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ECONOMIC EVALUATION

Practical Implications of Differential Discounting in Cost-Effectiveness Analyses with Varying Numbers of Cohorts

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ABSTRACT

Objective: To call attention to the influence of the number of birth-cohorts used in cost-effectiveness analysis (CEA) models on incremental cost-effectiveness ratios (ICERs) under differential discounting. **Methods:** The consequences of increasing the number of birth-cohorts are demonstrated using a CEA of cervical cancer prevention as an example. The cost-effectiveness of vaccinating 12-year-old girls against the human papillomavirus is estimated with the MISCAN microsimulation screening analysis model for 1, 10, 20, and 30 birth-cohorts. Costs and health effects are discounted with equal rates of 4% and alternatively with differential rates of 4% and 1.5% respectively. The effects of increasing the number of cohorts are shown by comparing the ICERs under equal and differential discounting. **Results:** The ICER decreases as the number of cohorts increases under differential discounting, but not under equal discounting. **Conclusions:** The variation of ICERs with the number of cohorts under differential discounting prompts questions regarding the appropriate specification of CEA models and interpretation of their results. In particular, it raises concerns that arbitrary variation in study specification leads to arbitrary variation in results. Such variations could lead to erroneous policy decisions. These findings are relevant to CEA guidance authorities, CEA practitioners, and decision makers. Our results do not imply a problem with differential discounting per se, yet they highlight the need for practical guidance for its use.

Keywords: cohort models, cost-effectiveness analysis, differential discounting, population models, study comparability.

Introduction

Debate over differential discounting

Discounting is used in cost-effectiveness analysis (CEA) to adjust future costs and health effects to their present values and volumes. This adjustment is to account for the positive time preference for goods, including health [1]. While discounting in general is widely accepted in CEA and other forms of economic analysis [2], whether discount rates for costs and effects should be equal has been debated extensively within health economics [2–9]. Equal discount rates for costs and effects are most commonly used [10]. Equal discounting is supported by a number of arguments, the most important of which are Weinstein and Stason's [4] consistency thesis, Keeler and Cretin's [3] postponing paradox, and the tradability of health argument [11]. Differential discounting is being advocated more frequently, whereby health effects are discounted at a different (typically lower) rate than costs [2,6,7,9,12]. Previous arguments for differential discounting were primarily based on the anticipation of an increasing societal value of health as income grows [7,12,13]. Recent work has shown, more generally, that differential discounting is justified if the cost-effectiveness threshold is anticipated to change, where the threshold may be defined with reference to either the consumption value of health or the cost-effectiveness of displaced interventions at the margin in the context of fixed health care budgets [14].

Currently, only a small number of CEA authorities recommend differential discounting [15]. The Dutch Health Care Insurance Board (College voor Zorgverzekeringen [CVZ]) revised its recommended rates in 2006, from equal rates of 4% to differential rates of 4% and 1.5% for costs and health effects respectively [12,16]. Belgium also recently adopted differential discounting at rates of 3% and 1.5% for costs and effects respectively [17]. The National Institute for Health and Clinical Excellence (NICE) in England and Wales used differential discounting from its inception with rates of 6% and 1.5% for costs and effects respectively, but reverted to equal discounting at 3.5% in 2004 [7,18].

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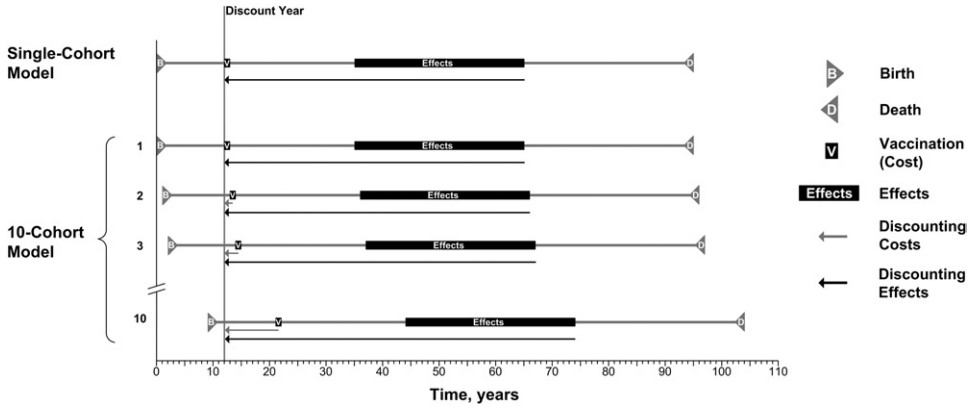

Fig. 1 – Comparison of discounting in a single cohort and a multi-cohort model with 10 cohorts (cohorts 4–9 not shown).

Modeling and decision rules in cost-effectiveness analysis

Modeling is widely used in cost-effectiveness analysis of healthcare interventions [19]. Modeling can be used both to extrapolate outcomes beyond trial follow-up periods and to simulate interventions that have not or cannot be assessed using controlled trials [1,20,21]. CEA models most commonly only simulate one cohort of individuals [22]. A multiple-cohort modeling approach is more appropriate in some cases, such as where risk factors change over time, leading to cohort effects; where the effects of a disease are dynamic, such as in infectious diseases; or where both prevalent and incident cohorts need to be considered [22–25].

Decision making using CEA relies on comparisons between analyses to determine which interventions are cost-effective. In theory, interventions can be ranked by their incremental cost-effectiveness ratios (ICERs) and accepted in order of cost-effectiveness until the budget constraint is reached [26]. In practice, it is more typical to accept interventions with ICERs below a given threshold as cost-effective [4]. Both decision rules compare interventions' ICERs, either directly in the case of the ranking rule, or indirectly through the threshold.

Overview

We compare the results of single-cohort and multiple-cohort CEAs of the same intervention to quantify the consequences of alternative numbers of cohorts (henceforth, CEA specification) under differential discounting. We show, using a CEA of vaccination against the human papillomavirus (HPV) as an illustrative example, that the ICER falls as more cohorts are included in the analysis under differential discounting, but remains constant under equal discounting. Recent work by Hoyle and Anderson [22] also noted that increasing the number of cohorts reduces ICERs under differential discounting. We address this particular issue in greater depth and consider its significance for CEA practice and health care decision making. In this article, we take no normative stance for or against differential discounting; however, we consider its consequences from the perspective of equal discounting being the policy norm in most countries to date. Most previous studies of differential discounting have addressed its theoretical merits; our study adds to the literature by explicitly considering the practical consequences of differential discounting for decision making using CEA.

Methods

We examined how an intervention's ICER changes as the number of cohorts modeled increases using the example of the MISCAN microsimulation model of cervical screening and HPV vaccination in The Netherlands employed in a recently published CEA [27]. Further details of the model specification and assumptions can be found in that publication. The model simulates the individual life histories of one or more birth-year cohorts of women, who, in the absence of either screening or vaccination, acquire a HPV infection at a certain rate; some develop a pre-invasive lesion and/or cancer and a proportion die from the disease. This results in an age and calendar time-specific output of disease incidence and mortality. The simulation is repeated, now including screening, both with and without vaccination. Screening is simulated as the current Dutch program: seven screens between the ages of 30 and 60 at 5-year intervals. Vaccination is administered at age 12. These interventions change some of the life histories, either by preventing disease or detecting and treating it earlier, resulting in improved health states, longer life, and reduced treatment costs. Treatment costs and quality of life adjustments are then applied to these consequences to estimate the intervention's treatment cost savings and quality-adjusted life year (QALY) gains. The difference between the total net discounted costs and health effects of screening alone and screening and vaccination combined is used to calculate the incremental cost-effectiveness of HPV vaccination.

A number of additional simplifying assumptions are made in the present study: the undiscounted costs and effects are the same for every cohort; no booster vaccination is required; and there are no start-up or fixed costs. A large number of women (1 billion) are simulated in each model to minimize differences due to random error. Each cohort in the multi-cohort models contains an equal proportion of the total number of individuals.

The ICER of HPV vaccination from a single-cohort analysis is compared to ICERs from analyses with 10, 20, and 30 cohorts. The analyses differ only in the number of cohorts used; all else is held constant. Each cohort is defined by its birth year and each receives the vaccination 1 year after the preceding cohort. Figure 1 depicts a single-cohort and a 10-cohort model. Costs and effects are discounted by 4% and 1.5% respectively, and also by a common rate of 4%. Costs and effects are discounted to the year the first cohort is vaccinated.

Results

Table 1 presents the results of the single and multi-cohort models under equal and differential discounting. The table reports the discounted incremental costs and effects and the corresponding ICERs in each of the models and discount rate assumptions. The table also reports the ICERs of the multi-cohort models as a percentage of that of the single-cohort model.

The ICERs are significantly lower under differential discounting

Table 1 – Incremental costs, incremental health effects, and ICER of adding vaccination against the HPV 16/18 to the current screening program in The Netherlands*.

	Equal discount rates: 4% & 4%				Differential discount rates: 4% & 1.5%			
	Single cohort	10 cohorts	20 cohorts	30 cohorts	Single cohort	10 cohorts	20 cohorts	30 cohorts
Incremental costs, €M	324,423	273,662	229,268	194,470	324,423	273,662	229,268	194,470
Incremental effects, QALYs (000s)	3190	2690	2254	1912	10839	10146	9444	8809
ICER, €/QALY (4 s.f.)	101,700	101,700	101,700	101,700	29,900	27,000	24,300	22,100
Ratio of ICERs, multiple/single cohort	Reference	100%	100%	100%	Reference	90%	81%	74%

HPV, human papillomavirus; ICER, incremental cost-effectiveness ratio; QALY, quality-adjusted life year.

* A comparison of a single cohort and multiple cohort models with 10, 20, and 30 cohorts under equal discounting of 4% for costs and effects and differential discounting of 4% and 1.5% for costs and effects respectively.

compared to equal discounting. This is due to the lower discounting of health effects; consequently, the discounted effects are larger while the discounted costs remain the same, resulting in lower ICERs.

The important result, however, is the variation in ICERs between models with different numbers of cohorts. The ICERs do not vary significantly with the number of cohorts under equal discounting; the small differences in costs and effects are due to random variation in the simulation model. Conversely, with differential discounting, the ICERs are considerably lower in the multi-cohort models and fall as the numbers of cohorts increase. The magnitude of the differences is large: the 10-cohort model has an ICER that is approximately 90% of the single-cohort model's ratio; the 30-cohort model has an ICER that is approximately 74% of the single-cohort model's ratio.

Figure 2 (panel A) shows the annual discount factors for the current Dutch discount rates for cost and effects of 4% and 1.5% respectively, where $t = 1$ is the discount year. The grey line in panel B indicates the ratios of ICERs of the nth future cohort relative to the first cohort at the discount year, where each cohort is $n - 1$ year from the discount year, and undiscounted costs and effects are equal for all cohorts. This line is also the ratio of the discount factors shown in panel A. The black line in panel B represents the ratio of ICERs of a multi-cohort model with n cohorts relative to a model of a single cohort at the discount year, with the points labeled for models with $n = 10$, 20, and 30 cohorts.

Discussion

Explanation

Our results are easily explained by considering the differences between equal and differential discounting. Under equal discounting, varying the length of time between the discount year and the intervention (and its effects) does not influence the ICER; although the present value of costs and effects change, they vary proportionately. It is with this respect that Lipscomb et al. [28] described CEA as "time neutral" under equal discounting; however, CEA is not "time neutral" under differential discounting. Increasing the length of time between the intervention and the discount year causes the present value of effects to fall less than proportionally to the reduction in the present value of costs, resulting in a lower ICER. Consequently, both shifting a single cohort to a later period relative to the discount year and adding later cohorts to a CEA will not cause the ICER to fall under equal discounting, but will under differential discounting. Our analysis demonstrates the second of these two effects.

We have highlighted the consequences of a lower discount rate on health effects, which is appropriate if the threshold is growing, as the discount differential should approximate the annual growth rate of the threshold [14]. However, the threshold may not necessarily grow over time, even with an expanding health care budget, but may be static or fall [29]. A falling threshold would imply a larger discount rate for health than costs [30], resulting in increasing ICERs as more cohorts are included.

Relevance for practice and policy

The analysis reveals that the number of cohorts used in CEA can influence ICERs. To understand the practical significance of this result we have to consider current CEA practice. The current understanding of appropriate CEA model specification most likely does not account for the influence of varying numbers of cohorts. Consequently, without clear guidance on the matter, CEA practitioners are likely to continue specifying studies with the minimum number of cohorts they consider necessary. Interventions differ in their modeling requirements, and this will continue to result in the variety of models' specifications evident in reviews of modeling methodologies [24,31,32].

The concern is that arbitrary variation in CEA specifications leads to results which, in part, vary arbitrarily too. A related concern is that CEAs may be deliberately specified with large numbers of cohorts or large lags between the discount year and the start of the intervention to achieve low ICERs. We have focused on the issue of multiple cohorts rather than unnecessarily long lags between the discount year and implementation because the latter is more easily recognized as inappropriate manipulation of the CEA. Such arbitrary or strategically chosen variations can compromise comparability between studies. As a result, CEAs may not be adequately reflecting the policy choices they are intended to inform. These concerns are compounded by the probable lack of awareness among decision makers of the influence of CEA specifications on results. Decision makers may well continue comparing ICERs directly, without taking the different model specifications into account or checking whether they adequately reflect the relevant policy choice. Such direct comparisons could lead to incorrect policy choices, whereby an intervention is deemed cost-effective as it has a lower ICER than the threshold or an alternative intervention, but where this result is due to arbitrarily or strategically chosen differences in the CEA specification, rather than the intervention's actual implementation and inherent characteristics.

Naturally, these concerns lead to a consideration of how to avoid or reduce arbitrary variations between studies. For instance, one could prescribe a base-case specification that imposes a standard number of cohorts for all CEAs. However, given the wide variation of the characteristics and implementation of interventions, a standardized CEA specification may not adequately reflect these differences and, thus, result in meaningless comparisons. Therefore, if standardization is not possible, it is not yet clear how or if CEA practice can be adapted to avoid arbitrary variation between studies. Consequently, CEAs should be evaluated on an informed, case-by-case basis. Accordingly, it is appropri-

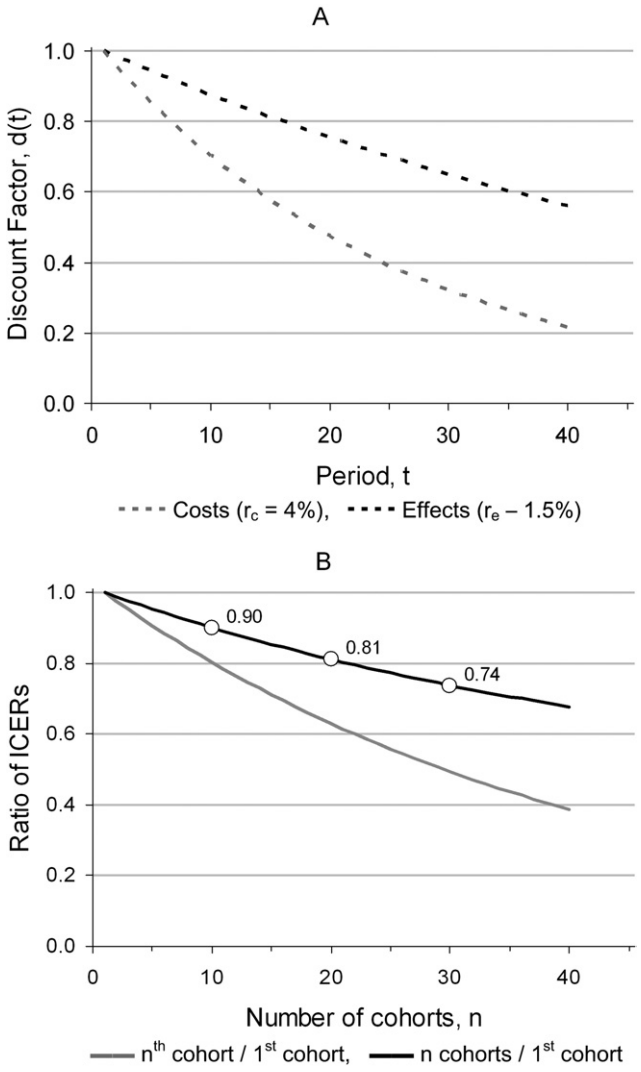

Fig. 2 – (A) Annual discount factors over time under discount rates of 4% and 1.5% for costs and effects respectively; (B) ratio of ICERs of the nth single cohort relative to the 1st single cohort at the discount year and the ratio of ICERs of a multi cohort model with n cohorts relative to the 1st single cohort under simplifying assumptions.

ate to demand a clear justification of the CEA specification from the CEA practitioner.

These questions of how to specify and interpret CEAs relate to doubts about the appropriateness of current CEA decision rules. A number of authors have indicated that ICERs are inappropriate for determining the optimal timing of interventions [2,33–35]. Counter-intuitive results arise under both equal and differential discounting. For example, decision makers choosing the period of implementation with the lowest ICER will prefer to (infinitely) postpone implementation under differential discounting (the postponing paradox) [3], whereas, unrealistically, they should be indifferent between immediate implementation or infinite postponement under equal discounting. While both these results are difficult to defend, it is the postponing paradox that has generated debate in the literature. The postponing paradox has been dismissed as irrelevant to actual policy choices [6]. Indeed, when using a threshold-based decision rule, any postponement will not be infinite, but until the ICER falls below the threshold.

While the relevance of the postponing paradox to actual policy choices is disputed, our results show that interventions modeled with a greater proportion of their implementation in the future have the advantage of lower ICERs. In this context, Cohen's [34] questioning of the appropriateness of current decision rules to health care services that exhaust their budgets annually without saving a surplus may be relevant. He commented that using CEA to compare interventions over multiple periods implies that cohorts compete for resources that are fungible across periods, whereas it might be more appropriate to use CEA to compare cohorts competing for resources within periods. Consequently, the debate over differential discounting and the implications for comparisons between studies may prompt a broader reconsideration of policy decision rules and the economic evaluation of health care.

Recommendations for CEA practice

The aim of this study is to promote awareness of the effects of alternative CEA specifications under differential discounting among CEA practitioners and decision makers. We hope CEA advisory bodies will recognize the significance of the findings presented here and reflect it in their guidance, for example: 1) require a justification of the CEA's specification; and 2) provide guidance to decision makers regarding the influence of the number of cohorts included. Such clarity is important, as confusion regarding the validity of comparisons between analyses can only serve to damage CEA's credibility with decision makers and others. Note that the issues raised in this article should not be interpreted as arguments against differential discounting; rather they should be understood as a call for greater understanding of its practical implications. CEA authorities considering adopting differential discounting should consider these practical implications in addition to the theoretical arguments. CEA practitioners and decision makers in countries already using differential discounting would benefit from recognizing its implications to ensure best practice and correct policy choices.

Limitations and further research

We emphasize that this article does not provide a complete discussion of the methodological implications of differential discounting. Such a discussion would require a detailed review of the underlying theoretical basis for comparing interventions across different time periods with a changing threshold, which is beyond the scope of this study. This remains an important area for future research and debate; see Claxton et al. [14] for further discussion. However, this study does call attention to some important practical issues related to differential discounting that both analysts and policy makers need to be aware of when using and comparing the results of cost-effectiveness analyses in practice.

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