Discounting and the Evaluation of Health Care Programs

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EXECUTIVE SUMMARY

CADTH's current recommendation for the discount rate to use in the economic evaluation of health technologies is 5% per annum for both costs and outcomes. This is substantially higher than the discount rate used by equivalent organizations in other economically developed countries. This report reviews the theoretical and empirical evidence for the appropriate discount rate for use in Canada, to inform the deliberations of CADTH and the advisors in developing the 4th Edition of the Guidelines for the Economic Evaluation of Health Technologies: Canada.

Since the publication of the 3rd Edition of the Guidelines, there has emerged an academic consensus that the choice of discount rate depends upon the perspective on social choice adopted by decision makers. Broadly, a welfarist or extra-welfarist perspective leads to the use the social rate of time preference for consumption as the appropriate discount rate, whilst a social decision making perspective supports the use of the real cost of borrowing as the appropriate source of the discount rate for costs, with adjustment for the rate of growth in the cost-effectiveness threshold required for the discount rate for outcomes.

The specification of the social rate of time preference for Canada requires evidence on: (a) the growth rate of per capita consumption; (b) the elasticity of the marginal utility of consumption; (c) the social catastrophe risk; and (d) the social rate of pure time preference for consumption. Whilst there is robust evidence for the first of these in Canada, the evidence for the remaining three parameters is either of poor quality, highly uncertain, or absent.

The specification of the discount rate under a social decision making perspective requires data on: (a) the real rate of interest faced by the health care funders; and (b) the rate of growth in the cost-effectiveness threshold of the health system. Robust evidence is provided on the former parameter, but there is currently no empirical estimate of the rate of growth in the cost-effectiveness threshold for any of the provincial or territorial health systems in Canada.

Under either social choice perspective, the available evidence indicates that the current discount rate of 5% is likely to be substantially higher than the theoretically correct rate. However, the evidence required to fully specify the discount rate for use in Canada is not available and therefore any recommended discount rate will have to be based in part on judgments. Specifically, a judgment will have to be made as to the most appropriate perspective on social choice to be assumed for economic evaluations of health technologies in Canada, and subsequently judgments will be required as to defensible estimates of the parameters for which there is no direct evidence.

INTRODUCTION

The 3rd Edition of CADTH's Guidelines for the Economic Evaluation of Health Technologies: Canada stipulates that both costs and health outcomes should be discounted at 5% per annum.[1] It also recommends that a sensitivity analysis using a discount rate of 0% be provided to illustrate the impact of discounting on the results of the evaluation.

CADTH's recommended discount rate is high compared to discount rates used by comparable agencies in other developed economies. For example, the National Institute for Health and Care Excellence (NICE) in the United Kingdom has recommended a discount rate of 3.5% for both costs and health outcomes since 2004, while Gold *et al.* (2006) recommended that 3% be used as the reference case rate for US cost-effectiveness analyses.[2,3] The Institut für Qualität und Wirtschaftlichkeit im Gesundheitswesen (IQWiG) in Germany has recommended a 3% discount rate since 2009, while the Haute Autorité de Santé (HAS) in France has recommended a slightly higher rate of 4% since 2005.[4,5]

Since publication of the current CADTH guidance in 2006, there has been significant progress in the elucidation of the underlying theoretical frameworks for characterizing and quantifying the discount rate. Collaborations between health economists in the UK, the Netherlands and Canada have moved a previously adversarial and contentious debate on, such that there is now considerable agreement regarding the principles that should guide decision makers' choice of discount rate.

The objectives of this report are to provide the CADTH Health Economics Working Group with an accessible overview of the alternative models for identifying the discount rate for use in economic evaluation, and to provide empirical evidence to support the estimation of the discount rate for Canada under each model. To this end, the remainder of this report is structured as follows:

- Section 1 briefly summarizes the concepts of personal and social time preference, the alternative perspectives that can be adopted for social choice (notably 'welfarist', 'extra-welfarist' and 'social decision making'), and introduces the Ramsey equation as a means for estimating the social rate of time preference for consumption. This section also highlights the important role of changes in the value of the shadow price of the budget constraint in determining the appropriate discount rate when the decision maker is faced with a constrained budget.
- Section 2 reports the findings of a review of the literature conducted to find empirical evidence to support the estimation of the social rate of time preference for consumption for Canada. Such an estimate may inform estimates of the discount rate under a 'welfarist' or 'extra-welfarist' perspective on social choice.
- Section 3 presents a quantitative analysis of the real cost of government borrowing for Canadian provinces, which would be required to inform estimates of the discount rate under a 'social decision making' perspective on social choice.
- Section 4 provides a summary of the theoretical and empirical evidence to support the specification of a reference case discount rate for CADTH's updated economic evaluation guidelines.

1. TIME PREFERENCE AND MODELS OF SOCIAL CHOICE IN HEALTH CARE

Discounting is concerned with taking account of the observed difference in the value attached to otherwise equivalent payoffs according to when those payoffs are received. This variation in preferences over time is a reflection of a number of factors:

1. *Decreasing marginal utility of consumption*, which means that marginal increases in future consumption are valued less as real incomes increase over time.
2. *Catastrophic risk*, which raises the possibility that future expected utility may not be realized. For an individual, the most obvious catastrophic risk is death. For a society, catastrophe risk arises not from individual deaths but from large scale disasters. Since such events are typically far less common than individual deaths, the catastrophe risk facing societies is smaller than that facing individuals.
3. *Pure time preference*, which reflects an underlying impatience and a desire to receive payoffs earlier rather than later. Some have argued that this is a 'myopic' preference that should not be taken into account by social decision makers; however, if individuals are genuinely myopic then the normative justification for excluding these preferences in social decision making is not obvious.

The direct translation of the individual model of discounting to a model of social time preference is quite straightforward. There is an opportunity cost associated with government utilization of resources, as it crowds out the use of those same resources by the private sector. Public funding of activities is efficient if the benefits exceed the benefits of their use in the private sector – this is called the marginal social opportunity cost (MSOC). The MSOC is approximated by the pre-tax return on zero-risk investments. As governments typically have a very low risk of bankruptcy, the return on a zero-risk investment is approximated by the real rate of interest on government bonds (gilts).

If governments wish to maximize the value of consumption over time, it is reasonable to assume that there is diminishing marginal utility of consumption over time at the societal level if real incomes are increasing.

Catastrophe risk is concerned with the risk of an event that would stop future payoffs from being realized. The types of events that stop societies from receiving expected future payoffs from current expenditures are extremely rare, but they do occur occasionally. These include earthquakes, tsunamis, volcanic eruptions, and other disasters, both natural and man-made. Since the risk of catastrophe is small but positive, the discount rate for social investments should include a component reflecting this reality.

Whilst we observe pure time preference in individuals' decision making, for a social decision maker to choose to incorporate a pure time preference is a normative decision, with equity implications. A number of philosophers, including Bentham, Hulme, Pigou and most recently Rawls, have argued that governments have a moral duty to give equal weight to the impact of expenditure on current and future generations. Logically, if we exclude pure time preferences, then (all else equal) social time preferences will be lower than private individual time preferences. However, this does not represent an argument against discounting on the societal level *per se*, since a positive discount rate is still required to account for diminishing marginal utility of consumption and catastrophe risk.

1.1 The Ramsey Specification of the Social Rate of Time Preference for Consumption

The standard economic model for the social rate of time preference for consumption is provided by the Ramsey equation:

$$\mu g + L + \delta \qquad (2.1)$$

where:

μ = Elasticity of the marginal utility of consumption
g = Consumption growth rate
L = Catastrophe risk
δ = Pure time preference

The elasticity of the marginal utility of consumption and the consumption growth rate are empirically measurable. We return to empirical estimates of this component in the next section.

There has been extensive discussion on the appropriate value for the catastrophe risk component in relation to the analyses by the International Panel on Climate Change.[6-9] Stern and colleagues assumed a rate of 0.1% without citing any empirical research to support this assumption. There are some empirical estimates of the risk of specific catastrophic events, but their magnitude varies substantially. For example, the risk of an extinction-level asteroid impact in the next 100 years has been estimated to be around one in 1 million (or 1/10,000th of 1%);[10,11] whilst the risk of a major earthquake (8.0 or higher on the Richter scale) hitting San Francisco in the next 30 years has been reported as 7%.[12] Given the geographical scale of provinces and territories in Canada, the use of catastrophe risk estimates for tightly defined geographical areas may not be appropriate since the destruction of a city (for example) is unlikely to entirely remove the provincial or national ability to receive the future payoffs of current investments in health care.

The Stern review also generated extensive discussion of the appropriate choice of pure time preference (which it referred to as “inherent time preference”). The review took the normative position that governments should value all generations equally, a position that was endorsed by many leading economists, including Solow, Stiglitz, Sen and Sachs. However, other economists argued that the divergence between the Stern discount rate and market interest rates was evidence of a flaw in Stern’s work. Nordhaus undertook one of the more substantial analytic critiques of Stern’s work, arguing that the appropriate specification of the problem was that governments act as infinitely lived economic agents, thus removing the normative issue of inter-generational equity.[13] Nordhaus’ approach also assumed that the capital markets endogenise all relevant information in determining the appropriate rate of interest for government bonds. Given the performance of the capital markets in assessing the risk of complex financial products prior to the 2007-08 global financial crisis, this assumption may be less convincing than it was at the time of the Stern review’s publication. There is no clear consensus in the policy or academic debate on the appropriate specification of the pure time preference component of the social rate of time preference for consumption to guide the Working Group’s discussions. Whilst coherence with the Stern review may be regarded as desirable, it would appear unsatisfactory to justify a position on such an important normative issue solely on the basis of an ‘appeal to authority’.

1.2 Alternative Perspectives on Social Choice

Since the early 1990s, there has been an ongoing academic debate in the health economics literature on whether costs and outcomes should be discounted at a common rate or at different rates. In 2004, NICE changed its guidance from allowing differential discounting to a reference case requirement that both costs and outcomes be discounted at a common rate of 3.5% per

annum.[14] An academic team from the Netherlands, led by Werner Brouwer, subsequently critiqued this decision.[15] In response, Karl Claxton and the other primary authors of the NICE guidance published an explanation of the change in practice.[16] The Dutch team then joined with Hugh Gravelle to provide a more detailed and theoretically grounded critique of common discount rates for costs and outcomes in health.[17]

Whilst other health economists have contributed to the debate on the appropriate discount rate for economic evaluations in health care, the groups clustered around Brouwer and Claxton have been the key contributors over the last decade. In 2011 the two groups published a joint paper that sought to provide a clear account of their competing approaches, the assumptions that underpinned their differences, and the implications for real world practice.[18] This paper provides a consensus which recognizes that the appropriate approach to discounting depends upon the perspective on social choice that the decision maker is assumed to be operating under, and whether or not the health care budget is assumed to be constrained.

Two broad perspectives on social choice are considered:

1. 'Welfarism' or 'extra-welfarism'. Welfarism is the perspective that underpins neo-classical economics. It assumes that rational individuals seek to maximize their individual utility by ranking available options and then choosing between them based upon their preferences. Only individuals can judge their utility maximizing choices, and utility is the only outcome considered. Social welfare is simply an aggregation of individual utilities. Extra-welfarism is very similar to welfarism – individual preferences remain paramount; however, the definition of social welfare is expanded to consider factors such as equity, individual characteristics and 'capabilities'. A criticism of welfarism and extra-welfarism is that the determination of social welfare requires the expression of an explicit 'social welfare function', and it is not apparent how this can be achieved while maintaining political legitimacy.[19,20]
2. 'Social decision making'. This perspective assumes that the health care decision maker is charged by a socially legitimate higher authority (such as an elected parliament or legislative assembly) with pursuing an explicit policy objective (such as improving health outcomes).[21] The higher authority allocates resources for the decision maker to use in pursuit of this objective. The decision maker seeks to maximize the degree to which the objective is achieved given the available resources. Under this perspective, an explicit social welfare function is not required; rather, the policy objective and resources provided by the higher authority are a partial expression of an underlying, latent social welfare function. The legitimacy of this particular social welfare function rests upon the legitimacy of the democratic process used to determine the objective and allocate resources.

In addition to identifying the perspective on social choice as a key determinant of the appropriate discount rate, the consensus paper highlighted the importance of understanding whether the decision maker's budget is constrained or unconstrained. A budget is considered unconstrained if the additional cost of the investment falls upon the other sectors of public expenditure or the taxpayer.

If the decision maker is operating with a constrained budget, the additional cost of a new investment falls upon the decision maker's budget, thus other health care interventions will be foregone or displaced. Since these interventions would have contributed towards satisfying the higher authority's objective, their displacement has an *opportunity cost*. This opportunity cost is represented by the *cost-effectiveness threshold*. In practice, it is difficult, if not impossible, to observe what gets displaced following an investment, so the opportunity cost is difficult to estimate. Given this difficulty, researchers are exploring empirical approaches to estimating the

opportunity cost. Since the threshold represents the change in output associated with a marginal change in the health system budget, recent empirical efforts in the UK have concentrated upon estimating the health system's production function.[22] Similar work has yet to be undertaken in Canada.

The consensus paper differentiated between decision makers by their perspective on social choice and whether they are operating under a constrained or unconstrained budget, and demonstrated the following determinants of discount rates:

- For a decision maker operating with a *welfarist or extra-welfarist* perspective and an *unconstrained* budget, where the objective is to maximize the present consumption value of population health, incremental costs should be discounted at the social rate of time preference for *consumption*. Incremental health outcomes should be discounted at the social rate of time preference for *consumption* minus the expected growth rate of the *consumption value of health*. Differential discounting is therefore appropriate if and only if the *consumption value of health* is changing over time.
- For a decision maker operating with a *welfarist or extra-welfarist* perspective and a *constrained* budget, where the objective is to maximize the present consumption value of population health, incremental costs should be discounted at the social rate of time preference for *consumption*, minus the expected growth rate of the *consumption value of health*, plus the expected growth rate of the *cost-effectiveness threshold*. Incremental health outcomes should be discounted at the social rate of time preference for *consumption* minus the expected growth rate of the *consumption value of health*. Differential discounting is therefore appropriate if and only if the *cost-effectiveness threshold* is changing over time.
- For a decision maker operating with a *social decision making* perspective and a *constrained* budget, where the objective is to maximize the present value of population health, incremental costs should be discounted at the social rate of time preference for *health* plus the expected growth rate of the *cost-effectiveness threshold*. Incremental health outcomes should be discounted at the social rate of time preference for *health*. Differential discounting is therefore appropriate if and only if the *cost-effectiveness threshold* is changing over time.

In 2012, Paulden and Claxton set out a theoretical framework for identifying the social rate of time preference for *health*, founded in the framework of social decision making rather than conventional welfare or extra-welfarist economics. They demonstrated that this is equal to the *real interest rate* faced by the higher authority minus the growth rate of the *cost-effectiveness threshold*. It follows that the discount rates described above for a decision maker operating with a *social decision making* perspective and a *constrained* budget may be restated as follows:

- For a decision maker operating with a *social decision making* perspective and a *constrained* budget, where the objective is to maximize the present value of population health, incremental costs should be discounted at the *real interest rate* faced by the higher authority. Incremental health outcomes should be discounted at the *real interest rate* faced by the higher authority minus the growth rate of the *cost-effectiveness threshold*. As before, differential discounting is appropriate if and only if the *cost-effectiveness threshold* is changing over time.

If the budget is constrained, it is important to be specific about the assumed rate of growth in the cost-effectiveness threshold. As observed above, the cost-effectiveness threshold – and, by extension, its rate of growth – is very difficult to estimate. In order to support judgements about the current rate of growth in Canada it may be useful to understand the key factors that impact upon the cost-effectiveness threshold.

Under the assumption that the budget of the health care system is constrained, Figure 1 summarizes the impact on the cost-effectiveness threshold of unilateral changes in: (a) the health care budget; (b) the efficiency of marginal technologies; and (c) the utilization of existing non-marginal health care services. The impact of these three factors is as follows:

- If the budget increases in real terms, whilst the efficiency and utilization remain unchanged, this will increase the cost-effectiveness threshold – i.e. less efficient technologies (with a higher incremental cost-effectiveness ratio) are now cost-effective. If the real terms budget decreases, with efficiency and utilization unchanged, the cost-effectiveness threshold will decrease, and hence new technologies will have to be more efficient to be cost-effective.
- If the marginal efficiency of the health system improves, whilst the budget and utilization remain unchanged, resources are released that can be used to fund new technologies, however, the choice of which technology to adopt will reference the improved efficiency of the health system and thus a lower cost-effectiveness threshold will apply. Conversely, if the system becomes marginally less efficient, with budget and utilization remaining unchanged, the cost-effectiveness threshold will increase.
- If utilization of non-marginal services increases, whilst the budget and efficiency remain unchanged, then the cost-effectiveness threshold will fall, as expansion in the utilization of more efficient interventions will crowd out less efficient interventions. By contrast, if utilization decreases, this will release funds that can be allocated to funding less efficient currently unfunded interventions, hence the cost-effectiveness threshold will rise.

In reality, all of these factors may be changing at once, making it more complex to identify a credible scenario for the direction of change in the cost-effectiveness threshold. Historically, health budgets have tended to increase in real terms, but there is certainly political pressure to stop this trend. Given the strong causal relationship between age and health care utilization, health systems serving ageing populations should expect increased utilization over time. As part of the pressure to curtail the growth in health care budgets, programmes such as Choosing Wisely and the Triple Aim are pushing to improve the efficiency of health care provision in Canada.[23,24] Deciding upon a specific assumption about the rate of change in the cost-effectiveness threshold requires a judgment to be made about whether improvements in efficiency and/or growth in the real terms health care budget will compensate for the impact of increased utilization.

FIGURE 1: COMPARATIVE STATICS OF DETERMINANTS OF CHANGE IN THE COST-EFFECTIVENESS THRESHOLD

Budget	Efficiency	Utilization	CE Threshold
↑	=	=	↑
↓	=	=	↓
=	↑	=	↓
=	↓	=	↑
=	=	↑	↓
=	=	↓	↑

2. ESTIMATING THE SOCIAL RATE OF TIME PREFERENCE FOR CANADA: A REVIEW OF THE LITERATURE

As described in the previous section, under a *welfarist* or *extra-welfarist* perspective on social choice, the discount rate is dependent upon the social rate of time preference for consumption. A common means of estimating this is via the Ramsey equation, which requires estimates of the following four parameters:

- The social rate of catastrophe risk;
- The social rate of pure time preference;
- The elasticity of the marginal utility of consumption; and
- The growth rate of real consumption per capita.

In this section we report a review of the economics literature which was undertaken to identify papers that might provide evidence to support Canadian estimates of each of these parameters, with a view to constructing a Canadian estimate of the social rate of time preference for consumption.

2.1 Methods

We developed a search strategy that addressed each component of the Ramsey equation separately. The exception to this was real per capita consumption growth, as this statistic is reported annually by Statistics Canada, obviating the need to find estimates in the published literature.[25] We developed an additional search strategy that was focused on papers dealing with "time preference" generally and/or the "social rate of time preference" specifically.

We searched the EBSCO, EconLit and University of Alberta databases. The searches were undertaken in April 2015, and covered publications since 1965. The search strategy is reported in Appendix A.

Papers were excluded from the review if: (a) they were written in a language other than English or French; (b) neither the title nor abstract contained any of the key words from the search strategy; (c) the title did not contain any of the key words from the search strategy and there was no abstract; and/or (d) if they were duplicates of other papers already identified. Abstracts were reviewed for eligibility by two of the authors independently (CM and SC). Discordance between these two reviewers was resolved through discussion. If consensus could not be reached through discussion, the paper would be retained for full review.

A data extraction form was developed for use with all papers deemed to be eligible for inclusion. Three of the authors (SC, BK and MP) then reviewed the papers and completed the data extraction forms. Each reviewer considered a different set of papers. The data extraction tables for all the papers are reported in Appendix B.

For each paper, a brief summary was made of its purpose. Consideration was then given as to whether the paper specifically addressed any of the parameters of the Ramsey equation. For papers that addressed specific parameters in the Ramsey equation, the methods and findings were summarized, the findings were categorized as Canada-specific or not, and the relevance to parameterizing the Ramsey equation was noted.

2.2 Results

Figure 2 presents a flow diagram analogous to the PRISMA flow diagram for systematic reviews. The search strategy (Appendix A) identified 649 papers. After the application of inclusion and exclusion criteria to the published abstracts, 55 papers were identified for full review.[8,18,26-78] Of these, 40 papers specifically addressed one or more components of the Ramsey equation, with 10 papers reporting specific findings that might aid in parameterizing the Ramsey equation.[33,37,41,45-48,55,58,73] Of these 10 papers, four reported findings specific to Canada.[33,37,47,55] Below we provide a narrative summary for the evidence on each component of the Ramsey equation.

2.2.1 The social rate of catastrophe risk

Schad & John (2012) considered that societal catastrophe risk must lie somewhere in the range between zero and 1%, since a typical individual's annual risk of catastrophe (death) is approximately 1% and the societal rate must be lower than this.[73] Although this range was not specific to Canada, Canadian life tables imply that the annual risk of death for males increases with age, from approximately 0.01% between ages four to 12, to 1% at age 63, to greater than 10% at age 87 (for females the 1% and 10% thresholds are met at ages 68 and 90 respectively).[79] Kula (1984), one of the four papers which reported Canada-specific results, used an estimate of individual catastrophe risk of 1% per annum to derive a social rate of time preference for consumption for Canada, without consideration as to whether an individual risk of catastrophe was appropriate for societal decision making.[55] None of the other papers reviewed provided estimates of catastrophe risk.

2.2.2 The social rate of pure time preference

Cline (1993) argued that there is a "strong tradition among economists" to set the pure time preference rate at zero, while Liu (2012) used modelling techniques to infer that "a value of [pure time preference] significantly larger than zero… is extremely unlikely".[41,58] In a book edited by Burgess & Jenkins (2010), Michael Spackman noted that, while some authors have argued for a zero rate of pure time preference, there "may be some consensus" among contemporary authors for a rate of pure time preference of "around 1.5% per year".[37] Although not Canadian-specific, each of these findings has relevance to the debate in Canada. In one of the four Canadian-focused papers, Boardman *et al.* (2008) cited Arrow *et al.* (1996) in support of a 1% per annum rate of pure time preference; however, while Arrow and colleagues made a case against a zero rate of pure time preference on the basis that this would imply a disproportionately high savings rate, they do not appear to have provided evidence in support of a 1% rate.[33,80]

2.2.3 The elasticity of the marginal utility of consumption

Spackman found that estimates of the elasticity of the marginal utility of consumption vary by estimation approach and by country.[37] Among numerous other studies, he cited Kula's (1984) estimate of 1.56 for Canada.[55] He also cited Scott & Dowley's (1977) intuition that the elasticity must exceed 1 above some income level.[81] Further Canadian estimates were provided by Boardman et al. (2008) [1.5] and Evans (2005) [1.25 for average income and 1.30 for high income].[33,47]

2.2.4 The growth rate of real consumption per capita

Although not the focus of our search (due to the existence of recent and reliable data from Statistics Canada), a number of papers reported estimates of the growth rate of real per capita consumption. Boardman et al. (2008) provided an estimate for Canada of 1.7%.[33] Kula (1984) assumed that Canadian consumption growth was 2.8% per annum, although this estimate is

now dated.[55] Schad & John estimated that consumption growth was 1.4% to 1.8% per annum, while Cline argued that long-term growth (over 300 years) cannot exceed 1%, although neither of these estimates was specific to Canada.

2.3 Summary

Our search identified only four papers that provided Canadian estimates of the parameters of the Ramsey equation. As a result, a social rate of time preference for consumption for Canada is difficult to estimate with any precision.

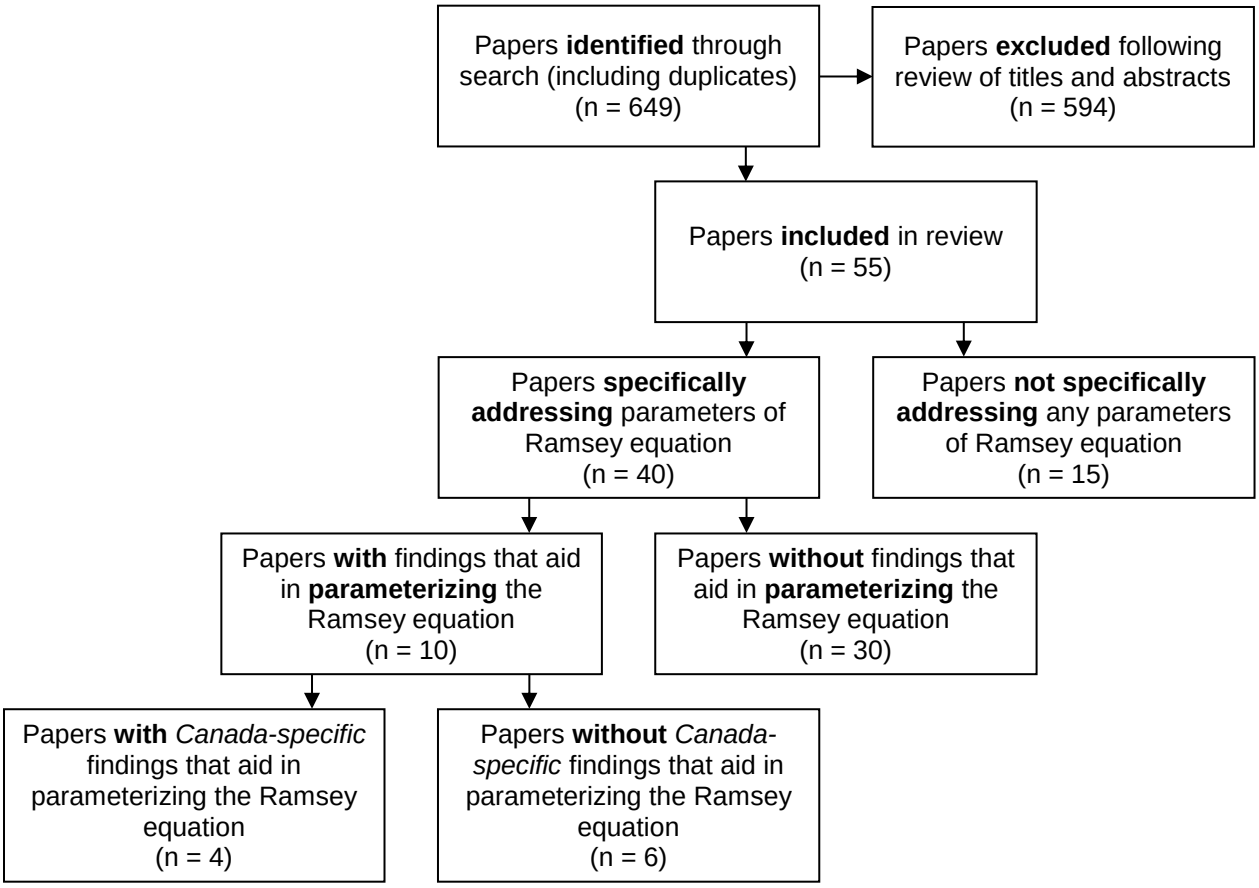
We identified two papers that attempted to estimate a social rate of time preference for consumption for Canada. Kula (1984) assumed that social time preferences could be inferred by estimating the time preferences of a "representative individual"; as a result, the estimate of "catastrophe risk" of 1% was a clear overestimate since it was based upon individual mortality risk rather than societal catastrophe risk.[55] Kula also adopted a relatively high estimate of consumption growth (by today's standards) of 2.8% per annum. The effect of both of these overestimates was to inflate the implied social rate of time preference for consumption, such that Kula's overall finding is not credible. Boardman et al. (2009) also assumed a 1% catastrophe risk; the authors cited Arrow et al. (1996) in support of this assumption, but the cited paper does not appear to provide adequate justification for this.

An accurate estimate of the social rate of time preference for consumption requires the following:

- An estimate of the catastrophe risk facing *society*, rather than individuals. The economics literature is sparse on this issue. Future reviews may wish to consider a broader literature; the bibliography provided by the Global Catastrophic Risk Institute may provide for a useful starting point for such work.[82]
- A consensus as to whether or not the rate of *pure* time preference for society ought to be zero.
- Consideration as to the correct approach for estimating the elasticity of the marginal utility of consumption. The review by Spackman identified a wide range of possible estimates of this elasticity, depending upon the approach adopted.[37] Very little guidance was provided, however, as to which approach to use.
- An estimate of real per capita consumption growth.

The most recent estimate of real per capita consumption growth from Statistics Canada is 1.79% per annum (CANSIM, table 380-0064, "final consumption expenditure", Q1 2014 to Q1 2015).[25] However, until each of the first three bullet points above has been resolved, any estimate of the social rate of time preference for consumption for Canada remains highly speculative.

FIGURE 2: FLOW DIAGRAM FOR THE REVIEW



3. THE REAL COST OF BORROWING FOR CANADIAN PROVINCES

If a *social decision making* perspective is adopted, then determining appropriate discount rates requires estimation of the real interest rate faced by the higher authority that funds the health system in question.

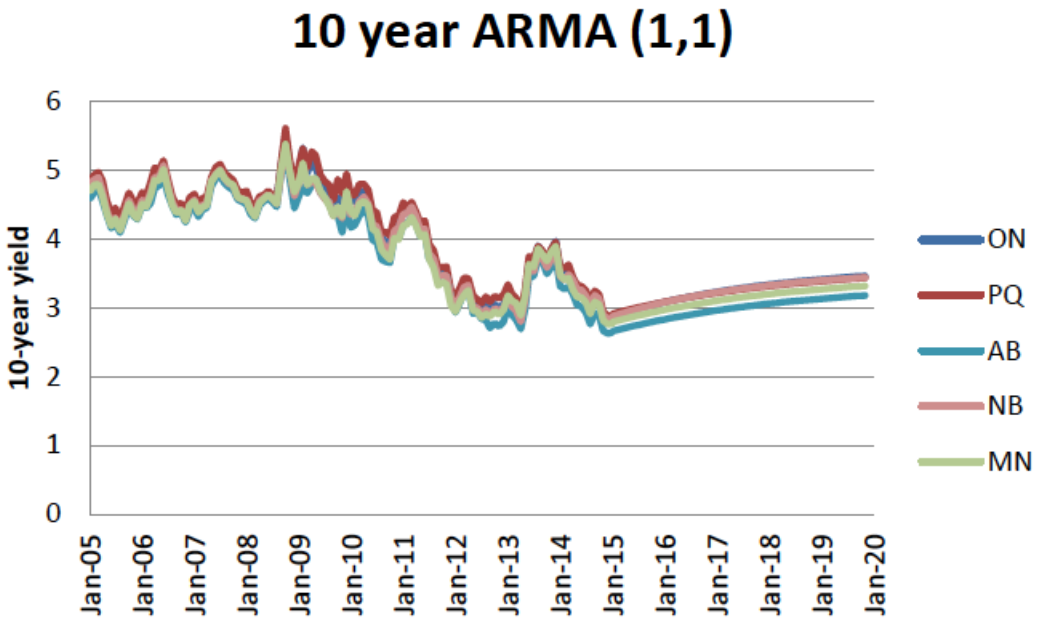
In Canada, the majority of health system funding is provided by provincial governments. Therefore the appropriate discount rates to adopt in each provincial health system depend upon the real interest rates (i.e. the real cost of borrowing) faced by the provincial government in question.

To estimate the real cost of borrowing faced by provincial governments, we estimated provincial bond yield curves for each Canadian province. A provincial bond yield curve summarizes the cost of borrowing for the province as a function of the length of its debt obligation. This cost varies with the economic conditions. For example, for Ontario the annual interest on a debt of $100 million Canadian dollars, to be repaid in full after five years, was 2.83% in December 2014, but 4.36% 10 years earlier. These interest rates correspond to a final payout of approximatively 115.01 and 123.8 million dollars respectively. Put differently, in December 2014 the market appeared to discount a five-year maturity payout of about 115 million Canadian dollars (CAD) to a current value of 100 million CAD. Ten years earlier, Ontario had to guarantee a payoff of about 123.8 million CAD to borrow 100 million CAD for five years.

3.1 Forecasting Yields with Auto-Regressive Models

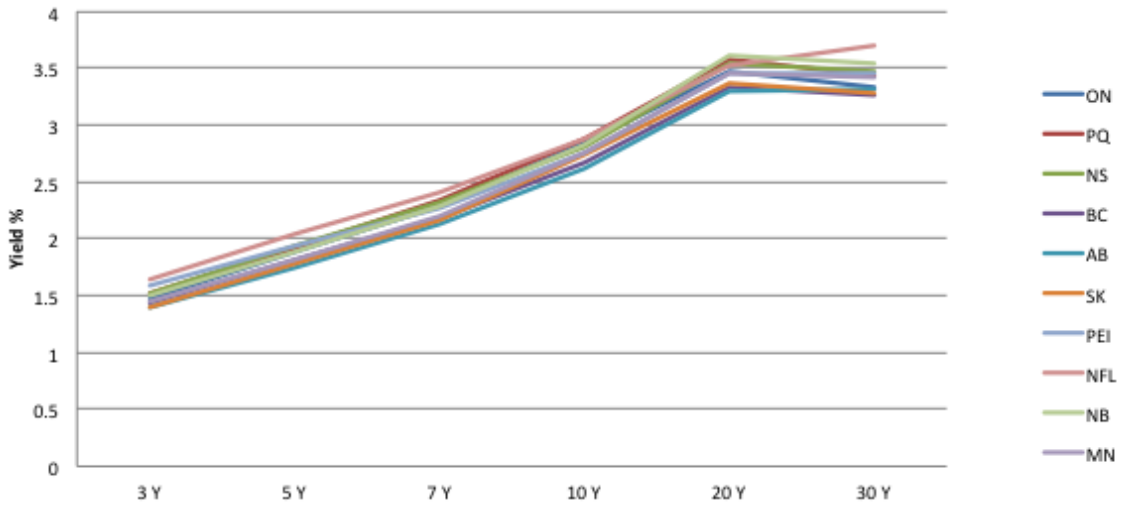
We employ the simplest possible Auto-Regressive with Moving Average model (ARMA), which is the ARMA (1,1). In this model the yield level is assumed to be a linear function of its lagged value and it is subject to normally distributed shocks that, in turn, depend on the magnitude of shock that occurred in the preceding period (the preceding month for our sample). The model fits the data well and produces reasonable forecasts of yields.

FIGURE 3: TEN-YEAR ARMA MODEL OF PROVINCIAL BOND YIELDS



As bond yields refer to the return of the nominal value of the loan, the yields are nominal rate of returns, i.e. they are not adjusted for inflation. The use of the real interest rate or nominal interest rate can have an important effect when the nominal rates are low and inflation is at its long-term level. In practice, the difference can be up to 2 percentage points, a gap that, for long-term liabilities, entails substantially different repayment obligations. Figure 4 plots the provincial nominal yield curves.

FIGURE 4: NOMINAL PROVINCIAL BOND YIELD CURVES



The series of monthly values of inflation for the provinces are highly seasonal, very volatile, and often display negative values. Statistics Canada does not release seasonally adjusted CPI for the provinces. Modelling inflation explicitly adds another layer of complexity to the valuation of future payoffs. However, inflation is one component of future nominal payoffs that we would be wrong to ignore. A simple solution is to model future inflation using the official inflation target of Bank of Canada, which is 2%.[83] This is also the approach adopted by the US Office of Management and Budget, among other institutional entities. Once a forecast for inflation is identified, the present value of a cash flow that is expressed in real terms can be calculated using real, rather than nominal, yields. Real yields are obtained by subtracting the forecasted inflation from the nominal yields. Figure 5 and Figure 6 plot the real provincial yield curves for each province based upon provincial inflation data and the Bank of Canada inflation target respectively.

FIGURE 5: REAL PROVINCIAL BOND YIELD CURVES – 2015 ARMA INFLATION FORECAST

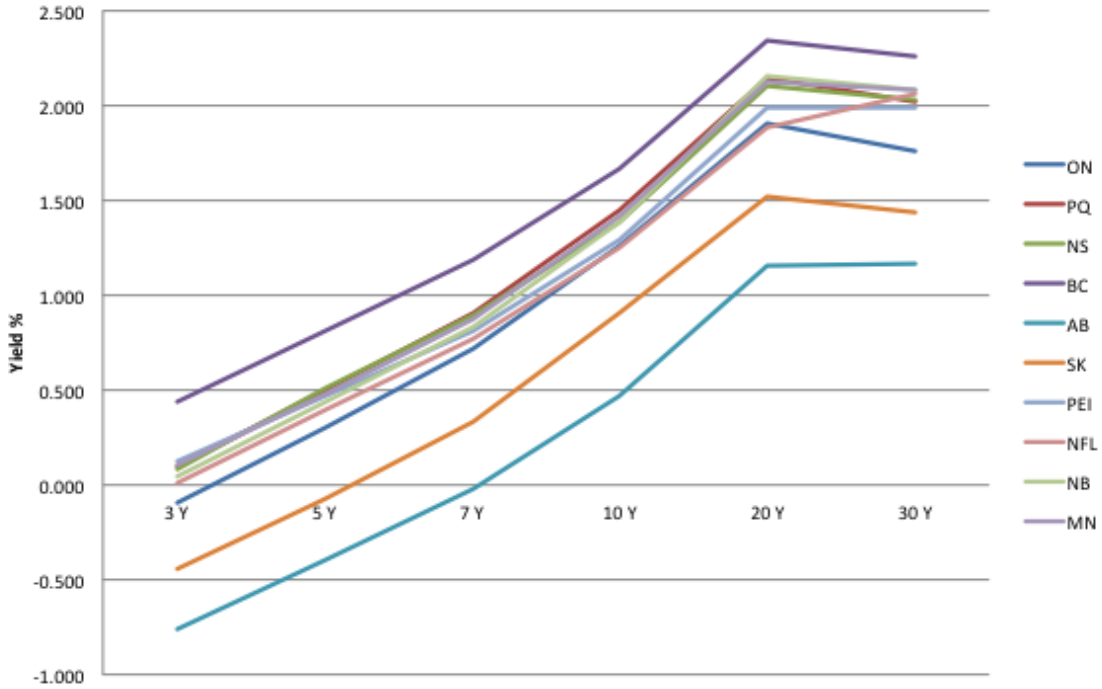


TABLE 1: REAL PROVINCIAL BOND YIELDS – 2015 ARMA INFLATION FORECAST

ARMA estimates of Inflation (See sheet "Inflation ARMA" for plot)												
	ON	PQ	NS	BC	AB	SK	PEI	NFL	NB	MN	Min	Max
3 Y	-0.097	0.098	0.083	0.439	-0.760	-0.442	0.121	0.008	0.046	0.106	-0.760	0.439
5 Y	0.307	0.499	0.513	0.815	-0.395	-0.068	0.470	0.399	0.435	0.481	-0.395	0.815
7 Y	0.724	0.910	0.895	1.190	-0.017	0.333	0.811	0.773	0.837	0.871	-0.017	1.190
10 Y	1.266	1.452	1.381	1.671	0.474	0.905	1.296	1.251	1.386	1.418	0.474	1.671
20 Y	1.906	2.151	2.108	2.339	1.155	1.522	1.991	1.890	2.159	2.126	1.155	2.339
30 Y	1.766	2.020	2.036	2.265	1.168	1.437	1.990	2.061	2.087	2.082	1.168	2.265

FIGURE 6: REAL PROVINCIAL BOND YIELD CURVES – BANK OF CANADA INFLATION TARGET

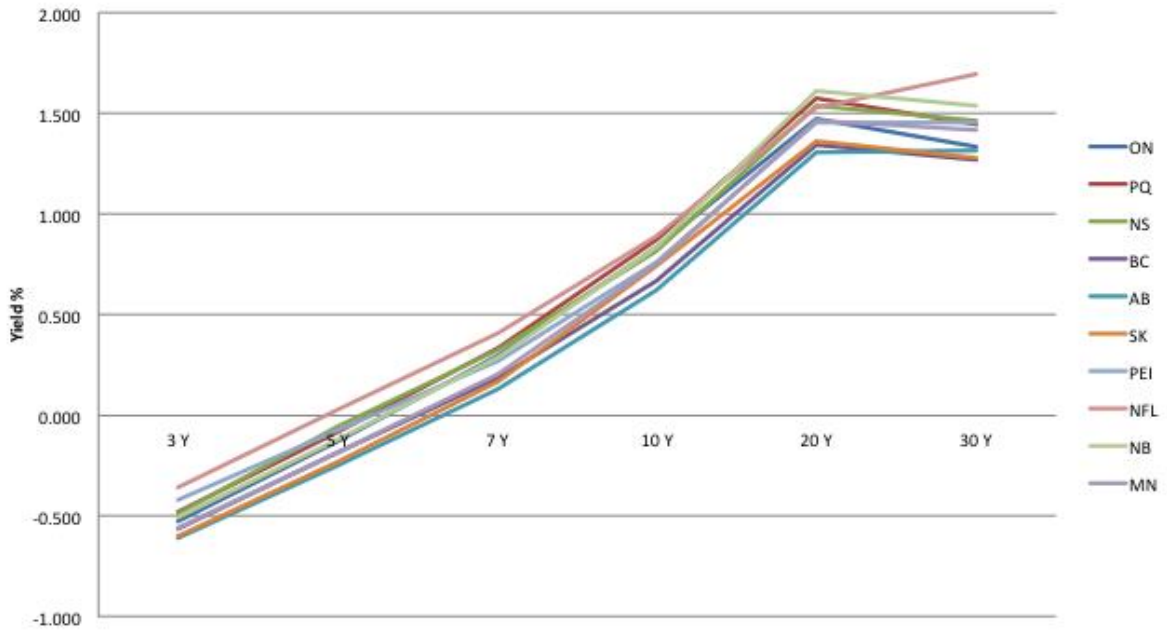


TABLE 2: REAL PROVINCIAL BOND YIELDS – BANK OF CANADA INFLATION TARGET

Bank of Canada												
	ON	PQ	NS	BC	AB	SK	PEI	NFL	NB	MN	Minimum	Maximum
3 Y	-0.526	-0.479	-0.486	-0.561	-0.610	-0.601	-0.418	-0.356	-0.504	-0.557	-0.610	-0.356
5 Y	-0.122	-0.078	-0.056	-0.185	-0.245	-0.227	-0.069	0.035	-0.115	-0.182	-0.245	0.035
7 Y	0.295	0.333	0.326	0.190	0.133	0.174	0.272	0.409	0.287	0.208	0.133	0.409
10 Y	0.837	0.875	0.812	0.671	0.624	0.746	0.757	0.887	0.836	0.755	0.624	0.887
20 Y	1.477	1.574	1.539	1.339	1.305	1.363	1.452	1.526	1.609	1.463	1.305	1.609
30 Y	1.337	1.443	1.467	1.265	1.318	1.278	1.451	1.697	1.537	1.419	1.265	1.697

The data for Figure 5 and Figure 6 are reported in Table 1 and Table 2.

.

3.2 Summary

Whilst the different methods for estimating inflation yield different results, the range of variation across the provinces is not radically changed by the choice of method when considered in the context of CADTH's current recommended discount rate of 5% per annum. All estimates are more than 3% lower than the current recommended rate.

Since inflation rates vary across time and across provinces, the 2015 ARMA inflation forecast provides a snapshot of inflation rates at the present time only. Meanwhile, the Bank of Canada has a long-term commitment to maintaining inflation at close to 2% per annum. The use of the Bank of Canada inflation forecast may therefore be considered the more appropriate measure of inflation for estimating real yields for long-term bonds.

Note that the estimates of real yields in Table 2 vary both across provinces and over the time to maturity. Since each province faces a different cost of borrowing, it follows that each province should (in principle) adopt different discount rates. However, given the similarity of rates across provinces and the administrative burden for CADTH of considering different rates for different provinces, it may be considered more practical for CADTH to adopt a common rate for all provinces.

The variation in the cost of borrowing for bonds with differing time to maturity is considerably more pronounced. For example, in Ontario the real cost of borrowing over three years is estimated to be -0.5% per annum, while the real cost of borrowing over 20 years is estimated to be 1.5% per annum. This implies that, in an economic evaluation conducted by CADTH, costs and health outcomes expected three years from now should (in principle) be discounted at a much lower annual rate than costs and health outcomes expected 20 years from now. Again, it may be considered more practical for CADTH to adopt a single fixed discount rate applicable to all years, but the biases introduced by this will likely be greater than those introduced by adopting a common discount rate across provinces.

If a social decision maker perspective is deemed to be appropriate, a pragmatic way forward might be for CADTH to adopt a non-constant discount rate that is common to all provinces. There is precedent for the use of a non-constant discount rate for the appraisal of cost-effectiveness analyses: since 1992, the US Office of Management and Budget, an executive office of the US President, has required that cost-effectiveness analyses of federal projects discount costs and benefits at a non-constant rate determined by "the real Treasury borrowing rate on marketable securities of comparable maturity to the period of analysis".[84] Each year the Office publishes a revised table of discount rates for analysts to use, with the most recent publication in December 2014.[85] In order to account for the differences in real interest rates for bonds of different maturities, the Office publishes discount rates corresponding to six specific time periods: three years, five years, seven years, 10 years, 20 years, and 30 years. For December 2014, the real interest rates on US Treasury bonds at each of these maturities were reported to be 0.1% at three years, 0.4% at five years, 0.7% at seven years, 0.9% at 10 years, 1.2% at 20 years and 1.4% at 30 years. In order to discount future costs and benefits that are expected at different times to those above, the Office recommends that analysts use "linear interpolation". For example, "a four-year project can be evaluated with a rate equal to the average of the three-year and five-year rates". The Office also recommends that "programs with durations longer than 30 years may use the 30-year interest rate".

For CADTH's purposes, the analogue to the real US Treasury bond rates published by the Office of Management and Budget are the real provincial bond yields reported in Table 2. A

pragmatic solution might be for CADTH to derive a weighted average of the provincial yields for each of the six time periods (with more populous provinces receiving a larger weight due to their greater health care expenditures) and adopt the same methodology as that used in the US (i.e. use linear interpolation for other years, and use the 30-year rate to discount costs and health outcomes expected beyond 30 years). In line with the US approach, CADTH could also publish revised estimates of discount rates each year, or whenever practicable. Such an approach would limit the administrative burden on CADTH and allow for a discounting methodology closely aligned with health economics theory. The technical burden of implementing such a time-varying discount rate in economic models is small, given the use of only six time periods with linear interpolation between these.

4. SUMMARY OF THEORETICAL AND EMPIRICAL EVIDENCE FOR CHOICE OF DISCOUNT RATE

Following an extensive and extended debate in the academic literature on the 'correct' approach to discounting in health care, there is now a degree of consensus regarding the determinants of the discount rate for a specific decision making context.

It is now accepted that the choice of discount rate depends upon: (a) the perspective on social choice adopted by the decision maker for whom an economic evaluation is designed to inform; and (b) whether the budget is considered to be constrained or unconstrained.

Welfarist and extra-welfarist perspectives lead to the social rate of time preference for consumption being the appropriate basis for the discount rate. Whilst there is agreement on which factors should be included in determining this, there is little Canadian evidence to inform three of the four parameters in the Ramsey equation, and extensive discordance regarding what would be defensible assumptions to use for both the rate of pure time preference and catastrophe risk. The choice of pure time preference rate is primarily a normative decision, with some philosophers and economists arguing that inter-generational equity requires that it be set at zero. However, there is no consensus on this point.

The UK Treasury claims to use the social rate of time preference for consumption as the basis for its 3.5% discount rate, which has been adopted by NICE since 2004.[86] However, it utilizes individual rather than social estimates of catastrophe risk and, as such, is almost certainly substantially inflated above its correct level.[87] This error was also made by Kula (1984) and Boardman et al. (2009) when producing estimates of the social rate of time preference for consumption for Canada.[33,55]

Adopting the social decision making perspective leads to the use of the real cost of borrowing being the appropriate determinant of the discount rate. This is implied by the real yield on government bonds, and can be estimated directly. We have shown that these estimates are substantially below CADTH's current recommended discount rate.

Another key factor is the rate of change in the cost-effectiveness threshold. Depending upon whether this is zero or not, the discount rate for incremental health outcomes must be discounted at the same or a different rate from incremental costs. However, the rate of growth in the threshold results from the interaction of a series of complex processes, is not directly observable, and has not, to date, been empirically estimated. Some judgement will therefore be

necessary to arrive at a recommendation for using the same or different discount rates for incremental costs and outcomes, and, if different, the magnitude of that difference.

4.1 Discussion

Our understanding of the appropriate methods for discounting in economic evaluations of health interventions has progressed substantially over the past decade. Since the consensus paper was published in 2011, which clarified the theoretical foundations for discounting and decision making under alternative perspectives on social choice, two further advancements have been made: a derivation of the social rate of time preference for health under a social decision making perspective, and the first real-world application of methods for estimating the cost-effectiveness threshold.[18,22,69]

However, there are substantial gaps to be addressed by future research. A critical component of discount rates within a budget constrained health care system (regardless of the perspective on social choice) is the expected growth rate of the cost-effectiveness threshold. To date, only one country (the UK) has invested in research to estimate the current cost-effectiveness threshold for its public health system.[22] To estimate the threshold *growth rate* requires that additional research be conducted so that estimates of the threshold may be projected over time. Until such work is completed in Canada, accurate estimates of discount rates cannot be derived and, perhaps more importantly, the true consequences (i.e. the opportunity cost) of adoption decisions based upon CADTH's recommendations remain unknown. (Until empirical estimates of cost-effectiveness thresholds are obtained for Canadian health care systems, CADTH will inevitably remain unaware about whether recommending a new technology will be expected to improve population health or damage it).

Other issues that require clarity are the perspective on social choice adopted by Canadian decision makers, and the appropriate assumptions to make concerning the fixity of health care budgets. Both have implications for the appropriate discount rates to adopt.

If a welfarist or extra-welfarist perspective is adopted, then research is required into the appropriate means for estimating catastrophe risk, the normative basis for determining the social rate of pure time preference, as well as the elasticity of the marginal utility of consumption. Until such work is complete, any Canadian estimate of the social rate of time preference for consumption remains highly speculative.

If a social decision making perspective is adopted and the health budget is constrained, then the appropriate discount rate to adopt for costs is determined by the real interest rates estimated in Section 3 of this report.[68] However, these interest rates will inevitably change over time, so it would be important that CADTH update these as appropriate. Since these rates are non-constant, careful consideration would be needed as to how best to incorporate such rates into CADTH's methods for the economic evaluation of health technologies.

APPENDIX 1: SEARCH STRATEGY

The following searches were conducted using the EBSCO and EconLit databases in April 2015.

The number of identified results is reported in square brackets following each search term. Note that some papers were identified from more than one search term so these are not mutually exclusive.

Catastrophe risk
"Catastrophe risk" & Canada [3]
"Catastrophe risk" [135]

Pure time preference
"Pure time preference" & Canada [1]
"Pure time preference" [43]

Elasticity of the marginal utility of consumption
"Elasticity of marginal utility of consumption" & Canada [13]
"Elasticity of marginal utility of consumption" [112]

Social rate of time preference (general)
"Social rate of time preference" & Canada [1]
"Social rate of time preference" [17]
"Social time preference rates" & Canada [1]
"Social time preference rates" [17]

Time preference (general)
"Time preference" [80]
"Time preference" & Canada [0]

As a complement to the searches described above, the following searches were conducted using the University of Alberta database in April 2015.

Pure time preference
"Pure time preference" [96]

Elasticity of the marginal utility of consumption
"Elasticity of marginal utility of consumption" [18]

Social rate of time preference (general)
"Social rate of time preference" [47]
"Social time preference rate" [6]

APPENDIX 2: DATA EXTRACTED FROM REVIEW

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information only if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
				Catastrophe risk (r)	*Pure time pref. (p)*	*Elasticity of marg. utility of cons. (e)*	*Growth in cons. (g)*	*Canada-specific*	*Methods and sources*	*Results and conclusions*	*Implications for parametrizing the Ramsey equation*
1	Agee, Mark D and Fah, Kenneth C (1995)	Social Discount Rates from Stratospheric Ozone Control	To infer on the social discount rate associated with investment in Stratospheric Ozone preservation.	☐	☐	☐	☐	N/A	N/A	N/A	N/A
2	Ahsan, Syed M (1980)	The Marglin-McFadden-Mishan debate on public investment criteria. Some Clarifications	To analytically review the claim and counterclaim of the idea that the social marginal rate of time preference is the appropriate social rate of discount for public projects, and reach to a conclusion.	☐	☐	☐	☐	N/A	N/A	N/A	N/A
3	Amendola, Aniello and Ermolieva, Tatiana and Linnerooth-Bayer, Joanne and Mechler eds., Reinhard (2013)	Integrated Catastrophe Risk Modeling: Supporting Policy Processes	Addresses the methodological complexities of assessing disaster risks. Incorporates stochastic simulation, optimization methods and economic modelling.	☐	☐	☐	☐	N/A	N/A	N/A	N/A

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information <u>only</u> if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
4	Anthoff, D and Tol, R S J and Yohe, G W (2009)	Discounting for Climate Change	The importance of relative risk aversion and rate of growth of per capita consumption in calculating social discount rate (in the context of determining the social cost of carbon)	□	□	□	□	No	Integrated assessment model FUND to test the hypothesis that Elasticity of marginal utility of Cons. is more important than the pure time preference rate in determining the social cost of carbon.	Social cost of carbon varies according to the assumption incorporated in the model. With very low discount rate the social cost of carbon is arbitrary. Income elasticity of the aggregate impact of climate change is probably negative.	None
5	Ayres, R U and Axtell, R (1996)	Foresight as a survival characteristic: When (if ever) does the long view pay?	Basic discounting methodology is claimed to be fundamentally flawed. The authors suggest some alternative, more general methodology.	□	□	□	□	N/A	N/A	N/A	N/A
6	Bayer, Stefan (2003)	Generation-adjusted discounting in long-term decision-making	To suggest generation-adjusted discounting for long-term decision making.	□	□	□	□	N/A	N/A	N/A	N/A
7	Beckerman, Wilfred and Hepburn, Cameron (2007)	Ethics of the Discount Rate in the Stern Review on the Economics of Climate Change	To give an ethical judgement on the discount rate, and consequently on its components, used in the Stern review on the economics on climate change.	□	□	□	□	No	Providing ethical judgement on the components of discount factor used in Stern review.	Authors suggest more attention should be given to agent-relative ethics instead of zero rate of pure time preference.	None

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information only if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
8	Bleichrodt, Han and Gafni, Amiram (1996)	Time preference, the discounted utility model and health	Identifies that discounting utility models at a constant rate is fundamentally flawed. Suggests two ways to incorporate individual intertemporal preference in health care programs.	☐	☐	☐	☐	N/A	N/A	N/A	N/A
9	Boardman, A E and Moore, M A and Vining, A R (2008)	The Social Discount Rate for Canada Based on Future Growth in Consumption	To propose discount rate for project evaluations by all levels of government in Canada.	☐	☐	☐	☐	Yes	Values of SDR are calculated based on 4 different models: Intragenerational projects with no crowding out of private investment Intragenerational projects with some crowding out of private investment Intergenerational projects with no crowding out of private investment Intergenerational projects with	Project is intragenerational and does not crowd out private investment: discount rate 3.5% Project is intragenerational and crowds out private investment: The flows should be converted into consumption equivalent using shadow price of capital of 1.1 & then discount at 3.5%. Project is intergenerational: schedule time declining SDR In general, the SDR recommended is	p = 1% (Arrow, 1996) e = 1.5 (with sensitivity analysis at 1 & 2) g = 1.7%

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information only if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
									some crowding out of private investment.	3.5% with sensitivity analysis of 2% and 5%. For longer periods time varying discount rate. 0-50 years = 3.5% 51-100 years = 2.5% 100-200 years = 2% >200 years= 1.5%	
10	Bonneuil, Noel and Boucekkine, Raouf (2014)	Viable Ramsey Economies	To check Ramsey model in perspective of viability theory (maintenance of controlled dynamical systems within closed sets.)	□	□	□	□	N/A	N/A	N/A	N/A
11	Bradford, David F (1975)	Constraints on Government Investment Opportunities and the Choice of Discount Rate	To show practical relevance of Arrow's claim that, if capital market imperfection takes the form of a fixed marginal propensity to save out of private income (independent of the rate of return), the optimal government investment policy in the long run is to invest to the point where the marginal	□	□	□	□	N/A	N/A	N/A	N/A

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information <u>only</u> if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
			rate of return on government capital equals the marginal rate of social time preference (whether or not derived from individuals' rates of time preference), regardless of the rate of return on private capital.								
12	Burgess, David (2008)	Removing Some Dissonance From the Social Discount Rate Debate	To show that in an economy with capital income tax distortion the social discount rate should reflect social opportunity cost of capital rather than the social rate of time preference.	□	□	□	□	N/A	N/A	N/A	N/A
13.	Burgess, David F and Jenkins eds., Glenn P (2010)	Discount Rates for the Evaluation of Public Private Partnerships	To provide a review of discounting methodologies specifically for the economic evaluation of public private partnerships	□	□	□	□	Yes	In Chapter 2, Michael Spackman provides a review of various authors' views on pure time preference and the different approaches to estimating the elasticity of the marginal utility	Pigou (1920), Ramsey (1928) and a "minority" of later authors advocated for a zero rate of pure time preference. More recently, Kopp & Portney (1999), Eckstein (1957) and Marglin (1963) have provided arguments against a zero rate, since a social	While some authors have argued for a zero rate of pure time preference, there "may be some consensus" in a rate of pure time preference of "around 1.5% per year". Estimates of the elasticity of the marginal utility of consumption vary by estimation approach and country:

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information <u>only</u> if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
									of consumption. The elasticity of marginal utility may be derived using a number of approaches and from a variety of data sources: the personal tax regime; personal savings behavior; evidence of personal risk aversion; income and price elasticities; international happiness data; intuition; and expert elicitation.	welfare function based upon consumer sovereignty must account for all tastes, including intertemporal preferences. Ramsey (1928), Hayek (1936) and Arrow (1996) have also shown that a zero rate of pure time preference implies an unrealistic savings rate. The author then cites (p. 109, footnote 34) estimates of pure time preference from Little & Mirrlees (1974; 2-3%), Scott & Dowley (1977; 1.5%), Scott (1988; 1.3%), Stern (1977; 2.5%), and Arrow (1996; 1%). The author cites a wide range of studies reporting estimates of the elasticity of the marginal utility of consumption, summarized in the column to the right.	Personal tax regime: UK: 1.29-1.42 (Cowell & Gardiner, 2000); 1.97 (Stern, 1977) US: 1.5 (Mera, 1969) OECD: 1.4 ± 0.2 (Evans 2005, 2007) Personal savings behaviour: UK: 1.2-1.4 or 0.34-1.0 (Cowell & Gardiner, 2000); 5 (Stern, 1977) US: 5.6 (Barsky et al., 1997) Personal risk aversion: US: 4.2 (Barsky et al., 1997) Income and price elasticities: UK: 2.8 (Brown & Deaton, 1972); 0.71 (Kula, 1985); 1.6 (Evans & Sezer, 2002); 1.6 or 1.2 (Evans, 2004) US: 1.89 (Kula, 1984) Canada: 1.56 (Kula, 1984) France: 1.8 or 1.3 (Evans, 2004)

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information only if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
											International happiness data: 1.26 (Layard et al., 2007) Intuition: Must exceed 1 above some income level (Scott & Dowley, 1977) Expert views: UK: 1-10 (Stern, 1977); 1.5 (Scott, 1989); 1-3 (Little & Mirrlees, 1974); 0.5-4.0 (Cowell & Gardiner, 2000); 1.4 (Evans, 2005) US: 0.5-2.0 (Eckstein, 1958); 1-2 (Feldstein, 1965); 1.5 (Cline, 1993); 1-2 (Boscolo et al., 1998); 1.5-2.0 (Arrow, 1996)
14.	Caliendo, Frank and Lyon, Kenneth (2003)	Optimal Discounting in Control Problems that Span Multiple Generations	The authors aim to show that under different control problems across multiple generations it is more suitable to use the market interest rate as the discount rate.	□	□	□	□	N/A	N/A	N/A	N/A

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information only if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
15.	Caney, Simon (2009)	Climate Change and the Future: Discounting for Time, Wealth, and Risk.	To explore the issues of intergenerational equity raised by climate change.	□	□	□	□	No	Philosophical argument put forward to suggest the aspects that need to be considered to obtain a social discount rate.	Considering the component of pure time preference the author suggests that a zero time preference should be considered on the basis of human rights. Author put forward arguments to undermine the idea that future generations will be wealthier than the current generation.	None
16.	Chami, Saade N and Butterfield, David W (1989)	The implications of myopic policy-making for macroeconomic performance	To find the implications of myopic behavior in policy making on intertemporal economic performance.	□	□	□	□	No	To minimize a loss function subject to the constraint of a macroeconomic model, having both short run & long run characteristics. The model consists of 12 behavioral equations and nine identities. Author used different discount rate to represent myopia in policy making	The results of both approaches confirm the existence of an intertemporal tradeoff between the effects of macroeconomic policies and indicate that as more and more emphasis is put on the present (future), the higher is the cost incurred in the future (present) relative to the gain realized.	None

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information only if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
									(time-neutral, myopic and farsighted). Another way used to represent myopia was the time horizon over which government tried to achieve their objectives.		
17	Claxton, Karl and Paulden, Mike and Gravelle, Hugh and Brouwer, Werner and Culyer, Anthony J (2011)	Discounting and decision making in the economic evaluation of health-care technologies	To address the debate around differential discounting and to describe how discounting ought to be conducted under various assumptions regarding the perspective on social choice, fixity of the budget, and the decision rule used	□	□	□	□	N/A	N/A	N/A	N/A
18	Cline, William R (1993)	Give greenhouse abatement a fair chance	To argue that the overall discount rate used for cost-benefit analyses of policies to reduce carbon emissions should be no more than 2% in real terms	□	□	□	□	No	To calculate the SRTP, the author "appeals to basic economic theory". The authors make use of an uncited	There is a "strong tradition" among economists to set the rate of pure time preference to zero. Combined with e = 1.5 and g = 1, this implies a SRTP of 1.5%.	r = 0 ("strong tradition") e = 1.5 (Fellner & Scott) g = 1% (author's assumption for per capita economic growth over "the next three centuries")

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information only if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
									estimate of the elasticity of the marginal utility of consumption by Fellner & Scott. Catastrophe risk is not considered. The other components of the Ramsey equation are parametrized through assumptions.		
19	Creedy, John (2008)	A Note on Discounting and the Social Time Preference Rate	To find the difference in monetary values of social evaluation when the evaluations are performed using a social time preference rate and pure time preference rate.	□	□	□	□	No	The authors construct an economic model to consider social evaluations based upon additive Paretian social welfare functions. This model is used to consider the impact of different time preference rates.	The author shows that the evaluations performed using social discount rate and the pure time preference rate on different consumption streams will have different values (unless the elasticity of MU of consumption is less than 1 and the consumption streams have same initial value).	None

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information only if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
20	Creedy, John (2007)	Policy Evaluation, Welfare Weights and Value Judgements: A Reminder	The author reviews and critically examines a number of frameworks in which the concept of the 'elasticity of marginal valuation', in the context of evaluating a social welfare function, is central. The author argues that central elasticity concept cannot in fact be measured objectively but necessarily involves value judgements.	□	□	□	□	No	The author introduced the single period's social welfare function with welfare weights. He further used the multi-period welfare function. Also he questions the idea that the value of the elasticity is implicit in an income tax structure.	The author found that results are highly sensitive to the context and model specification assumed. He claimed that The various estimates and models may be of interest, but they cannot be used by economists to *impose* value judgements. The main contribution economists can make is to examine the implications of adopting a range of alternative value judgements. The values calculated for elasticity of MU of consumption are highly sensitive to the context and model specification that would be assumed for calculations.	None

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information only if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
21	Creedy, John and Guest, Ross (2008)	Discounting and the Time Preference Rate	To provide an analytical review of a central issue in the evaluation of alternative time streams of consumption (that of discounting), and the closely related concept of time preference.	□	□	□	□	No	The authors used the analysis of optimization over time. Approaches giving rise to declining discount rates over time were discussed, including alternative welfare functions, the role of uncertainty, methods used to estimate a time preference rate.	The analysis of the optimization led to the concept of social time preference rate. The difficulty with using this rate was highlighted and complications by non-income differences between individuals were examined.	None
22	Evans, David (2009)	Uncertainty and Social Discounting for the Very Long Term	To examine uncertainty in the social discount rate and explore the conditions favouring the application of higher present value welfare weights in the cost-benefit analysis (CBA) of very long-term social projects.	□	□	□	□	No	Analysis of the uncertainty conditions for a plausible range of discount rate values in relation to the social time preference rate (STPR) recommended for application in European social project appraisal. Use of simulations	Present value welfare weights decline to less than 2 per cent within 200 years if discounting is based on the full STPR. Important appraisal contexts are identified where only the utility discount rate is relevant and this yields non-trivial discount factors for distant future years. Possible values for the utility discount	A value range for the elasticity of marginal utility of consumption (e) of 0.4-1.6 is judged to be appropriate with unity as the central rate.

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information only if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
									based on alternative plausible probability distributions to explore the future time paths for discount factors.	rate based on the views of experts range from 0 to 2% per annum. The value of the discount factor becomes trivial after about 200 years and this still presents a problem when appraising the present value of costs and benefits for the longest-term projects.	
23	Evans, David (2004)	The Elevated Status of the Elasticity of Marginal Utility of Consumption	To estimate the marginal utility of consumption (e) and associated empirical evidence considering a measurement approach based on consumer demand analysis in relation to a preference independent product group.	□	□	□	□	No	Alternative market demand models were used to obtain *e* for the UK based on consumer demand analysis. The constant elasticities model (CEM) was tested against the 'almost ideal demand system' (AIDS) and the quadratic extension of this (QUAIDS).	The preferred regression results based on the CEM specification for the demand for food yield a plausible estimate of *e* for the UK that is close to 1.6.	*e* = 1.6

<table>
<tr><th>Index</th><th>Authors (Year)</th><th>Title</th><th>Purpose</th><th colspan="4">Does the paper specifically address any of the following parameters of the Ramsey equation?</th><th colspan="4">Provide the following information <u>only</u> if the paper specifically addresses one or more of the parameters of the Ramsey equation</th></tr>
<tr><td>24</td><td>Evans, David (2005)</td><td>The Elasticity of Marginal Utility of Consumption: Estimates for 20 OECD Countries</td><td>To present new evidence on the elasticity of marginal utility of consumption based on the structure of personal income tax rates for 20 OECD countries.</td><td></td><td></td><td></td><td></td><td>Yes</td><td>Cross-country regression estimates of e based on pooled ‘low’ and ‘high’ income data were used. One specification was the restricted model imposing constancy. Another specification was the unrestricted model including shift and slope dummy variables. Two other specifications were partially restricted models.</td><td>The tax-based estimates of e produce a best average estimate for countries that is close to 1.4. On the strength of the pooled income regression results for the preferred restricted model, the lower and upper 95 per cent confidence limits for average e are 1.21 and 1.51 respectively.</td><td>Tax-based e for Canada at high and low income levels: 1.25 for average income and 1.30 for high income.

e = 1.4 for the full sample.

<table><tr><th></th><th>p (%)</th><th>g (%)</th><th>e</th><th>SRTP (%)</th></tr><tr><td>France</td><td>1.0</td><td>2.0</td><td>1.35</td><td>3.7</td></tr><tr><td>Germany</td><td>1.0</td><td>2.2</td><td>1.35</td><td>4.0</td></tr><tr><td>Japan</td><td>1.0</td><td>2.5</td><td>1.35</td><td>4.4</td></tr><tr><td>UK</td><td>1.0</td><td>2.1</td><td>1.35</td><td>3.8</td></tr><tr><td>USA</td><td>1.0</td><td>2.2</td><td>1.35</td><td>4.0</td></tr></table>
Note: g = average annual per capita growth for real consumer spending;
p = approximate average annual death rate in recent years.</td></tr>
<tr><td>25</td><td>Guest, Ross (2011)</td><td>Social Time Preference and the Optimal Carbon Price</td><td>To examine the implications of alternative social time preference assumptions for the optimal carbon price by numerical simulations of a simple Ramsey model.</td><td></td><td></td><td></td><td></td><td>No</td><td>Three specifications of social time preferences were compared: a constant social time preference rate (STPR), decreasing social impatience or</td><td>The results show nontrivial effects on the optimal carbon price.
The policy implication is that value judgements about intergenerational welfare, reflected in STPR, have implications for</td><td>e = 1.0</td></tr>
</table>

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									hyperbolic social preferences and increasing social impatience.	policies aimed at achieving a target carbon price. These value judgements therefore ought to be made explicit in setting target carbon prices over time.	
26	Herbener (2013)	Comment on 'A Note on Two Erroneous Ways of Defending the Pure Time Preference Theory of Interest'	To respond to Topan and Paun's criticism of two arguments made in defense of the Pure Time Preference Theory of interest.	☐	☐	☐	☐	N/A	N/A	N/A	N/A
27	Hope, Chris (2008)	Discount Rates, Equity Weights and the Social Cost of Carbon	To show that the social cost of carbon is higher without equity weights (an elasticity of marginal utility with respect to income of 0) than with them.	☐	☐	☐	☐	No	The PAGE2002 integrated assessment model was used.	As the elasticity goes from 0 to −0.5 to −1.0, the social rate of time preference rises, and the drop in present values that results far outweighs the small increase in impacts that equity weights bring.	None
28	Dumas P., Hourcade J.C. and Perrissin Fabert, B. (2010)	Do we need a zero pure time preference or the risk of climate catastrophes to justify a 2°C global warming target?	To confront the wide political support for the 2°C objective of global increase in temperature, reaffirmed in Copenhagen, with the consistent set of hypotheses on	☐	☐	☐	☐	No	Use of an optimal stochastic control model balancing the costs and benefits of climate policies resolved sequentially in	The model shows that 26% of the worldviews selecting the 2°C target are not characterized by one of the extreme assumptions about pure time preference or climate change	None

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			which it relies.						order to account for the arrival of new information (the RESPONSE model). This model describes the optimal abatement pathways for 2,304 worldviews, combining hypotheses about growth rates, baseline emissions, abatement costs, pure time preference, damages, and climate sensitivity.	damages. Neither an almost zero pure time preference nor concerns about catastrophic damages in case of uncontrolled global warming are prerequisites for policy decisions preserving the possibility of meeting a 2°C target.	
29	Kam, Eric (2005)	A note on time preference and the Tobin Effect	To propose an alternative time preference specification to Uzawa preferences	□	□	□	□	No	The authors revisited Uzawa's time preference specification by modelling the rate of time preference as an increasing function of real wealth.	The resulting Tobin Effect and steady state stability do not rest on the counterintuitive preference assumptions that challenge Uzawa's time preference specification but rather on optimizing behaviour.	None

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30	Khanna, Neha and Chapman, Duane (1996)	Time preference, abatement costs, and international climate policy: An appraisal of IPCC 1995	To appraise current economic methodologies used in analyzing the social rate of time preference and discounting, abatement costs, and value of life estimates as they relate to climate change.	□	□	□	□	No	Integrating discount rates, abatement costs, and value of life estimates when assessing climate policies.	The incorporation of these factors when assessing climate policies highlighted important and contrasting implications of international climate policy for developing and high-income countries.	None
31	Krahn, Murray and Gafni, Amiram (1993)	Discounting in the economic evaluation of health interventions	To verify whether theories that underlie discounting have specific implications for program evaluation in health.	□	□	□	□	No	The authors reviewed current recommendations and practice within the field of economic evaluation in health, outlined the major economic arguments underlying discounting, considered earlier economic and philosophical views, and considered specific implications of these theoretical insights for discounting in health care.	Shepard and Thompson (1979) recommended a discount rate in the range of 5% to 15%. Drummond et al. (1980) also suggested the initial choice of 5% as a discount rate. Both the Office of Management and Budget in the United States and the Ministry of Supply and Services in Canada have suggested discount rates of 10%. The British Government maintained a test discount rate of 5% for public projects, but following a	None

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										review in 1988-89, it was set at 6%.	
32	Kula, Erhun (1984)	Derivation of social time preference rates for the United States and Canada	To derive the social time preference rates for the United States and Canada under the assumptions that communities are not influenced either by prospective diminution of future enjoyment or by risk aversion, but each member discounts the utility of future consumption by the probability of being alive to enjoy it.	□	□	□	□	Yes	Use of a representative agent model with two-period consumption utility function that has conventional properties, i.e., smoothness, differentiability, and quasi concavity; is additive; and has constant elasticity.	Results for these two countries are almost the same, as one would expect them to be, since they have very similar economic and social structures.	<table><tr><td></td><td>*p (%)*</td><td>*g (%)*</td><td>*e*</td><td>*SRTP (%)*</td></tr><tr><td>USA Canada</td><td>1.0 1.0</td><td>2.3 2.8</td><td>1.89 1.56</td><td>5.3 5.2</td></tr></table> *Note: g = growth rate of per capita consumption; e = elasticity of marginal utility of consumption; p = average survival probability for an individual.*
33	Lecocq, Franck and Hourcade, Jean-Charles (2004)	Le taux d'actualisation contre le principe de précaution	To show based on the example of climate mitigation policies why applying rigorously the discounting is necessary to clarify the issues at stake in the decision.	□	□	□	□	No	Use of decision making framework with increasing information to demonstrate that the value of pure time discounting matters less than the assumptions about future growth,	Intergenerational equity issues go beyond the value of pure time preference. We also need to consider the nature of the bequest to future generations, in terms of stocks of physical capital and of knowledge in particular, because it shapes their ability	None

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									productivity of capital, preferences and beliefs about climate change impacts.	to adapt to new information.	
34	Lesser, A., Jonathan and Zerbe, JR., O., Richard (1995)	What can economic analysis contribute to the sustainability debate?	To examine the usefulness of economic analysis, especially benefit-cost analysis, to address competing policy goals associated with sustainability and sustainable development. It argues that the critics have misunderstood the proper role of benefit-cost analysis.	□	□	□	□	No	The analysis addresses several issues within the sustainability debate: concerns about intergenerational equity including the appropriate discount rate for projects with environmental consequences; implications for burdens on future generations; and the moral basis for benefit-cost analysis.	The authors argue that the correct discount rate for all such projects is the social rate of time preference, and that suggestions for using lower discount rates result from attempting to prevent inequities by adjusting prices. They also argue that economic analysis, especially benefit-cost analysis, can play a useful role in providing information to decision makers, who ultimately will face resource allocation issues as they seek to implement policies promoting sustainability.	None

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35	Liu, Liqun (2012)	Inferring the rate of pure time preference under uncertainty	To study how to infer the rate of pure time preference (ρ) from the Ramsey Rule when multiple asset returns exist due to uncertainty.	□	□	□	□	No	Use of a Generalized Uncertainty Ramsey Rule derived from a model that separates intertemporal substitution and risk aversion.	One main numerical finding is that the combination of ρ=0 and $\alpha_u \leq 1$ is very much consistent with the Generalized Uncertainty Ramsey Rule for all the values of α_u within a plausible range. Another main numerical finding is that the value of ρ tends to fall in the negative zone for larger values of α_u, suggesting that a value of ρ significantly larger than zero (say 3%) is extremely unlikely.	The results suggest that it is appropriate to use ρ=0 ($\alpha_u \leq 1$) as a benchmark for economic analysis of environmental policies.
36	Lowry, Rosemary and Peterson, Martin (2011)	Pure time preference	To provide some counter arguments to Sidgwick, Ramsey, Rawls, and Parfit views of the irrationality of pure time preference.	□	□	□	□	No	The authors questioned Rawls' claim that rationality implies an impartial concern. They also examined three of the most important theories of justificatory reasons for action, and discussed the link between individual and	The authors argue that it is not always irrational to be guided by pure time preferences. Even if the mere difference of location in time is not a rational ground for a preference, time may nevertheless be a normatively neutral ground for a preference, and this makes it plausible to claim that the preference is	None

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									collective preferences and the implications of their argument for the social rate of pure time preference.	rationally permitted.	
37	MacKeigan, Linda, D., O'Brien, Bernie, J. and Gafni, Amiram (2003)	Double discounting of QALYS	To determine the magnitude of the double discounting effect and the effectiveness of a suggested method for avoiding double discounting in a TTO-based QALY model.	☐	☐	☐	☐	No	Use of holistic and composite preference scores obtained with the TTO technique in a prior study of four hypothetical treatment paths in type 2 diabetes.	Discounted composite preference scores were significantly discrepant from holistic preference scores. Adjusting TTO-based quality weights prior to external discounting reduced the discrepancy only slightly. Since time preference effects may vary with health state context, the double discounting effect needs further investigation.	None
38	Mahboub-Ahari, M., Pourreza, A., Sari, A., Fouroushani, R., A., Heydari, and Hassan (2014)	Stated time preferences for health: a systematic review and meta-analysis of private and social discount rates	To provide better insight on methodological issues related to time preference studies, and to estimate private and social discount rates, using a rigorous	☐	☐	☐	☐	No	The authors searched PubMed, EMBASE and ProQuest databases in June 2013. All studies had estimated private and	Reported time preference rates for own health were from 0.036 to 0.07 and for social health from 0.04 to 0.2. Private and social discount rates were estimated at 0.056 (95% CI: 0.038,	None

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information only if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
			systematic review and meta-analysis.						social time preference rates for health outcomes through stated preference approach, recognized eligible for inclusion. They conducted both fixed and random effect meta-analyses using mean discount rate and standard deviation of the included studies. I-square statistics was used for testing heterogeneity of the studies. Private and social discount rates were estimated separately via Stata11 software.	0.074) and 0.066 (95% CI: 0.064, 0.068), respectively	

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39	Marini, Giancarlo and Scaramozzino, Pasquale (2000)	Social time preference	To prove that observed practice of discounting the future should not be rationalized on the grounds of myopia or selfishness. A positive rate of pure time preference is necessary to ensure that heterogeneous generations are treated in an egalitarian fashion.	□	□	□	□	No	Use of a social welfare function which meets the requirements of time consistency and of symmetry across generations. Extension of the analysis to the case of endogenous growth considering a prototypical learning-by-doing model.	A zero social discount rate would yield intertemporal allocations which are biased against the current generations. Endogenous productivity growth requires that the social discount rate be set above the subjective rate of pure time preference. Positive social time preference, far from discriminating against future generations, is essential for a fairer inter temporal allocation of resources.	None
40	Mehrez, Abraham and Gafni, Amiram (1990)	Resource allocation, equity and public risk: dying one at a time vs dying all together	To focus on the evaluation, from an individual and societal perspective of risk in terms of possible loss of life due to an exposure to two different types of events over a period of time (risk of death from a catastrophic event) and risk of death from another	□	□	□	□	No	The analysis considered the extreme case in which these two types of events have the same probabilities of death every year and the same expected number of fatalities over the planning period. The	The model suggests that the choice between these types of events depends on the value of the following variables: the probability of death over the planning period, the length of the planning period, the individual's time preference pattern and the utility of	None

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			event.						individual's decision problem is described using a von-Neumann Morgenstern (VNM) utility function.	being in different anxiety states.	
41	Mendelsohn, Robert (1981)	Choice of discount rates for public projects	To criticize Bradford's calculation of the social present value of a dollar of private investment.	☐	☐	☐	☐	No	The authors corrected Bradford's model to indicate that the social present value of a dollar of private investment is often worth considerably more than a dollar of today's consumption.	It is clearly not a wise rule of thumb to use the social rate of time preference as the public discount rate. No single discount rate can act as a satisfactory rule of thumb under all circumstances. If the social rate of time preference is used as the public discount rate, the opportunity cost of public investment would be understated, often-times by a factor of three or more.	None
42	Moore, Mark A., Boardman, Anthony E. and Vining, Aidan R. (2013)	The choice of the social discount rate and the opportunity cost of public funds	To clarify the key sources of disagreement between the two largely opposing viewpoints on the correct method for	☐	☐	☐	☐	No	The authors used the social rate of time preference-shadow price of capital (STP-SPC), also	The "Most Appropriate Social Discount Rate (MASDR)" practice advocates the use of a 7% social discount rate (SDR).	None

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			choosing and estimating a social discount rate (SDR).						known as the "shadow price algorithm" which reflects the values that "society" places on consumption at various points in time.	Burgess and Zerbe (2011) use 8.5% estimate of the US return on investment (ROI). The authors suggested a SDR = 3.5%.	
43	Parson, Edward A. (2007)	The big one: a review of Richard Posner's catastrophe: risk and response	To identify and describe the four risks examined by Richard Posner (2004) which could end advanced human civilization (asteroid impacts, a catastrophic chain reaction initiated in high-energy particle accelerators, global climate change, and bioterrorism); to highlight the inadequate attention they are receiving, and advance a persuasive argument for their more serious examination.	□	□	□	□	No	This study reviewed knowledge of these risks and critically examined Posner's claims for a consistent analytic approach. He argues that these all warrant more thought and response than they are receiving, and that they can usefully be assessed using a simple analytic framework based on cost–benefit analysis.	The authors concluded that Posner develops his proposed framework thinly and applies it unevenly. Applying such a framework consistently to catastrophic risks would require engaging some fundamental problems that Posner does not address.	None

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44	Parsonage, Michael and Neuburger, Henry (1992)	Discounting and health benefits	To challenge the conventional practice of discounting nonmonetary health benefits at the same rate as variables which are expressed in monetary terms.	☐	☐	☐	☐	No	The paper explores the various influences of rising income, age and pure time preference on the relative value of current and future health states. It examines various arguments advanced to justify the current practice of discounting health benefits at the same rate as monetary costs including uncertainty and delay.	Discounting at the same rate carries hidden implications, for example about the future value of health benefits, which do not look to be well founded. The appropriate discount rate for nonmonetary health benefits is at, or close to, zero. Use of such a rate appears to have important implications for the cost-effectiveness ranking of alternative health service procedures.	None
45	Paulden, Mike (2014)	Time preference and discounting	To explain the rationales for discounting and discuss some of the more contentious issues in discounting, such as the merits of differential or non-constant discounting.	☐	☐	☐	☐	N/A	N/A	N/A	N/A

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46	Paulden, Mike and Claxton, Karl (2012)	Budget allocation and the revealed social rate of time preference for health	To examine the relationship between the social time preference rate for health, the growth rate of the cost-effectiveness threshold and the rate at which the higher authority can borrow or invest.	□	□	□	□	N/A	N/A	N/A	N/A
47	Price, Colin (1993)	Time, discounting and value	To argue the following premise: "weighting the value of future consumption by a uniform negative exponential function of time is an extraordinary process, and needs special justification: if that justification is not found and agreed to, we should stop doing it"	□	□	□	□	N/A	N/A	N/A	N/A

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48	Rahman, Anisur (1969)	Intertemporal equity and elasticity of marginal utility from consumption	To demonstrate that there is intrinsic ethical merit in a utility function with the elasticity of marginal utility with respect to consumption exceeding unity (i.e. $\nu > 1$ or $\eta < 1$ as originally claimed by Hicks). (Where ν and η represent the elasticity of marginal utility with respect to consumption and the marginal utility respectively.)	□	□	□	□	No	Use of the theory of individual consumer behaviour concerning choice of consumption paths over time.	The study confirmed Hicks' original proposition that $\eta\ (= 1/\nu)$ should be less than unity. With $\eta < 1$ it is no longer necessary for the rate of time discount to be positive. Thus we can also retain the 'Ramsay ethic' of neutrality between generations.	None
49	Redelmeier, Donald A. and Heller, Daniel N. (1993)	Time preference in medical decision making and cost-effectiveness analysis	To examine three features of the conventional time discount model applied in medical economics.	□	□	□	□	No	The authors examined three assumptions of the exponential discount model by assessing the time preferences of individuals towards hypothetical health states and calculating implicit annual discount rates.	Of all the discount rates, 62.1 % equalled zero, 10.0% were less than 0.00, and 15.7% were greater than 0.10. Mean discount rates for relatively proximal time intervals tended to be larger than those for relatively more distant intervals (0.041 vs. 0.025, $p < 0.01$). Mean	None

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									They used a random sample of 121 medical students, house officers, and attending physicians (a response rate of 81%). The participants considered three temporary events (colostomy, blindness, depression) that were destined to occur at five sequentially distant times in the future (one day, six months, one year, five years, and 10 years). The utility of each prospect was measured using two elicitation techniques (standard gamble and categorical scaling), and 1,394 implicit discount rates	discount rates for blindness tended to be smaller than those for colostomy or depression (0.023 vs 0.039 vs 0.037, respectively, $p < 0.005$). Therefore, peoples' implicit discount rates are not always small positive numbers that are constant over time and the same for all settings. This suggests that the conventional exponential discount model may not fully characterize the time preferences held by individuals. Discount rates fell outside the interval between 0.00 and 0.10.	

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									were calculated.		
50	Schad, Mareike and John, Jürgen (2012)	Towards a social discount rate for the economic evaluation of health technologies in Germany: an explanatory analysis	To identify the appropriate value of a social discount rate to be used by the German Statutory Health Insurance for the economic evaluation of health technologies.	□	□	□	□	No	On theoretical grounds, the authors built on the widespread view of contemporary economists that the social rate of time preference (SRTP) is the adequate social discount rate. For quantifying the SRTP, they first applied the market behaviour approach, which assumes that the SRTP is reflected in observable market interest rates. As a second approach, they derived the SRTP from optimal growth theory by using	Depending on various assumptions, their empirical findings result in the range of 1.75–4.2% for the SRTP. A reasonable base case discount rate for Germany, thus, would be about 3%.	<table><tr><th></th><th>*p (%)*</th><th>*g (%)*</th><th>*e*</th><th>*SRTP (%)*</th></tr><tr><td>Lower Best Upper</td><td>0.0 0.5 1.0</td><td>1.4 1.6 1.8</td><td>1.25 1.50 1.80</td><td>1.75 2.90 4.20</td></tr></table> *Note: the upper estimate of p is based on individual catastrophe risk, the lower estimate the minimum possible societal risk, and the "best" estimate is the mid-point of these*

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information only if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
									the Ramsey equation. A major part of the paper is devoted to specify the parameters of this equation.		
51	Soman, D., Ainslie, G., Frederick, S., LI, X., Lynch, J., Moreau, P., Mitchell, A., Read, D., Sawyer, A., Trope, Y., Insead, Klaus W., Zauberman, Gal (2005)	The Psychology of Intertemporal Discounting: why are distant events valued differently from proximal ones?	To address the following questions in the literature: Why are future outcomes not as valuable as present outcomes? What implications does this have for future researchers in the area of intertemporal choice? What are some of the key questions and directions in which the work in this area can be extended?	□	□	□	□	No	The paper revisited the experimental paradigm used to measure discounting; critically examined and articulated implicit assumptions; distinguished between intertemporal effects arising due to time preference versus those due to changes in utility as a function of time, and identified issues and questions that serve as avenues for future research.	They found that intertemporal choice research is at a crossroad. While they believe that a great deal has been done in terms of documenting intertemporal discounting effects, future efforts need to focus on: (a) disentangling the effects of time preference from changes in utility; (b) understanding the psychological antecedents of both time preference and utility changes; and (c) developing richer, descriptive and fertile models that explain intertemporal choices.	None
52	Tol, Richard S.J. (2002)	On dual-rate discounting	To reinterpret dual rates of pure time	□	□	□	□	No	The authors reinterpreted	If we assume that $r = r'$, then the	None

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			preference introduced for analyzing long-term environmental problems as shifts in preferences						Yang's dual discounting assuming that the consumption and environmental quality discount rates (r_c, r_q) are equal to the discount rate for conventional consumption (r'_c) and the discount rate for environmental quality (r'_q) respectively.	difference between Yang's pure rates of time preference equals the rate of appreciation of the marginal willingness to pay for environmental quality. If per capita income grows at 2% a year, the marginal willingness to pay for environmental quality is proportional to income (Ψ=1), and risk aversion is unity, then Yang's consumption discount rate would be 2% higher than Yang's environmental discount rate. Since a difference of 3% is needed to justify the Kyoto Protocol, an increase risk aversion from 1 to 1.5 is needed. The income elasticity of environmental quality should be approximately 1.5 to justify the Kyoto Protocol. Yang used 1.	

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information only if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
53	Topan, Vladimir Mihai and Paun, Cristian (2013)	A note on two erroneous ways of defending the pure time preference theory of interest	To show that two particular types of arguments in favour of the pure time preference theory of interest (PTPTI) are mistaken.	□	□	□	□	No	The authors demonstrated that the idea that the logical opposite of time preference consists in the proposition that one must always prefer the future (and that therefore one would never consume or act), is problematic. They also showed that the idea that the rate of interest as it emerges in the exchange of present money for future money simply reflects pure time preference is problematic.	The negation of a universal affirmative proposition is not the universal negative, but the particular negative. Therefore, the opposite of time preference is rather the thesis that man at least once prefers the future, other things equal. Moreover, to say that pure interest is isolated by money interest which, in turn, is a composite magnitude which cannot be grasped unless one already operates with the concept of pure interest, is to argue in a circle.	None
54	Traeger, Christian P. (2012)	Once upon a time preference: how rationality and risk aversion change the rationale for discounting	To develop an axiomatic framework for rational decision making in the context of discounted expected utility model.	□	□	□	□	No	The author derives three discounted expected utility models that permit a more comprehensive risk evaluation. These models differ regarding	Imposing all rationality constraints jointly eliminates pure time preference from economic evaluation. If uncertainty is endogenous to the decision process, the new rationale for	None

Index	Authors (Year)	Title	Purpose	Does the paper *specifically* address any of the following parameters of the Ramsey equation?				Provide the following information only if the paper *specifically* addresses one or more of the parameters of the Ramsey equation			
									the consistency requirements that are imposed in the evaluation of uncertain scenarios.	discounting will yield quite different policy implications than the discounted expected utility model based on pure time preference.	
55	Traeger, Christian P. (2009)	Recent developments in the intertemporal modeling of uncertainty	To discuss the models and concepts that aim at disentangling time and risk attitude and briefly sketch a generalization of risk attitude to situations where uncertainty is not captured by unique probability measures.	□	□	□	□	No	The paper pointed out two limitations of the standard model for modelling risk aversion in a dynamic setting. First, the model confines Arrow-Pratt risk aversion to coincide with the aversion to intertemporal consumption fluctuations, implying intertemporal risk neutrality. Second, the model cannot capture an attitude for uncertainty that is not characterized by unique probability measures.	The intertemporal risk aversion and ambiguity aversion affect the social discount rate. The higher the aversion, the lower the certainty equivalent discount rate. Thus, under intertemporal risk aversion and risk, or under ambiguity aversion and uncertainty, projects featuring a certain transfer of consumption into the future are optimal. Finally, the pure rate of time preference was seen to be a contribution to the social discount rate that is in a way special to the discounted expected utility model.	None

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