Vaccine 33 (2015) 3788–3794

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

Review

Discounting in the evaluation of the cost-effectiveness of a vaccination programme: A critical review

Mark Jit[a,b,*], Walter Mibei[a]

[a] Department of Infectious Disease Epidemiology, London School of Hygiene and Tropical Medicine, London WC1E 7HT, United Kingdom
[b] Modelling and Economics Unit, Public Health England, London NW9 5EQ, United Kingdom

ARTICLE INFO

Article history:
Received 5 February 2015
Received in revised form 21 June 2015
Accepted 22 June 2015
Available online 2 July 2015

Keywords:
Vaccination
Cost-effectiveness
Discounting

ABSTRACT

Discounting future costs and health benefits usually has a large effect on results of cost-effectiveness evaluations of vaccination because of delays between the initial expenditure in the programme and the health benefits from averting disease. Most guidelines currently recommend discounting both costs and health effects at a positive, constant, common rate back to a common point in time. A review of 84 published economic evaluations of vaccines found that most of them apply these recommendations. However, both technical and normative arguments have been presented for discounting health at a different rate to consumption (differential discounting), discounting at a rate that changes over time (non-constant discounting), discounting intra-generational and inter-generational effects at a different rate (two-stage discounting), and discounting the health gains from an intervention to a different discount year from the time of intervention (delayed discounting). These considerations are particularly acute for vaccines, because their effects can occur in a different generation from the one paying for them, and because the time of vaccination, of infection aversion, and of disease aversion usually differ. Using differential, two-stage or delayed discounting in model-based cost-effectiveness evaluations of vaccination raises technical challenges, but mechanisms have been proposed to overcome them.

1. Introduction

Economic considerations increasingly drive public investments in vaccines [1]. A key decision-making tool is economic evaluation, which weighs the incremental cost of vaccination against the incremental health and economic benefits that it brings. Since vaccines prevent future disease from occurring, the costs and benefits associated with vaccination usually fall at different times. Economists regard present *consumption* (see Table 1 for definitions of terms in italics) as more valuable than future consumption, because (i) there is an *opportunity cost* to consuming now rather than later, since the money spent could have been invested elsewhere to generate some returns, and (ii) most people simply prefer to consume now rather than later, all other things being equal [2]. The standard approach to collectively capture these preferences for present over future consumption is by *discounting*, which reduces the value of future costs and benefits compared to those in the present [3].

The most common method is to apply a constant (exponential) discounting rate, and to use the same rate for consumption and health. Constant rate discounting is supported by the discounted utility model, which states that the utility derived from consumption at a future time t is the same as the utility now multiplied by a discounting factor $(1+r)^{-t}$. However, this standard model of discounting has been challenged [4–10], particularly for the case of vaccines [11–16], since they have distinct characteristics not shared by many other health interventions and hence their cost-effectiveness can be particularly sensitive to discounting. In light of the importance of discounting to economic evaluations of vaccines, this paper aims to survey the methodological basis and merits of alternatives to standard discounting schemes, as well as to consider how they may apply to vaccination. We first review how discounting is used in current economic evaluations of vaccination, then list the main features of vaccination that distinguish it from other health interventions. We explore how alternatives to the standard discounting model may address these features with respect to four key areas: differential discounting (discounting health at a different rate to consumption), societal preferences, inter-generational effects and the timing of health gains. Finally, we propose solutions

Abbreviations: NICE, National Institute for Health and Care Excellence; WHO, World Health Organization.

* Corresponding author at: Modelling and Economist Unit, Public Health England, 61 Colindale Avenue, London NW9 5EQ, United Kingdom. Tel.: +44 20 83277803; fax: +44 2082007868.
E-mail address: mark.jit@phe.gov.uk (M. Jit).

http://dx.doi.org/10.1016/j.vaccine.2015.06.084

Table 1
Glossary of key economic terms used.

Consumption	The final purchase for use of goods or services by individuals (consumers).
Cost–benefit analysis	A type of economic evaluation in which the incremental costs and benefits of an intervention are both expressed in monetary units.
Cost-effectiveness analysis	A type of economic evaluation in which the incremental costs of an intervention are compared to the incremental outcomes of the intervention expressed in physical units such as cases of disease averted, lives saved or quality adjusted life years gained.
Discounting	Reduction in the value of a future cost or benefit at a pre-specified rate, which depends on its temporal distance from a common time (such as the time at which an intervention like a vaccination programme is initiated).
Externality	Cost or benefit that does not fall on the person producing or consuming a good.
Opportunity cost	The value of the next best alternative use of resources which is foregone when the resources are consumed.
Social rate of time preference	The rate at which society values present over future consumption.
Standard gamble	Method of eliciting the value that individuals place on a health state by asking them their preference between being in a health state, and being in perfect health but with some given risk of instant death.
Stated preference	Method of eliciting individuals' preferences for different options by asking them what they would do in hypothetical situations.
Stationarity	Preference between two outcomes that depends only on the time interval between them and not on when the first event occurs.
Time tradeoff	Method of eliciting the value that individuals place on a health state by asking them their preference between a shorter time spent in perfect health, and a longer time spent in that health state.

to some of the technical issues that may arise with alternative discounting schemes.

2. Review of discounting in economic evaluations of vaccination

2.1. Methods

We examined how discounting is used in economic evaluations of vaccination reviewed in six recent systematic reviews of economic evaluations of vaccines against human papillomavirus [17] ($n = 12$); *Streptococcus pneumoniae* [18] ($n = 15$), [19] ($n = 10$); rotavirus [20] ($n = 17$); *Haemophilus influenzae* type B [21] ($n = 13$); and seasonal influenza [22] ($n = 18$).

3. Results

In total 84 unique economic evaluations of vaccines published from 1993 to 2014 were examined (see appendix for details).

Of these, 19 (23%) did not discount at all. These included 14 evaluations of paediatric influenza vaccination and two of pneumococcal conjugate vaccination [23,24], where the time horizon over which costs and effects are assessed was less than a year. The time horizons of less than 1 year and the lack of discounting were not inappropriate in most cases, as there were no long-term consequences to consider in the analysis. However, some of these evaluations included considerations of years of life saved beyond the time horizon, which would normally be discounted. One evaluation of rotavirus vaccination had a time horizon of 5 years, which the authors considered short enough to ignore discounting effects [25]. Two others (on *Haemophilus influenzae* type B [26] and pneumococcal conjugate vaccination [27]) had longer time horizons but gave no justification for failing to discount. A further four (5%) discounted benefits alone (and not costs), while 11 (13%) discounted costs alone (and not benefits).

Of the remaining 50 studies discounting both costs and effects, 43 (51%) used the standard discounting scheme of discount rates that are constant over time and equal for both costs and effects (with rates ranging from 3 to 6%). However, one (1%) used stepwise equal rates (reflecting United Kingdom Treasury recommendations [28], see section on "non-constant discounting" for details) and six (7%) used constant rates but discounted costs at a higher rate than benefits. Of the studies with differential discounting, five of them reflected national guidelines (as the United Kingdom prior to 2004, the Netherlands and Belgium recommended differential discounting). However, one (set in France) did not, instead justifying the choice by appealing to the controversy over whether economic evaluations of vaccination should use equal discounting [29].

Of the 84 studies, 52 (62%) involved tracking a single age cohort. A further 16 (19%) tracked a range of age groups, but either only followed outcomes for a year or less, or did not consider the timing of outcomes at all. Of the remaining 16 (19%) studies that tracked multiple cohorts over several years, eight were static or pseudo-dynamic models with no interactions between effects in different cohorts. The remaining eight were dynamic models with inter-cohort effects.

4. Distinctive intertemporal features of vaccination

Vaccination has several distinctive intertemporal features compared to most other health interventions. First, there are often long delays between vaccine administration (when costs are incurred) and disease averted (when benefits are obtained), so benefits are greatly affected by discounting. For example, vaccination against human papillomavirus [15] or hepatitis B [14] involves decades-long delays between initial costs and eventual benefits. In contrast, interventions without long-lasting effects (such as pain relief that provides immediate but short-term relief of symptoms) may be largely insensitive to discounting.

Second, vaccines have positive *externalities*: they not only reduce disease risk in vaccinees but also provide "herd" or community-level protection to others who might otherwise have been infected by vaccinated individuals. The externalities are non-linear with respect to coverage: if a single individual is vaccinated, the health gain to others is small, but if most susceptible individuals are vaccinated, there is a substantial health gain to others. Herd protection from vaccination can persist for years, and indeed indefinitely in the case of eradication. Hence there can be delays between the earlier cost of vaccination and realisation of herd protection effects. Capturing these effects often requires multiple cohort models that stretch further into the future compared to models of non-infectious diseases.

The interaction between time differences and generational differences can be complex. They are illustrated in Table 2 for four vaccines:

- Considerable expense was spent on smallpox eradication until it was achieved in 1979. Today, expenditure on smallpox vaccination is virtually zero, but we continue to receive benefits from having eradicated smallpox (which was estimated to cost the world $1.35 billion a year in 1967 [30]). Note that even in the 1970s there were generational differences in benefits of vaccination: children were protected from disease, while their parents were already immune due to prior vaccination or infection.
- Human papillomavirus vaccination protects current adolescents from future cervical cancer. It has a smaller effect on current adults because the vaccine is only prophylactic, and many of them