover, vaccinating a single birth cohort gives rise to benefits of €56 million in tax revenue gains, €126 million incremental health cost-savings, €8 million disability savings, and €6 million special education savings over the lifetime of the cohort. The net fiscal gain, for the lifetime of the cohort, is estimated at €105.4 million in the present value when the cost of vaccination (€91 million) is deducted from the fiscal gains. When longevity is factored into the analysis, government costs increase by €10 million in unrelated health-care costs and €14 million due to old-age pension costs. Tax revenue gains were highest for measles, diphtheria, and pneumococcal (Table 2).

The findings reported here can be further described as per person based on the number of children in the vaccinated birth cohort. From this perspective, the averted discounted tax revenue over the lifetime of each child vaccinated is €471. The per-person averted disability transfers and special education costs over the lifetime of the birth cohort is estimated to be €68 and €44, respectively.

Based on the costs for delivering the PIP, we estimate a fiscal benefit cost ratio (fBCR) of €2.2 return for government

Table 2. Lifetime fiscal impact of pediatric immunization in Belgium from single birth cohort societal and fiscal perspectives base year 2020 (€ discounted in 2020 million (M)).

		Fiscal perspective						
	Societal perspective	Averted tax revenue loss and public costs				Longevity costs		
Vaccination[†]	Gross earnings gain (averted losses)	Averted tax revenues loss	Averted disability transfers cost	Averted special education costs	Disease-related healthcare savings	Unrelated healthcare costs, i.e. Medicare age > 64	Retirement pensions' costs
Diphtheria	20.55 M	13.27 M	–	–	0.89 M	2.28 M	3.65 M
Tetanus	3.27 M	2.11 M	–	–	2.73 M	0.40 M	0.68 M
Pertussis	1.53 M	0.99 M	–	–	0.80 M	0.15 M	0.16 M
Hib	4.74 M	2.75 M	2.00 M	3.28 M	9.98 M	0.24 M	0.23 M
Measles	36.95 M	23.75 M	2.01 M	–	19.18 M	3.57 M	3.74 M
Mumps	–	–	–	–	36.96 M	–	–
Rubella	0.07 M	0.04 M	–	–	4.62 M	–	–
Pneumococcal	11.21 M	7.59 M	2.14 M	2.69 M	24.32 M	2.21 M	4.83 M
Polio	3.24 M	2.02 M	0.34 M	–	17.53 M	0.29 M	0.47 M
Rotavirus	0.49 M	0.32 M	–	–	7.23 M	0.05 M	0.05 M
Meningitis C	5.05 M	3.22 M	1.52 M	0.27 M	1.48 M	0.49 M	0.60 M
Total	**88 M**	**56 M**	**8 M**	**6 M**	**126 M**	**10 M**	**14 M**

[†]Changes in HepB cases excluded.

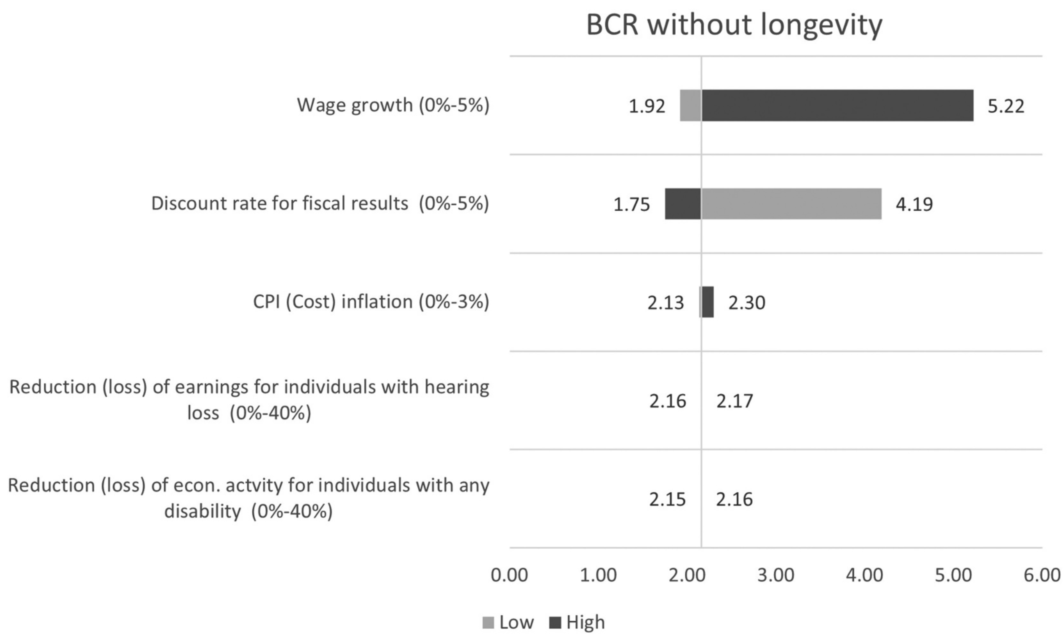

Figure 1. Sensitivity analysis exploring impact of changes on the fiscal benefit-cost ratios (fBCR) excluding costs of longevity.

from every €1 invested when longevity costs (pensions and future unrelated health-care costs) are excluded and a fBCR of €1.7 when longevity costs are included.

3.2. Sensitivity analysis

The sensitivity analysis illustrates that the fBCR ratios are most sensitive to future wage growth rates and discount rates applied. Increased inflation had a small but positive impact on the fBCR. The known comorbidities associated with the pediatric infectious conditions, e.g. hearing loss, epilepsy, and renal failure did not have a meaningful impact on the fBCRs shown in Figures 1 and 2. The lack of movement around the BCR mid-point highlights that these parameters are not likely to influence overall BCRs.

4. Discussion

The introduction of routine national immunization programs for children has given rise to a range of benefits for society from reduced morbidity and mortality that enable people to invest in human capital and engage in a range of economic activities that fuels economic growth [16]. To the list of benefits attributed to childhood immunization, we can now

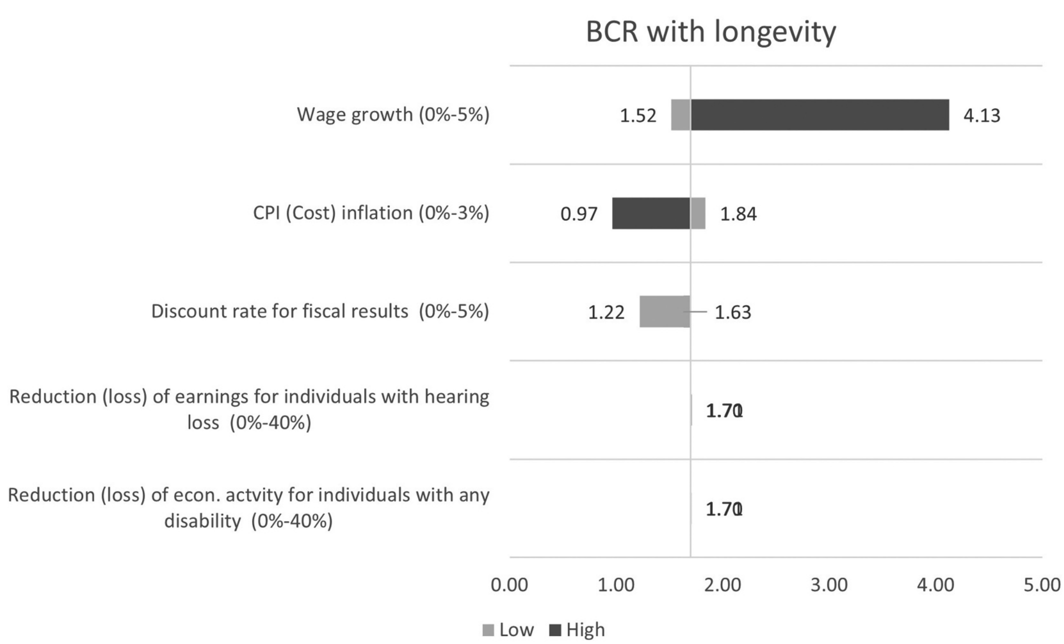

Figure 2. Sensitivity analysis exploring impact of changes on the fiscal benefit-cost ratios (fBCR) including longevity.

include tax revenue for the government, which totals €55 million in Belgium over the lifetime of a single birth cohort. This reflects the current state of PIP, but as newer vaccines are developed for emerging pathogens and become publicly available, additional societal and fiscal gains are likely to be achieved. In our analysis, we demonstrate an aggregate BCR to reflect the entire portfolio of gains and losses. While not all future vaccines may have fiscally positive returns, i.e. a fiscal BCR greater than 1.0, the fact that surplus net taxes are generated from existing vaccines in PIP for Belgium suggests that these gains from existing vaccines can help fund vaccines with lower BCRs.

The greatest economic effects are attributed to averted deaths in childhood that enable more children to survive and thus enter the workforce in the future. As reported by Carrico et al., the conditions accountable for the highest mortality, e.g. measles, diphtheria, and invasive pneumococcal, generated the highest tax revenue gains reported in our analysis since the introduction of vaccines (Table 2). Within the fiscal analysis described here, the increased number of workers in the future has been translated into increased tax revenue for governments. These numbers can be considered an underestimate as they do not include the lost productivity of parents during periods of childhood illness. While these mostly reflect short periods of absenteeism for parents while caring for their children, these costs amplified across economic domains can represent important tax losses [37]. While we do not expect this approach to replace the conventional cost-effectiveness approach considering the health service, perspective, as most vaccines are tax financed in Europe, we believe this approach can complement current approaches used to evaluate vaccines performed by national bodies.

To reflect the monetary gain for the government for investing in PIP in Belgium, we present fiscal benefit-cost ratios which reflect changes in fiscal outcomes in relation to the cost of implementing the program. The fBCR can be described from a range of perspectives to reflect how gains can vary across different economic domains. From the results of the previous health economic analysis we can estimate that from the health service perspective the ratio of benefits to costs is 1.4 for the Belgium PIP [16]. When a broader government perspective is applied, we estimate the fBCR to be €2.1 from every €1 invested excluding pension costs and health-care costs that occur in the future as these children will live longer. When longevity costs were considered for the birth cohort under-study, PIP investment costs yielded €1.7 for every €1 invested. In contrast, by applying an even broader perspective that considers the societal losses of the pediatric cohort, the ratio of benefits to costs reaches €2.4. As previously reported, including the productivity losses of parents or caregivers in BCRs yields €3.2 for every €1 invested in PIP [16]. This reflects the difference in the proportion of a workers earnings transferred to government, i.e. fiscal perspective, compared to the societal perspective in which all future earnings are accounted for in the BCR. Additionally, the results shown here are for the aggregate of all vaccines included in the current PIP for Belgium. While it is tempting to speculate about the relative value for individual vaccines, this type of analysis is not feasible as many of the vaccines are administered as a bundle with a single price. Furthermore, it is true that some vaccines may offer better relative fiscal value, the modeling approach described here is limited and does not consider the full range of benefits available and could lead to misinterpretation of the findings.

Vaccine-preventable conditions to which children are most vulnerable have varying public health burden [16]. These differences are reflected in the overall societal and fiscal impacts reported here and projected gains achieved from introducing the PIP in Belgium. Infectious conditions giving rise to the biggest societal and fiscal gains for society and government, respectively, were measles, diphtheria, and pneumococcal infections. The tax revenue gains from preventing measles, diphtheria, and pneumococcal were €23.7 million, €13.3 million, and €7.0 million, respectively. In total, we observe €55 million in lifetime tax revenue gain for the Belgian government from a single birth cohort. In practice, these fiscal gains from past immunization programs are invisible to governments or perhaps taken for granted, as they are reaping the rewards of past investments that have mostly eliminated pediatric infections. The ongoing investment in PIPs helps to sustain public health and contributes to fiscal sustainability that enables people to fulfill a normal healthy life trajectory. The fiscal consequences reported here would only be felt in the absence of available vaccines.

The merits of conducting this analysis in Belgium with a functional public health system and good vaccine coverage rates could be questioned. Nevertheless, in Belgium, not all vaccines are included in the PIP including varicella and MenB, and there have been calls by the Superior Health Council in Belgium to expand the age limits on HPV vaccination that have not been recognized [7,38]. Affordability is an important factor for sustaining health systems and decisions must be made to allocate resources, consequently some technologies are limited or not funded at all. However, it is our belief that resources can be better allocated when taking into consideration a broader range of costs and benefits that impact government public accounts. This is particularly important as new vaccines are being introduced and considered for inclusion in immunization schedules such as Respiratory Syncytial Virus (RSV). In addition, tax gains from a PIP could help to fund programs addressing the inequalities in vaccine access, such as improving the low vaccination coverage rates among vulnerable populations. Furthermore, the framework described here highlights what is a stake for government when coverage rates are low. This is particularly pertinent in the post-pandemic period, where issues of vaccine confidence and hesitancy have increased since the post-pandemic period leading to reduced coverage [15,39].

Economic gains are also achieved from reduced long-term morbidity. While most children do not experience lifelong disabilities associated with vaccine-preventable conditions, a small proportion will experience debilitating conditions such as cognitive or physical limitations that prevent them from fully engaging in the workforce in the future [16]. This will result in increased spending on special needs programs for these children into adulthood and will reduce the expected tax revenues due to reduced work activity in these individuals. The present analysis reflects the possibility for a small proportion of those infected with HiB, measles, meningitis C, polio, and pneumococcal will result in permanent disability. In these special cases, children may have special educational needs and, in some cases, receive permanent disability payments.

Deterministic sensitivity analysis was performed to identify those parameters that are likely to influence the investment returns for government reflected using the fBCR. The most influential variables were wage growth, which determines the amount of taxes people pay and the discount rate, which is a function of the perceived future value of money. As shown in the sensitivity analysis, increases in wage growth increase the fBCR to 5.0 as more income tax is collected by the government as wages grow, and consumption increases, thereby higher indirect taxes are paid. A reduction in wage growth decreased the fBCR, however the fBCR was still >1.0 indicating a positive fiscal return for the government. The discount rate was the second most sensitive variable in which an increased discount rate decreased the fBCR to 1.7. Additionally, the fBCR ratios reported here are likely conservative as they are based on the published prices for vaccines in Belgium and not the actual net prices paid by the government. As is common practice in pharmaceutical vaccine procurement, purchasers often negotiate prices downward; therefore, the price originally agreed is seldom the price that is paid by a national insurer or regional procurement agency; hence why our fiscal BCRs are conservative.

The findings reported here are likely to underestimate some of the fiscal gains attributed to vaccination. One of the positive externalities associated with vaccinations is a reduced need for antibiotic prescribing, which would result in lower rates of antimicrobial resistance (AMR). Because AMR is associated with increased rates of morbidity and mortality, which may increase in the coming years, this suggests that use of vaccines will have additional societal outcome gains that are not accounted for in our analysis [40,41]. Additional outcome gains can be achieved by reducing demand on hospital bed-days and improving working conditions for medical staff. For example, a study in Belgium has previously reported that following the introduction of rotavirus vaccination, bed-day occupancy, and turnover of hospital beds decreased during the peak winter months for rotavirus-attributable hospitalizations compared with the pre-vaccination period. The investigators also reported that reduced stress among hospital staff on wards for treating gastroenteritis-related symptoms, during a seasonal outbreak, would improve the quality of care provided which would likely improve outcomes [42]. A further limitation is the lack of data on hepatitis B cases included in our analysis, which would likely have some positive fiscal gains that are not shown here. For example, were hepatitis B included this could prevent some additional deaths and hepatitis comorbidities. Furthermore, the economic gains from microeconomic assessments of vaccination, that capture individual financial transactions between cohorts similar to the study reported here, do not capture the interactions between economic domains and the multipliers that can give rise to additional macroeconomic gains. For example, more children that survive childhood will demand more goods in the future creating demand for goods in the future. Between the microeconomic and macroeconomic domains there are many intermediate factors that are influenced by the presence of infectious diseases. People free from communicable disease will change behavior and make human capital investments, which will give rise to additional economic gains not accounted for in microeconomic assessments, suggesting that these results are underestimates of the likely fiscal gains governments can achieve through pediatric vaccinations. Vaccination of children may also influence educational attainment and cognition as previous reported in developing countries [43,44]. Although this is mostly relevant in developing countries today, since in advanced economies many of these human capital gains have been achieved from past investments in vaccination programs and reflected in economic growth and living standards, there is still the possibility that education benefits could be achieved in an advanced economy like Belgium, which would not be reflected in our findings.

Several limitations are worth highlighting as they could have a marginal impact on the base case results. Firstly, vaccine-preventable conditions can give rise to additional costs for government due to survival. In our analysis, we have included future health and pension costs which creates a tariff for survival, however we have not included future costs attributed to education as more children would survive and require schooling. This would impact government costs for in-kind benefits to these children that would appear during schooling years only, which we believe would only minimally influence our findings. Additionally, our analysis focuses on direct transactions linked to individuals, for example, taxes paid to the government or direct benefits received or in-kind benefits, i.e. healthcare. The analysis described here does not include congestible goods such as marginal costs for roads, policing, or other government infrastructure with nonzero costs. The costs of these goods at the individual level would be limited and not likely influence the results reported here.

The analysis described here illustrates the cross-sectorial impact of national immunization across a range of government budgets. It is important to recognize that government is not a single entity and there can be different departments responsible for funding specific programs. Consequently, some government entities are responsible for funding, but may not realize the fiscal gains on their budgets. For example, in Belgium, the regional authorities are responsible for making vaccine purchasing decisions. However, the fiscal gains, mainly through tax revenue, will be collected through central government, i.e. Treasury. This suggests the need to apply a broader range of thinking in relation to budget decisions that take into consideration the broader impact across a range of government budgets.

A wide range of factors are important for ensuring a vaccine is available within the country as part of a national immunization program. In addition to research and development, there are regulatory challenges, manufacturing capacity, distribution – often transported through cold chain, and administration [45]. Whilst pricing might be perceived as one of the key challenges, international studies indicate that vaccine acquisition often represents a small amount of the overall health budget [5]. In Belgium, a study has reported that the per capita costs per year for vaccine are estimated to be €8.50, a cost much lower than most medical interventions [10]. As shown here, vaccine investments are recouped fiscally for the government over the lifetime of the cohort. Previous fiscal analyses of vaccination programs have shown that variations in vaccine prices have a limited impact on lifetime net tax revenues [46]. This can be reconciled by the knowledge that budgets, especially health-care budgets, are a matter of today and often finite, whereas the fiscal rewards from improving outcomes occur in the future over many generations and are considerably greater than the initial vaccine acquisition costs.

5. Conclusions

Vaccine programs offer a wide range of population-wide benefits in terms of reducing morbidity and mortality. These improvements in outcomes can translate into many economic gains for society, which in turn will generate downstream benefits for governments from improved tax revenue and reduced spending on public benefits programs. The recent COVID-19 pandemic represents an extreme example of this where people were out of work for health or lockdown reasons or died prematurely. This negatively influenced government tax revenue due to reduced labor activity and consumption at a time when governments were spending money on a wide range of public benefits programs [47]. We believe the findings here can be used to inform continued investment in vaccine development and prioritization of vaccine programs to support economic growth.

Funding

This study was funded by Merck Sharp & Dohme LLC, a subsidiary of Merck & Co., Inc., Rahway, NJ, USA

Declaration of interest

G Bencina and A Bento Abreu are employees of Merck Sharp & Dohme LLC, a subsidiary of Merck & Co., Inc., Rahway, NJ, U.S.A., and may own stocks and/or stock options in Merck & Co., Inc., Rahway, NJ, U.S.A.. M P Connolly and N Kotsopoulos received funding from Merck. The authors M P Connolly and N Kotsopoulos were funded by Merck & Co., Inc. The authors have no other relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript apart from those disclosed.

Acknowledgments

We would like to thank Anja Termote and Lien Tam Co of STATBEL (Statistics Belgium) for the provision of statistical data that was pivotal to the conduct of this study.

The research described here was previously presented at the European International Society for Pharmacoeconomics and Outcomes Research (ISPOR) meeting in November 2023.

Authors contribution

N Kotsopoulos; research aim, model design, methodology, data identification, model development, interpretation of results, drafting of manuscript, critical edits final manuscript
A Bento-Abreu; research aim, model design, data identification, interpretation of results, critical edits final manuscript
G Bencina; research aim, model design, data identification, interpretation of results, critical edits final manuscript
M P Connolly; research aim, model design, methodology, data identification, model development, interpretation of results, drafting of manuscript, critical edits final manuscript

CONSORT statement

The study reported here is not a clinical trial or investigational study. The economic modeling work described here uses no individual patient data and did not include any interventions with animal or human subjects. The analysis is based on a secondary analysis of previously published sources. No ethics approval was required.

Data availability statement

The data on which this study are based have been derived from publicly available sources. No proprietary data has been used in this modeling work. All sources used for conducting this analysis have been cited and where the necessary links are available. No individual patient or named person data is used in our work.

Reviewer disclosures

Peer reviewers on this manuscript have no relevant financial or other relationships to disclose.

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References

1. Orenstein WA, Ahmed R. Simply put: vaccination saves lives. Proc Natl Acad Sci, USA. 2017;114(16):4031–4033. doi: 10.1073/pnas.1704507114
2. Andre FE, Booy R, Bock HL, et al. Vaccination greatly reduces disease, disability, death and inequity worldwide. Bullet World Health Organ. 2008;86(2):140–146. doi: 10.2471/BLT.07.040089
3. Carrico J, La EM, Talbird SE, et al. Value of the Immunization Program for Children in the 2017 US Birth Cohort. Pediatrics. 2022;150(3). doi: 10.1542/peds.2021-056007
4. Quilici S, Smith R, Signorelli C. Role of vaccination in economic growth. J Mark Access Health Policy. 2015;3(1):27044. doi: 10.3402/jmahp.v3.27044
5. Ethgen O, Rémy V, Wargo K. Vaccination budget in Europe: an update. Human Vaccines Immunother. 2018;14(12):2911–2915. doi: 10.1080/21645515.2018.1504528
6. Excler J-L, Saville M, Berkley S, et al. Vaccine development for emerging infectious diseases. Nature Med. 2021;27(4):591–600. doi: 10.1038/s41591-021-01301-0
7. Bencina G, Bento-Abreu A, Sabale U, et al. Estimating the lifetime cost of vaccination in 23 European countries: a modeling study. Expert Rev Vaccines. 2023;22(1):148–160. doi: 10.1080/14760584.2023.2157266
8. Laigle V, Postma MJ, Pavlovic M, et al. Vaccine market access pathways in the EU27 and the United Kingdom -analysis and recommendations for improvements. Vaccine. 2021;39(39):5706–5718. doi: 10.1016/j.vaccine.2021.07.040
9. BH MI, Neels L. Belgian vaccines landscape analysis assessment and plan with recommendations for policy proposals to address

shortcomings Ingrid. In: Maes H, editor; 2020. p. 47. https://www.inovigate.com/media/filer_public/b8/df/b8df7b0b-80e3-4384-8dd3-14afd49037fe/vaccine_landscape_report_22-09-20_final.pdf
10. Vermeersch S, Bento-Abreu A. Horizon scanning of immunisation budget for Belgium using an immunisation planning tool. In: Value in Health. New York (NY): Elsevier Science Inc; 2020. p. S564–S564.
11. Commission E. Vaccination: commission calls for stronger EU cooperation against preventable diseases. Brussels: European Commission; 2018.
12. Bell E, Neri M, Steuten L. Towards a broader assessment of value in vaccines: the BRAVE way forward. Appl Health Econ Health Pol. 2022;20(1):105–117. doi: 10.1007/s40258-021-00683-z
13. Annemans L, Beutels P, Bloom DE, et al. Economic evaluation of vaccines: Belgian reflections on the need for a broader perspective. Value Health. 2021;24(1):105–111. doi: 10.1016/j.jval.2020.09.005
14. Auerbach AJ, Gokhale J, Kotlikoff LJ. Generational accounts: A meaningful alternative to deficit accounting. Tax Policy Econ. 1991;5:55–110. doi: 10.1086/tpe.5.20061801
15. Organization WH. The big catch-up: an essential immunization recovery plan for 2023 and beyond. 2023.
16. Carrico J, Mellott CE, Talbird SE, et al. Public health impact and return on investment of Belgium's pediatric immunization program. Front Public Health. 2023;11. doi: 10.3389/fpubh.2023.1032385
17. Mauskopf J, Standaert B, Connolly MP, et al. Economic analysis of vaccination programs: an ISPOR good practices for outcomes research task force report. Value Health. 2018;21(10):1133–1149. doi: 10.1016/j.jval.2018.08.005
18. OECD. Consumption tax trends 2022: vAT/GST and excise, core design features and trends. Paris: OECD Publishing; 2022. doi: 10.1787/6525a942-en
19. OECD. Taxing Wages 2023: Indexation of Labour Taxation and Benefits in OECD Countries. Paris: OECD Publishing; 2023. doi: 10.1787/8c99fa4d-en
20. STATBEL. Taxable income. Belgium in figures; 2023
21. FPS Social Security. (2023)
22. Kidslife.be. Care allowance benefits. Brussels: KidsLife Brussels; 2023.
23. Zhou F, Shefer A, Wenger J, et al. Economic evaluation of the routine childhood Immunization Program in the United States, 2009. Pediatrics. 2014;133(4):577–585. doi: 10.1542/peds.2013-0698
24. Vlaanderen.be. Compulsory education. In: Informatie van de Vlaamse overheid; 2023. https://www.vlaanderen.be/en/studying/compulsory-education
25. Federale Pensioendienst. Jaarlijkse statistiek van de uitkeringsgerechtigden 2020; 2020.
26. European Commission. European semester 2020-2021 country fiche on disability equality - Belgium consultancy. In: He, editor. Directorate-general for employment, social affairs and inclusion, directorate C — social affairs, unit C3 — disability & inclusion, Luxemburg; 2021.
27. Kim EJ, Byrne B, Parish SL. Deaf people and economic well-being: findings from the life opportunities survey. Disability Soc. 2018;33(3):374–391. doi: 10.1080/09687599.2017.1420631
28. Huda A, Newcomer R, Harrington C, et al. High rate of unemployment after liver transplantation: analysis of the United Network for Organ Sharing database. Liver Transpl. 2012;18(1):89–99. doi: 10.1002/lt.22408
29. Sillanpaa M, Schmidt D. Long-term employment of adults with childhood-onset epilepsy: a prospective population-based study. Epilepsia. 2010;51(6):1053–1060. doi: 10.1111/j.1528-1167.2009.02505.x
30. de Jong RW, Boezeman EJ, Chesnaye NC, et al. Work status and work ability of patients receiving kidney replacement therapy: results from a European survey. Nephrol Dial Transplant. 2022;37(10):2022–2033. doi: 10.1093/ndt/gfab300
31. Roed C, Sorensen HT, Rothman KJ, et al. Employment and disability pension after central nervous system infections in adults. Am J Epidemiol. 2015;181(10):789–798. doi: 10.1093/aje/kwu359
32. Schoppen T, Boonstra A, Groothoff JW, et al. Employment status, job characteristics, and work-related health experience of people with a lower limb amputation in the Netherlands. Arch Phys Med Rehabil. 2001;82(2):239–245. doi: 10.1053/apmr.2001.18231
33. OECD. Labor Force Survey (LFS) by age and sex - indicators. OECD. Stat. OECD; 2023. https://stats.oecd.org/Index.aspx?DataSetCode=lfs_sexage_i_r
34. SEBOIO. Twenty years of societal impact. The value of medicines in Belgium. AFFAIRS, SP (2020)
35. STATBEL. Consumer Price Index figures. Brussels: STATBEL; 2023.
36. STATBEL. Labour cost index. Indicators - Labour. Brussels: STATBEL; 2023.
37. Kotsopoulos N, Haitsma G, Connolly MP, et al. Estimating the money flow in the economy attributed to rotavirus disease and vaccination in the Netherlands using a Social Accounting Matrix (SAM) framework. Expert Rev Pharmacoecon Outcomes Res. 2020;20(6):603–612. doi: 10.1080/14737167.2020.1693269
38. Conseil Supérieur de la Santé. Vaccination contre le papillomavirus humain (HPV). In: SCC, editor. CSS Number 9181. Bruxelles: Conseil Supérieur de la Santé; 2017.
39. Wiegand M, Eagan R, Karimov R, et al. Global declines in vaccine confidence from 2015 to 2022: a large-scale retrospective analysis; 2023. http://dx.doi.org/10.2139/ssrn.4438003
40. Kim C, Holm M, Frost I, et al. Global and regional burden of attributable and associated bacterial antimicrobial resistance avertable by vaccination: modelling study. Inter J Infect Dis. 2023;130:S9. doi: 10.1016/j.ijid.2023.04.026
41. Jansen KU, Knirsch C, Anderson AS. The role of vaccines in preventing bacterial antimicrobial resistance. Nature Med. 2018;24(1):10–19. doi: 10.1038/nm.4465
42. Standaert B, Alwan A, Strens D, et al. Improvement in hospital quality of care (QoC) after the introduction of rotavirus vaccination: an evaluation study in Belgium. Human Vaccines Immunother. 2015;11(9):2266–2273. doi: 10.1080/21645515.2015.1029212
43. Anekwe TD, Newell M-L, Tanser F, et al. The causal effect of childhood measles vaccination on educational attainment: a mother fixed-effects study in rural South Africa. Vaccine. 2015;33(38):5020–5026. doi: 10.1016/j.vaccine.2015.04.072
44. Bloom DE, Canning D, Shenoy ES. The effect of vaccination on children's physical and cognitive development in the Philippines. Appl Econ. 2012;44(21):2777–2783. doi: 10.1080/00036846.2011.566203
45. Wouters OJ, Shadlen KC, Salcher-Konrad M, et al. Challenges in ensuring global access to COVID-19 vaccines: production, affordability, allocation, and deployment. Lancet. 2021;397(10278):1023–1034. doi: 10.1016/S0140-6736(21)00306-8
46. Kotsopoulos N, Connolly MP, Postma MJ, et al. Fiscal consequences of changes in morbidity and mortality attributed to rotavirus immunisation. Vaccine. 2013;31(46):5430–5434. doi: 10.1016/j.vaccine.2013.09.002
47. Chernick H, Copeland D, Reschovsky A. The fiscal effects of the COVID-19 pandemic on cities: An initial assessment. National Tax J. 2020;73(3):699–732. doi: 10.17310/ntj.2020.3.04