Memorandum

TO: Lucia Ramirez
FROM: HDR and CH2M Hill
DATE: March 15, 2011
RE: Discounting Recommendations for Least Cost Planning in Oregon

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Executive Summary

Discounting is a method used to convert future costs and benefits into a common year. The procedure expresses future outcomes in their present value and permits the level-playing field comparison of options whose costs and benefits occur at different rates over time. The conversion involves the use of a discount rate -- the annual percentage change in the present value of a future dollar (or other unit of account). This memorandum addresses three questions in relation to the development of Least Cost Planning in Oregon, namely, whether OLCP should employ discounting; If so, at what rate? And how to approach the discounting of costs and benefits in the distant future.

Whether to discount in the OLCP process

SSC Options: YES or NO.

Consultant recommendation: YES, we believe discounting is a necessary feature of OLCP.

The size of the discount rate

SSC options: i) Continue ODOT's current practice based on Oregon's borrowing costs (about 4-5 percent in recent years); ii) Follow guidance from the White House Office of Management and Budget (OMB) and use a relatively high central rate (7 percent); iii) Follow OMB guidance, with sensitivity analysis at 3 percent; iv) Use OMB "analytically preferred" approach (3 percent with adjustments for the opportunity cost of public spending); and v) Use another discount rate value.

Consultant recommendation: Use a central rate of 3 percent, with "shadow pricing" of public expenditures and explicit considerations of project risks; always provide sensitivity analysis at 7 percent (without "shadow pricing"); consider sensitivity analysis using ODOT's current practice.

What to do about the distant future

SSC options: i) Keep the discount rate constant throughout the period of analysis; or ii) Use a discount rate that declines over time.

Consultant recommendation: Keep the discount rate constant for the first 30 years, and let the rate decline linearly from 3 percent to 2.5 percent between Year 31 and Year 50, and by 0.5 percentage points between Year 51 and Year 100, to a lowest value of 2.0 percent. Conduct sensitivity analysis on the rate of decline.

1. Introduction

This memorandum reviews the question of discounting and discount rates in relation to the development of Oregon's Least Cost Planning framework (OLCP). Section 2 explains the practice of discounting and the rationale behind it. Subsequent sections address three questions of relevance to the Stakeholder Steering Committee, namely, whether OLCP should employ discounting; If so, at what rate? And how to approach discounting in the distant future.

The more technical sections and paragraphs in this memorandum have been singled out under a Technical Discussion heading, and provide further information for interested readers.

2. What is Discounting?

Discounting is a method used to convert future costs and benefits into a common year for comparison. It is a procedure to express future outcomes in their present value. The conversion typically requires the use of a discount rate: the annual percentage change in the present value of a future dollar (or other unit of account).

While the technical details of discounting can become very intricate and obscure, and the choice of a discount rate has been debated for years in the literature, the basic proposition underlying discounting is a very simple one – namely, that in general people attach less value to outcomes that occur in the future as compared to outcomes that occur in the present. In other words, discounting relates to the idea that, *even with zero inflation*, the value attached to $1 received one year from now is typically less than the value attached to $1 received today. This in turn, reflects a general preference for the present, for instant rather than delayed gratification. This is why interest rates exist on savings accounts: people need to be paid something in order to delay the enjoyment of their money. As simple as it is in principle, the question of discounting leads to confusion and a wide range of issues and debate.

Why is it that the simple proposition of discounting generates so much confusion and debate?

Firstly, because in addition to the general preference for current consumption, outlined above, the need for discounting also arises in investment. From the investment perspective, future cashflows are discounted to account for their "opportunity cost", i.e., the need to forego rewards from alternative uses of funds[1]. We expand this discussion later, but note here that, under highly simplified and unlikely conditions, the consumption view and the investment view would lead to comparable discount rates. Such conditions include no tax or investment risk so that the rate at

[1] Note that the cost of *delaying* consumption, in the consumption perspective, is also an "opportunity cost" (cost of foregone *current* consumption).

which savers are rewarded for delaying consumption is equal to the rate at which investors borrow funds, which is itself equal to the rate of return on all investments. Confusion arises party because such conditions rarely pertain in the real world.

A second source of confusion is the impact of inflation and the distinction between "nominal" and "real" discount rates. As noted above, the need for discounting is not related to the general increase in the price of goods and services over time (i.e., inflation) and the corresponding erosion of the real purchasing power of a dollar. It is in addition to that. And the appropriate discount rate depends on whether the forecasts to which it is applied (e.g., future consumption or cashflows) is expressed in "nominal" terms (in inflated dollars) or "real" terms (in dollars of constant purchasing power relative to a base year, i.e., after the effects of inflation have been removed). A "real" discount rate should be used to discount future values measured in constant-dollar terms; a nominal discount rate should be used to discount future values measured in inflated-dollars[2]. In Benefit-Cost Analysis (BCA), which is concerned principally with the real value of economic resources, it is appropriate to use *real* discount rates.

A third source of confusion arises from the fact that a discount rate may be defined in reference to future consumption (or cashflows, dollars, project costs) or future "utility". Utility, in economics, means satisfaction or well-being. People consume food, automobiles, and hair-cuts, not for the sake of consuming but because they expect they will feel better-off having done so (their utility will increase). Similarly, when weighing the decision to delay consumption, people do not compare consumption today to consumption tomorrow, but the utility from consuming today to the utility from consuming tomorrow (they compare utility across different points in time). Yet, the discount rate is typically applied to benefits, costs, or cashflows with a direct equivalent in terms of consumption, not utility. We show later in the text that the discount rate on consumption may be expressed as the sum of a discount rate on utility and an adjustment for the growth of consumption per capita over time. The discount rate on consumption is what most economists have in mind when they simply refer to a "discount rate" (or, more precisely, as discussed below, to the rate of social time preference). The discount rate on utility is a more obscure concept, and has been referred to differently by different authors: "utility discount rate", "time preference for marginal utility", "pure time discount rate" (Stern (2006)), or "time discount rate" (Nordhaus (2008))[3].

Finally, selecting a *value* for the discount rate - in particular for use in the public sector - has generated many discussions, and publications. As explained later, a number of theoretical justifications have been put forward. A fundamental debate pits those who believe that the discount rate should be based on available evidence about peoples' preferences (e.g., how much income people actually chose to save every year; the actual return on competing investments; people's attitude towards the risk of death) against those who think that government discounting is a matter

[2] The nominal rate n is given by $(1+n) = (1+d)*(1+i)$, where d is the real discount rate and i is annual inflation.

[3] The discount rate on utility is also the discount rate on consumption if consumption (per capita) is constant over time.

of policy, that the discount rate should be set by decision-makers and/or public policy experts. The debate between these two views has been at the forefront of the discussions on climate change, in particular as to whether - and if yes, at what rate - the *utility* of future generations should be discounted.

Technical Discussion

2.1 How Discounting Works

Discounting is most commonly applied to an annualized time series of costs, benefits, and/or cashflows, expressed in constant dollars, through the following expression:

$$PV = FV / (1 + d)^t \qquad \textit{Equation 1}$$

Where: FV is the value, in year t, of a cost or benefit to be realized t years in the future;

d is the (real) discount rate; and

PV is the present value (or present discounted value) of the cost or benefit.

In this approach, the discount factor $(1/(1+d)^t)$ is falling exponentially over time; and the rate at which future values are adjusted – the discount rate – is *typically* held constant throughout the forecasting horizon[4]. This is called exponential discounting. This implies, in turn, that the relative valuation of costs (or benefits) arising at two points in the future only depends on the time between these two points, and not on the gap between the current period and the two future points[5].

These assumptions, however, have been challenged by some economists who, in the light of surveys and experiments, argue that individuals *tend to* make choices that are *not* consistent over time. For example, an individual may prefer to receive $1 today rather than $2 tomorrow; but may also prefer $2 in one year and one day to $1 in one year. This set of preferences is not compatible with "exponential" discounting. Alternatives have been proposed in the literature, including discounting at a declining rate or "hyperbolic" discounting.

There are different forms of hyperbolic discounting. But all implicitly assume that the ability to make distinctions between available options diminishes for more distant events[6], and that as a result people tend to use discount rates that decline over time. In its simplest form, hyperbolic discounting may be applied using the following formula, where all terms are defined as in Equation 1:

$$PV = FV / (1 + d \times t) \qquad \textit{Equation 2}$$

[4] See discussion on discounting in distant future later in the text.

[5] In other words, the marginal rate of substitution between consumption at any pair of points in time depends only on how far apart these points are.

[6] Karp (2005), page 264.

With hyperbolic discounting, the annual percent change in the discount factor - the *effective* discount rate - is *declining* over time. For example, from Equation 2 with $d = 7$ percent, the discount factor would fall by 7 percent between Year 0 and Year 1, but only by about 3 percent between Year 19 and Year 20.[7] In other words, the effective discount rate would fall from 7 percent to 3 percent within 20 years.

End of Technical Discussion

2.2 Core Decision Issues for SSC

The rest of the memorandum is structured around three core issues to be considered by the STIP Stakeholder Committee:

- Section 2: Whether to discount in the OLCP process;
- Section 3: The size of the discount rate; and
- Section 4: What to do about the distant future.

The memorandum also includes three technical appendices and a brief annotated bibliography. Appendix A provides estimates of discount factors for different years and using different discount rates (all estimates assume discounting at a constant rate). Appendix B provides a brief overview of government discounting in selected countries around the world. The schedule of discount rates we are recommending for use in OLCP can be found in Appendix C.

3. Should OLCP Use Discounting?

The benefits and costs[8] of transportation plans, projects or actions typically arise over multiple years. A light rail construction project, for example, would see large capital outlays in the first 3 to 5 years of the project, followed by 20 to 30 years of travel cost savings, emission reductions and livability benefits. Similarly, a pricing policy may have limited immediate set-up costs but long-lasting effects on congestion, travel times and air quality.

The purpose of discounting is to level the playing field when comparing alternatives whose costs and benefits occur through time at different rates and in different amounts. And because benefits and costs occurring at different points in time are valued differently (see Section 1), they must be *adjusted* prior to aggregation into a synthetic measure of social value, such as total net benefits or the benefit/cost ratio. More precisely, *if* we believe that benefits and costs occurring at different points in time are valued differently, *then* discounting becomes a necessary feature of the evaluation of transportation plans, projects and actions.

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[7] (1 + 0.07 x 1) / (1 + 0.07 x 0) – 1 between Year 0 and Year 1, and (1 + 0.07 x 20) / (1 + 0.07 x 19) – 1 between Year 19 and Year 20.

[8] And possibly other transportation "impacts" that do not fall in either category (e.g., change in local tax revenue).

3.1 SSC Options and Consultant Recommendation

SSC Options

The options available to the SSC are YES (discount transportation costs, benefits and other effects) and NO (do not discount).

Consultant Recommendation

Our recommendation is YES. We believe discounting is a necessary feature of OLCP.

In addition:

- *All* streams of costs and benefits should be discounted, but not necessarily at the same rate. Changes in greenhouse gas emissions, for example, should be discounted using the rate implicit in the estimate of the Social Cost of Carbon, regardless of what discount rate is used in the present valuation of other costs and benefits.[9] Certain health effects, in particular those expressed directly in terms of utility, may also need to be discounted at a specific rate.

- The discount rate may be applied to both monetized and non-monetized benefits[10]. We believe this option should be considered in OLCP, where applicable.

4. Size of the Discount Rate

This section explores the question of selecting a *value* for the discount rate. We first illustrate the impacts of different rates on the valuation of future outcomes and prioritization of plans (projects or actions) with different time profiles. We then provide an overview of the common theoretical justifications for setting a discount rate in the public sector and conclude with a set of recommendations for OLCP.

4.1 Effects of Discounting on Project/Plan Appraisal and Prioritization

In general, with higher discount rates, less value is assigned to future costs and benefits. Because benefits tend to arise later then costs, higher discount rates will typically reduce the project's apparent value proposition[11].

The impact of changes in the discount rate on the present value of future outcomes is illustrated in Table 1 below. The table shows the present value of $10 million worth of environmental benefits

[9] Interagency Group on the Social Cost of Carbon (2010).

[10] Circular A-4 of the White House Office of Management and Budget (OMB), for example, refers to a 1998 study, where the U.S. Environmental Protection Agency estimated cost-effectiveness by discounting both monetary costs and non-monetized emission reduction benefits at a 7 percent real rate.

[11] In a typical transportation project capital costs occur first while benefits materialize once the project is complete, and may extend well into the long term. Higher discount rates thus reduce the present value of future benefits more so than costs and thereby reduce the project's net benefits.

arising either 10, 30 or 50 years from now (in columns), assuming a real discount rate of 0 percent (no discounting), 3 percent, 7 percent, or 15 percent (in rows).

Table 1: Present Value of Future Environmental Benefits under Alternative Discount Rates, an Illustration

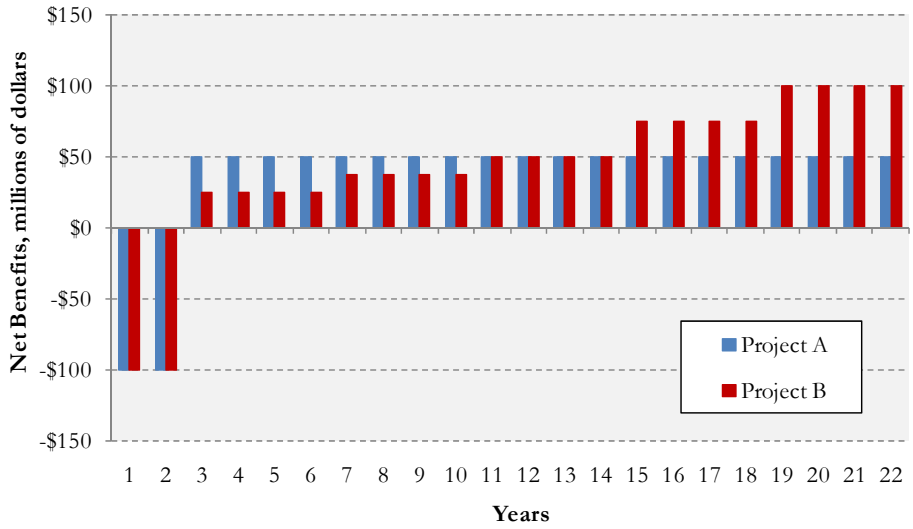
Discount Rate	Present Value of $10 million in Environmental Benefits Arising		
	10 Years from Now	30 Years from Now	50 Years from Now
0%	$10,000,000	$10,000,000	$10,000,000
3%	$7,440,939	$4,119,868	$2,281,071
7%	$5,083,493	$1,313,671	$339,478
15%	$2,471,847	$151,031	$9,228

Table 1 shows that, with an annual discount rate of 3 percent, the present value of $10 million in benefits arising in 50 years would be less than $2.3 million. With a discount rate of 15 percent, the present value would be reduced to less than $10,000! The relative impact of discounting is smaller for closer horizons.

But the choice of a discount rate not only impacts the present value of benefits and costs and the extent with which a given project (plan or action) may be deemed worthy, it also affects the ranking of projects whose costs and benefits are distributed differently over time.

To illustrate this, we consider two infrastructure investments of equal amounts ($200 million), generating comparable transportation benefits, but spread differently over a period of analysis of 20 years (20 years of operations, after project completion). Project A generates a steady annual flow of benefits, while Project B's benefits, initially low are increasing over time (Figure 1).

Figure 1: Time Profile of Costs and Benefits for Projects A and B



We then estimate the present value of future costs and benefits using different discount rates and calculate the Net Present Value of both projects (total discounted benefits *minus* total discounted costs). The outcomes of this analysis are shown in Figure 2.

Figure 2: Net Present Value of Projects A and B under Alternative Discount Rates

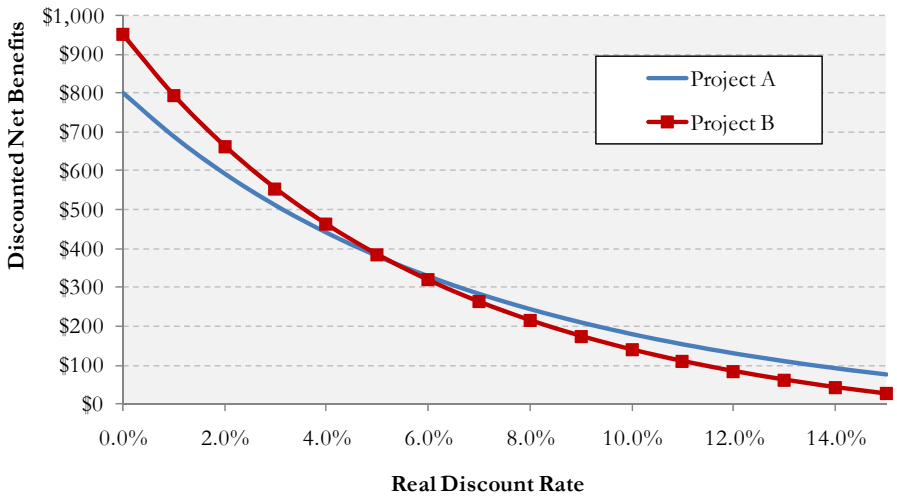


Figure 2 shows that with a low discount rate (5 percent or less), Project B would generate a higher Net Present Value than Project A and may be considered a "better" investment[12].

With real discount rates in excess of 5 percent, on the other hand, the Net Present Value associated with Project A would be greater, *suggesting* that Project A is a better investment. This obviously has important implications for OLCP, in particular for comparisons across modes.

In summary, what can we learn from these two examples?

- A higher discount rate will reduce the present value of benefits (and costs) arising late in the planning horizon;
- Under exponential discounting, benefits (and costs) occurring in later years may be reduced *considerably*;
- Changes in the discount rate may alter the relative ranking of projects (plans or actions) whose effects arise differently over time; and
- Other things being equal, a higher discount rate will tend to penalize projects (plans or actions) whose benefits arise relatively late.

[12] Other measures of worth would be used to validate this finding, including the Internal Rate of Return (the discount rate at which the present value of costs is equal to the present value of benefits, and the Net Present Value is zero), which – by definition – does not depend on the discount rate selected for analysis; or the Net Present Value per dollar of public investment, which does.

4.2 Theoretical Basis for Setting a Discount Rate

This section gives an *overview* of three approaches ("schools of thought") to setting the discount rate and summarizes their strengths and weaknesses. The section borrows from a number of existing syntheses, including OMB Circular A-94, OMB Circular A-4, and Spackman (2004) who provides an excellent summary of academic research and real world applications.

Cost of Capital

In the private sector, discounting is applied from the sole point of view of the prospective investor. The discount rate is typically set equal to – or at least based on – the cost of capital. The private sector cost of capital is commonly defined as the Weighted Average Cost of Capital (WACC): the rate that a company is expected to pay *on average* to all its security holders to finance its assets, including debt and equity. This approach to discounting has been referred to as "financial" discounting, as it focuses on the direct cost of funds, to the investor.

In the public sector, an equivalent approach consists of using the government's borrowing cost as a basis for setting the discount rate. This approach, however, has been criticized, in particular when applied in situations where the use of public funds may "displace" private investment (see Social Opportunity Cost of Capital, below)[13]. Others have remarked that the government cost of capital (derived from market rates and adjusted for corporate tax paid in the private sector) may be used as a sound basis for deriving the opportunity cost of public spending, but not for "time discounting"[14]; as current borrowing costs may not provide much insight into society's appreciation of future outcomes (i.e., time preference).

Discounting at the Oregon Department of Transportation

There is no official guidance for discounting at ODOT, but economists at the Department typically set the discount rate at the cost of borrowing to the State (Oregon's real cost of long-term debt). In recent applications, an annual interest rate of 4.75% (on 25-year bonds) has been used as a basis for discounting. With respect to the issue of project risk, the discount rate is viewed as "an effective tool to evaluate the risk associated with future benefits." In addition, it is typically assumed that the risk of an ODOT project is reflected in the spread between the risk-free interest rate of a long-term Treasury bond and Oregon's cost of long-term debt, and no premium is added to the latter for fear of "double-counting".

Sources: Conversation with Jack Svadlenak (03/03/2011); EDRG and Parametrix (2009)

[13] Harrison (2010).
[14] Spackman (2004), page 503.

Social Opportunity Cost of Capital

Discounting using the social opportunity cost (SOC) of capital is based on the premise that public spending and investment entails giving up another investment, possibly in the private sector.

The term "opportunity cost" is a central concept of economics, which holds that the true cost of resources is not necessarily what we pay to acquire them, but what we need to forego. Applied to public investment appraisal, the opportunity cost of capital reflects the rate of return on the investment elsewhere in the economy that may be foregone because of the proposed plan or project. This approach, grounded in the investment (or producer's) view of discounting, is applied to determining a discount rate for both public expenditures (e.g., plan or project costs) and benefits, typically measured in terms of consumption.

The value of the SOC for public investment depends on assumptions regarding the alternative use of government funds. If public funds are considered fixed (i.e., determined independently of the needs for public investment), the relevant comparator is the foregone return on other uses of funds within the public sector. If, on the other hand, total government spending may vary so that more - or fewer - investment projects may be accommodated in the private sector, then the SOC should be based on the (marginal) return on investment in that sector.

The SOC is commonly used as a basis for discounting in the United States. According to the OMB, it is the "appropriate discount rate" whenever the *main effect* of a project, plan or regulation is to displace or alter the use of capital in the private sector. The rate recommended by the OMB (7 percent, real) approximates the pretax rate of return on an average investment in the private sector in the 1970s and 1980s.[15] It is a broad measure that reflects the return to real estate and small business capital, as well as corporate capital.[16]

The SOC may be the "appropriate discount rate" under the above circumstances, but the OMB also comments that it is not the "analytically preferred means of capturing the effects of government projects on resource allocation in the private sector" (OMB Circular A-94, page 9). The "analytically preferred" method, according to the OMB, would consist of discounting at the rate of social time preference, and apply a "shadow price" to the use of public funds (both concepts are explained in the sections below). This view is shared by many economists.

[15] OMB Circular A-94, page 9.
[16] OMB Circular A-4.

Social Time Preference

Social Time Preference is defined as the value society attaches to present, as opposed to future, consumption. The Social Time Preference Rate (STPR) is used in the United Kingdom and other European countries (Appendix 2) as a basis for discounting in government. The associated discount rate is in the range of 3-4 percent.

Technical Discussion

In technical terms, the STPR is typically expressed as follows:[17]

$$r = \rho + \mu \cdot g \qquad \textit{Equation 3}$$

Where r is the STPR; ρ is the rate at which people discount future consumption over present consumption, *on the assumption that no change in per capita consumption is expected*; μ is the elasticity of the marginal utility of consumption[18]; and g the annual growth in consumption per capita[19]. The term $\mu \cdot g$ reflects the idea that if consumption grows over time, then the incremental satisfaction or well-being associated with one extra dollar of consumption (the marginal utility of consumption) will be lower in future. That extra dollar will be "discounted" accordingly.[20]

Furthermore, guidance on the STPR defines:

$$\rho = L \cdot \delta \qquad \textit{Equation 4}$$

Where L is associated with a "catastrophe risk" and is the likelihood that there will be some event so devastating that all returns from policies, programs or projects are eliminated, or at least radically and unpredictably altered (e.g. technological advancements that lead to premature obsolescence or natural disasters), and δ is the component associated, strictly, with pure time preference, reflecting individuals' preference for the present, with an unchanging level of consumption per capita over time, and absent a "catastrophe".

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[17] This presentation borrows heavily from HM Treasury (2003) and implies multiple simplifying assumptions regarding society's welfare function.

[18] The elasticity of the marginal utility of consumption is the relative weight or value society puts on a small increase in consumption. For example, with $\mu = 1.0$, the same increment in consumption would be valued half as much in a state of the world where utility (or well-being) is twice as large.

[19] Authors have suggested the addition of a third, "precautionary" effect, as follows: $r = \rho + \mu \cdot g - \frac{1}{2\rho^2\sigma^2}$, where σ is the standard deviation of the growth in per capita consumption.

[20] Importantly, growth in consumption, in and of itself, is a reason for discounting future costs and benefits.

A number of studies have attempted to estimate the STPR by quantifying its individual components. Estimates for ρ range between 1.0 and 1.6 percent per year[21]; μ is estimated to be around 1.0 or 1.5[22], and g typically assumed to be between 2.0 and 2.5 percent per year. Thus, HM Treasury estimates the STPR to be exactly 3.5 percent using the most widely accepted parameter values and assumptions: $r = 1.5\% + 1.0 \times 2.0\% = 3.5\%$.

End of Technical Discussion

In the United States, the rate that the average saver uses to discount future consumption is used as a measure for the STPR. As such, the real rate of return on long-term government debt is considered a fair approximation to this rate.[23] The OMB reports that it has averaged around 3 percent in real terms on a pre-tax basis, between 1973 and 2003.

Summary and Conclusions

An emerging consensus, among economists, involves using an estimate of the STPR to discount future benefits and costs. Since the STPR only focuses on the relative valuation of future vs. current consumption, with no reference to the opportunity cost of public funds, economists further recommend to adjust (to "shadow price")[24] expenditures to account for the social cost of public spending: the idea is that raising one extra dollar in taxation imposes a welfare loss (or cost to society) equivalent to more than one dollar of consumption. This gap is typically associated with the administrative cost of tax collection, as well as impacts on consumers and businesses, *including* impacts on private sector investment[25].

Another consensus concerns the treatment of uncertainty specific to a project, plan or action (e.g., the "optimism bias"[26] in the estimation of demand, or uncertainty in project costs). An approach commonly used to account for that uncertainty is to augment government borrowing costs, or other measures used as a basis for discounting, with a "risk premium." It is now widely believed, however, that uncertainty should be assessed directly, by considering probable variations in project cost and/or demand estimates through scenario testing or risk analysis; and that discount rates used in the public sector should not include any adjustment for plan or project risks.

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[21] Individual estimates for L and δ have also been derived.

[22] Although available estimates (derived from personal saving behavior, tax regimes, or experiments) vary considerably in magnitude, from 0.5 to 10! A range of 0.5 to 2.0, however, is generally considered most likely.

[23] In this context, the return on long-term government debt is thought to *reveal* social time preference; which is conceptually different from the approach in terms of borrowing costs introduced earlier.

[24] A "shadow price" is a factor by which an effect (cost or benefit) expressed in monetary terms is multiplied to calculate its "social" value. In the context of public expenditures, a factor of 1.2 or 1.3 has been proposed. The distortionary effects of government borrowing may also be considered in a BCA through the use of a shadow price.

[25] Note that the shadow pricing of public expenditures is recommended for benefit-cost analysis but is generally considered "irrelevant" for cost-effectiveness analysis.

[26] The optimism bias refers to the tendency of project appraisers, in the public and private sectors, to be overly optimistic. Evidence suggests that appraisers systematically overstate future demand, and systematically understate project costs (HM Treasury Green Book (2003), page 29).

These recommendations, however, are generally considered difficult to implement in practice and agencies throughout the world have often used "shortcuts":

- As stated earlier, in the United States, the OMB recommends the use of a central rate of 7 percent (based on an estimate of pre-tax return on private investment) for BCA. Upon review and approval by the OMB, agencies may also use a lower rate of 3 percent (derived from the federal borrowing rate) as the central rate, provided they shadow price public expenditures.[27] The U.S. Department of Transportation, in its latest TIGER application guidelines, recommends using the lower rate (3 percent) *for sensitivity analysis*, but makes no reference to shadow pricing.

- Many of the other countries listed in Appendix 2 are still basing their discount rates on estimates of return in the private sector or other measures of the social opportunity cost (of capital).

- France, on the other hand, provides an interesting case study. For over 20 years, a real rate of 8 percent was used to assess public investment projects and plans. This rate reflected, essentially: i) social time preference; ii) project risks; and iii) the shadow price of public funds. In 2005, a panel of experts recommended that the discount rate be reduced to 4 percent and instructions were given to assess project risks via scenario testing, and to shadow price the portion of project costs paid for with public subsidies (by a coefficient of 1.3).[28]

4.3 SSC Options and Consultant Recommendations

SSC Options

The options available to the SSC are as follows:

- **Option 1**: Continue ODOT's current practice of setting the discount rate at the cost of borrowing to the State, with no further adjustments for project risks;

- **Option 2**: Follow OMB guidance and (in situations where BCA techniques are used in OLCP) use a central rate of 7 percent;

- **Option 3**: Follow OMB guidance, with sensitivity analysis at 3 percent, and possibly lower or higher discount rates;

- **Option 4**: Follow OMB "analytically preferred" option and use a central rate of 3 percent (as a proxy for the STPR), with shadow pricing of public expenditures;

- **Option 5**: Use another discount rate value, to be determined by the SSC.

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[27] The federal borrowing rate is also recommended for use in cost-effectiveness analysis, without shadow pricing.
[28] De Robien (2005).

Consultant Recommendations

We believe that OLCP should generally comply with Federal grant requirements but not necessarily be restricted to the Federal requirements.

Our recommendation is to use **a central rate of 3 percent** (real), with shadow pricing of public expenditures and with explicit considerations of project risks (with scenario testing and/or risk analysis). This is, essentially, Option 4.

Our recommended central rate is based on the OMB's estimate of the STPR, which is viewed in the academic literature and among an increasing number of practitioners as the relevant concept for discounting in the public sector. Discounting at the STPR, however, fails to recognize the social cost of public spending and taxation. As a result, we also recommend that spending (net of user fees and tolls) be "shadow priced," using a coefficient whose exact value will be determined at a later stage of OLCP development.

Sensitivity analysis with a rate of 7 percent (without shadow pricing of public expenditures, but with explicit considerations of project-specific risks) should also be conducted. SSC may also consider using other discount rates for sensitivity analysis, including a rate based on Oregon's cost of capital, for continuity.

These recommendations only apply in situations where BCA techniques are used in OLCP.

5. What to do about the Distant Future

Economists generally agree that the discount rate should be reduced over time, for appraisals with time horizons *greater than 30 years*. This is due to a number of factors, including uncertainty about the determinants of the discount rate itself,[29] and – as mentioned in the introduction – empirical evidence suggesting that people discount at a lower annual rate for trade-offs involving the distant future. Both factors are somewhat distinct from another issue, that of inter-generational discounting (discussed below).

Although the idea of lower long-term discount rates is increasingly accepted, only a few agencies appear to recommend the use of declining rates in plan/project appraisal (including the UK Treasury and France's Commissariat au Plan, see Appendix 2). One problem, often highlighted in the literature, is the possibility of time inconsistencies, whereby a plan or project with short-term costs but benefits arising only in the very long term may appear more beneficial merely by waiting a year to do the analysis (OMB Circular A-4). Another problem is the added confusion created for analysts by a schedule of rates, as opposed to a single value.

[29] With longer horizons, the appropriate value of the discount rate becomes increasingly uncertain (e.g., far-distant consumption levels and interest rates are largely unknown). Economists have shown that, in these conditions, a properly weighted certainty-equivalent discount factor corresponds to the lowest discount rate having any substantial probability of occurring (OMB Circular A-4). This happens because future states of the world with higher discount rates are more heavily discounted in the estimation of the certainty-equivalent discount factor.

Discounting in the very long run, across generations, is an ethically loaded issue. Some believe that it is "ethically impermissible" to discount the *well-being* of future generations and that government should treat all generations equally (as discussed below, this is the position taken, with some nuances, by Sir Nicolas Stern in his famous 2006 climate change analysis). Others reject the *implications* of zero or very low long-term discount rates and believe it is more "equitable" to build-up the productive base of economies – in particular of poor countries – than to spend for future generations (Dasgupta (2006)). They also point out that if future generations are expected to be better off, the use of lower long-term discount rates might help transfer resources from poorer people today to richer people tomorrow, which many would consider unfair.

Spackman (2004) makes a distinction between policies[30] whose impacts "fall largely in the short and medium term but also extend into the very long term" on one hand, and those "dominated by the very long term", such as global warming, on the other hand (page 500). He argues that while present valuation with lower (*but not zero*) discount rates for impacts beyond 40 or 50 years may be reasonable for the former, the use of discounting seems inappropriate for the latter, as it may "hide" intergenerational judgment or distract analysts and decision makers from the real issues. He also highlights the "ethical maze" associated with distributing costs and benefits of climate change policies between developed economies and developing countries.

Technical Discussion

5.1 Setting a Discount Rate for the Very Long Term

Choosing a discount rate for the distant future is best approached with reference to the STPR and its components (Equation 3). This choice involves consideration of inter-generational trade-offs (reflected in ρ, the rate at which individuals discount future consumption over present consumption, holding consumption constant) *and* assumptions on how society values changes in the distribution of well-being and consumption risk among all people (implicit in the elasticity of the marginal utility of consumption).

Recall from Section 3.2 that ρ comprises two elements: the rate of pure time preference (δ) and catastrophe risk (L), the combined value of which has been estimated to range between 1.0 and 1.6 percent[31], based on *observed* saving rates and/or attitude towards risk of death. This "descriptive" approach to determining ρ has been criticized by many prominent economists, including Nobel Prize winners Robert Solow and Amartya Sen who have argued, convincingly, that decisions made by individuals over their own life time cannot be used as a basis for weighing the *welfare* of future generations. The critique was embraced by Sir Nicholas Stern in his 2006 Review of the Economics of Climate Change who explains: "the only sound ethical basis for placing less value on the utility

[30] Plans, projects or actions.
[31] See Section 3.2

(…) of future generation is the uncertainty over whether or not the world will exist, or whether these generations will all be present" (Part I, page 45).

But Stern's general position – of limiting the rate of inter-generational time preference (holding consumption constant) to the risk of extinction, independently of how current generations may actually be concerned about future generations – is controversial. Opponents include those who consider "consumer sovereignty" as a central tenet of BCA (the idea that plans, projects or actions must be evaluated primarily on the basis of consumers' tastes, including their inter-temporal preferences), and those who insist that, in a democracy, decision makers only represent current generations and should implement policies accordingly[32].

There is also considerable debate on the second component of the rate of social time preference ($\mu \cdot g$), and the elasticity of the marginal utility of consumption (μ) in particular. The value of 1.0 selected by Stern (2006), for example, implicitly assumes that the distribution of income and well-being amongst people within a generation, current or future, does not matter much. This assumption has been criticized by numerous authors, including those considering that egalitarian preferences should be given more weight in setting the STPR. This would entail, other things being equal, a *higher* value of μ.

Several additional considerations are relevant to select a discount rate for the very long term, many of which are summarized in Nordhaus (2008), Spackman (2006) or Stern (2006). In the table below, we provide plausible values of the STPR based on the limited set of parameters introduced in this section. These estimates are *for illustration only*. As discussed above, they imply views on equity and social justice Oregonians have not made. At the very least, the table suggests that significant sensitivity testing on the OLCP discount rate will be required.

Table 2: Plausible Values of the STPR

Utility Discount Rate	Elasticity of Marginal Utility of Consumption	Annual Growth Rate of Consumption Per Capita (g)					
		-1.0%	**0%**	**+1.0%**	**+2.0%**	**+3.0%**	**+4.0%**
$\rho = 0.1\%$	$\mu = 1.0$	-0.9%	0.1%	1.1%	2.1%	3.1%	4.1%
	$\mu = 1.5$	-1.4%	0.1%	1.6%	3.1%	4.6%	6.1%
	$\mu = 2.0$	-1.9%	0.1%	2.1%	4.1%	6.1%	8.1%
$\rho = 1.0\%$	$\mu = 1.0$	0.0%	1.0%	2.0%	3.0%	4.0%	5.0%
	$\mu = 1.5$	-0.5%	1.0%	2.5%	4.0%	5.5%	7.0%
	$\mu = 2.0$	-1.0%	1.0%	3.0%	5.0%	7.0%	9.0%
$\rho = 1.5\%$	$\mu = 1.0$	0.5%	1.5%	2.5%	3.5%	4.5%	5.5%

[32] Nordhaus (2008), in a broader critique of Stern's assumed social welfare function, summarizes this view in these terms: "It takes the lofty vantage point of the world social planner, perhaps stoking the dying members of the British Empire, in determining the way in which the world should combat the dangers of global warming. The world, according to Government House utilitarianism, should use the combination of time discounting and consumption elasticity that the Stern Review's authors find persuasive from their ethical vantage point." (page 174)

	$\mu = 1.5$	0.0%	1.5%	3.0%	4.5%	6.0%	7.5%
	$\mu = 2.0$	-0.5%	1.5%	3.5%	5.5%	7.5%	9.5%

Note that Stern (2006) considers annual consumption per capita growth rates ranging from 0 to 6 percent, but uses a preferred value of 1.3 percent, leading to a long-term STPR of 1.4 percent (0.1% + 1.0 x 1.3% = 1.4%).

End of Technical Discussion

5.2 SSC Options and Consultant Recommendations

SSC Options

Two options are available to the SSC. The first option is to keep the discount rate constant beyond 30 years, and throughout the period of analysis.

The second option is to use a discount rate that declines over time.

Consultant Recommendations

Our recommendation is to keep the discount rate constant for costs and benefits occurring within 30 years into the future, and let the rate decline linearly from 3 percent (our preferred central value) to 2.5 percent between Year 30 and Year 50, and from 2.5 percent to 2.0 percent between Year 51 and Year 100[33].

Our recommendation is based primarily on the empirical evidence outlined earlier in this paper, suggesting that people discount the distant future at declining rates, along with theoretical justifications in terms of uncertainty about the future. The rate of decline itself is somewhat subjective, but is in line with current guidance in the United Kingdom and France (see Appendix B). The impact of declining long-term discount rates on OLCP indicators and OLCP outcomes should be limited, in part because the decline itself is limited (from 3 to 2 percent over 70 years), and in part because projected outcomes after 30 years will already be severely discounted[34].

We also recommend that **additional sensitivity tests** be performed, using alternative rates of decline. More aggressive rates of decline may be considered, but the discount rate – even in the far distant future – should remain **greater than zero**.

Our recommended annual discount rates for the distant future can be found in Appendix C; this schedule of rates may be used as a direct input in future OLCP analyses.

[33] It is unlikely that the period of analysis for assessing plans, projects and actions under OLCP will extend beyond that horizon (100 years into the future).

[34] Recall that the discount rate is the annual percent change in the discount factor, whose value in Year 30 will be about 0.4 (with a 3 percent discount rate).

Appendix A: Discount Factors

The discount factor is the value $1/(1+d)^t$. It indicates how 1 dollar received t years in the future (where t varies from 1 to 30) would be perceived today, by an individual who discounts future income exponentially, at a discount rate d.

Year *(t)*	Discount Rates *(d)*										
	1.0%	**2.0%**	**3.0%**	**4.0%**	**5.0%**	**6.0%**	**7.0%**	**8.0%**	**9.0%**	**10.0%**	**15.0%**
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1	0.990	0.980	0.971	0.962	0.952	0.943	0.935	0.926	0.917	0.909	0.870
2	0.980	0.961	0.943	0.925	0.907	0.890	0.873	0.857	0.842	0.826	0.756
3	0.971	0.942	0.915	0.889	0.864	0.840	0.816	0.794	0.772	0.751	0.658
4	0.961	0.924	0.888	0.855	0.823	0.792	0.763	0.735	0.708	0.683	0.572
5	0.951	0.906	0.863	0.822	0.784	0.747	0.713	0.681	0.650	0.621	0.497
6	0.942	0.888	0.837	0.790	0.746	0.705	0.666	0.630	0.596	0.564	0.432
7	0.933	0.871	0.813	0.760	0.711	0.665	0.623	0.583	0.547	0.513	0.376
8	0.923	0.853	0.789	0.731	0.677	0.627	0.582	0.540	0.502	0.467	0.327
9	0.914	0.837	0.766	0.703	0.645	0.592	0.544	0.500	0.460	0.424	0.284
10	0.905	0.820	0.744	0.676	0.614	0.558	0.508	0.463	0.422	0.386	0.247
11	0.896	0.804	0.722	0.650	0.585	0.527	0.475	0.429	0.388	0.350	0.215
12	0.887	0.788	0.701	0.625	0.557	0.497	0.444	0.397	0.356	0.319	0.187
13	0.879	0.773	0.681	0.601	0.530	0.469	0.415	0.368	0.326	0.290	0.163
14	0.870	0.758	0.661	0.577	0.505	0.442	0.388	0.340	0.299	0.263	0.141
15	0.861	0.743	0.642	0.555	0.481	0.417	0.362	0.315	0.275	0.239	0.123
16	0.853	0.728	0.623	0.534	0.458	0.394	0.339	0.292	0.252	0.218	0.107
17	0.844	0.714	0.605	0.513	0.436	0.371	0.317	0.270	0.231	0.198	0.093
18	0.836	0.700	0.587	0.494	0.416	0.350	0.296	0.250	0.212	0.180	0.081
19	0.828	0.686	0.570	0.475	0.396	0.331	0.277	0.232	0.194	0.164	0.070
20	0.820	0.673	0.554	0.456	0.377	0.312	0.258	0.215	0.178	0.149	0.061
21	0.811	0.660	0.538	0.439	0.359	0.294	0.242	0.199	0.164	0.135	0.053
22	0.803	0.647	0.522	0.422	0.342	0.278	0.226	0.184	0.150	0.123	0.046
23	0.795	0.634	0.507	0.406	0.326	0.262	0.211	0.170	0.138	0.112	0.040
24	0.788	0.622	0.492	0.390	0.310	0.247	0.197	0.158	0.126	0.102	0.035
25	0.780	0.610	0.478	0.375	0.295	0.233	0.184	0.146	0.116	0.092	0.030
26	0.772	0.598	0.464	0.361	0.281	0.220	0.172	0.135	0.106	0.084	0.026
27	0.764	0.586	0.450	0.347	0.268	0.207	0.161	0.125	0.098	0.076	0.023
28	0.757	0.574	0.437	0.333	0.255	0.196	0.150	0.116	0.090	0.069	0.020
29	0.749	0.563	0.424	0.321	0.243	0.185	0.141	0.107	0.082	0.063	0.017
30	0.742	0.552	0.412	0.308	0.231	0.174	0.131	0.099	0.075	0.057	0.015

Appendix B: Government Discount Rates in Selected Countries

The table below provides some information on government discounting in a sample of countries, as well as guidance by the European Commission to countries applying for EU funds. The table is adapted from Spackman (2006) and Harrison (2010). All values are in real terms (i.e., real discount rates).

Country	Source	Theoretical Basis	Value
Australia	Commonwealth Finance Ministry, BCA Handbook, 2006	SOC for BCA; STP for specific applications (rarely used)	SOC rate reviewed annually
	Office of Best Practice Regulation, 2010	SOC, based on market interest rates	7% (with tests using 3 and 10%)
Canada	Treasury Board, BCA Guide, 2007	SOC (foregone private sector investment and consumption, with adjustments)	8%
France	Commissariat Général du Plan (experts working groups)	STP rate (since 2005)	4% (declining to 3% for $t > 100$)
Germany	Federal Finance Ministry guidance	Based on federal refinancing rate, adjusted for inflation	3%
Italy	Central guidance to Regional Authorities, 2001	Apparently based on STP	5%
Mexico	Federal guidance for BCA of investment programs and projects, 2008	Unknown	12%
New Zealand	Finance Ministry, BCA Primer, 2005	Based on Capital Asset Pricing Model	10%
Norway	Government wide recommendations	Apparently based on Government borrowing rate	3.5%
Spain	Central guidance, varies by sector	Apparently based on STP	6% (transportation)
United Kingdom	Her Majesty's Treasury, Appraisal and Evaluation in Central Government	STP rate (since 1980's)	3.5% (declining to 1% for $t > 300$)
United States	OMB Circular A-94	SOC (pretax return to private sector investment in the 1980's) for BCA; federal borrowing rate for CEA; use of lower rate for BCA possible, with shadow pricing of public spending	7% for BCA (3% for CEA)
European Commission	Directorate General Regional Policy, BCA Guide, 2008	STP rate for BCA. Higher rate for countries with *faster* growth / convergence requirements.	3.5% (5.5% for Cohesion Fund countries)

Sources: Spackman (2006), Table A.1; Harrison (2010), Table 2.1.

Notes: BCA stands for Benefit-Cost Analysis; CEA, Cost-Effectiveness Analysis; SOC, Social Opportunity Cost; and STP, Social Time Preference.

Appendix C: Recommended Schedule of Discount Rates

Year *(t)*	Discount Rate *(d)*	Year *(t)*	Discount Rate *(d)*
1	3.0%	51	2.5%
2	3.0%	52	2.5%
3	3.0%	53	2.5%
4	3.0%	54	2.5%
5	3.0%	55	2.5%
6	3.0%	56	2.4%
7	3.0%	57	2.4%
8	3.0%	58	2.4%
9	3.0%	59	2.4%
10	3.0%	60	2.4%
11	3.0%	61	2.4%
12	3.0%	62	2.4%
13	3.0%	63	2.4%
14	3.0%	64	2.4%
15	3.0%	65	2.4%
16	3.0%	66	2.3%
17	3.0%	67	2.3%
18	3.0%	68	2.3%
19	3.0%	69	2.3%
20	3.0%	70	2.3%
21	3.0%	71	2.3%
22	3.0%	72	2.3%
23	3.0%	73	2.3%
24	3.0%	74	2.3%
25	3.0%	75	2.3%
26	3.0%	76	2.2%
27	3.0%	77	2.2%
28	3.0%	78	2.2%
29	3.0%	79	2.2%
30	3.0%	80	2.2%
31	3.0%	81	2.2%
32	3.0%	82	2.2%
33	2.9%	83	2.2%
34	2.9%	84	2.2%
35	2.9%	85	2.2%
36	2.9%	86	2.1%
37	2.8%	87	2.1%
38	2.8%	88	2.1%
39	2.8%	89	2.1%
40	2.8%	90	2.1%
41	2.7%	91	2.1%
42	2.7%	92	2.1%
43	2.7%	93	2.1%
44	2.7%	94	2.1%
45	2.6%	95	2.1%
46	2.6%	96	2.0%
47	2.6%	97	2.0%
48	2.6%	98	2.0%
49	2.5%	99	2.0%
50	2.5%	100	2.0%

Annotated Bibliography

De Robien, Gilles, "Instruction Cadre relative aux Méthodes d'Evaluation Economique des Grands Projets d'Infrastructures de Transport", March 2004, updated May 2005, Ministère de l'Équipement, des Transports, du Logement, du Tourisme et de la Mer

> *This document from the French Ministry of Transportation provides a general framework and a set of guidelines for the economic appraisal of infrastructure projects in the transportation sector. It covers a number of appraisal issues (e.g., definition of the base case, use of macro-economic forecast, development of demand forecast, benefit categories and sensitivity analysis) and includes a section and a technical appendix on discounting. The appendix provides general recommendations on the use of discounting in government and addresses, in some detail, the issues of risk, opportunity cost of public funds, and fiscal constraints.*

Economic Development Research Group and Parametrix, "Economic Comparison of the Alternatives for Tolling Projects", White Paper 6, prepared for the Oregon Department of Transportation, February 2009

> *This White Paper describes the use of benefit-cost analysis for prioritizing tolling project alternatives and comparing tolled against un-tolled options. It provides a number of recommendations for implementing benefit-cost analysis in Oregon, including guidance on discounting and the choice of a discount rate.*

European Commission, Directorate General Regional Policy, "Guide to Cost Benefit Analysis of Investment Projects, Structural Funds, Cohesion Fund and Instrument for Pre-Accession", July 2008

> *This document provides a broad conceptual framework and a "common appraisal language" for use by benefit-cost analysis practitioners in Europe. It includes guidance on financial analysis, economic analysis and on the calculation of performance indicators. The guide establishes a clear distinction between financial and economic discounting and includes a technical appendix on the choice of a discount rate. The appendix sets out the different rationales for discounting in the public sector and provides estimates of the Social Time Preference Rate for a sample of European Countries.*

Harrison, Mark, "Valuing the Future: the Social Discount Rate in Cost-Benefit Analysis", Australian Government Productivity Commission, April 2010

> *This paper explains the rationale for discounting in benefit-cost analysis, describes the different approaches to selecting a discount rate (focusing on the distinction between descriptive and normative approaches), and sets out a number of recommendations. The paper suggests using a discount rate based on the marginal rate of return on private capital, adjusted for taxation and foreign borrowing, of about 8 percent.*

Her Majesty's Treasury, "The Green Book: Appraisal and Evaluation in Central Government", Treasury Guidance, London, 2003, http://www.hm-treasury.gov.uk/data_greenbook_index.htm, last accessed 02/15/2011

> *The Green Book is a guidance document for the assessment (ex-ante and ex-post) of policies, programs and projects in UK Government. It describes the options and techniques that should be considered in benefit-cost analysis and provides detailed guidance on a number of issues, including the treatment of risk and uncertainty, distribution impacts, and discounting. The discussion on discounting is exclusively in terms of Social Time Preference, the recommended approach to selecting a government discount rate.*

Interagency Working Group on the Social Cost of Carbon for Regulatory Impact Analysis, Under Executive Order 12866, 2010, http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/sem_finalrule_appendix15a.pdf, last accessed 03/09/2011

> *This document provides an overview of the approach adopted by a group of Federal agencies to develop and recommend a set of estimates for the social cost of carbon. It provides an overview of the estimates used in past regulatory assessments and describes and documents a number of technical assumptions, including the choice of a discount rate. For the purpose*

of estimating the social cost of carbon, the working group recommends a central value of 3 percent, with sensitivity analysis at 2.5 percent and 5 percent.

Karp, Larry, "Global Warming and Hyperbolic Discounting", *Journal of Public Economics*, No. 89, 2005, pp. 261–282

This paper discusses the use of discounting in the study of long-lived environmental problems. It describes hyperbolic discounting as "a plausible description of how people think about the future" and demonstrates its implications in a theoretical model of global warming. The paper also addresses the issue of time inconsistencies introduced by declining discount rates.

Nordhaus, William, "A Question of Balance, Weighing the Options on Global Warming Policies", Yale University Press, 234 pages, 2008

This book uses the tools of economics and mathematical modeling to analyze different approaches to slowing global warming. It describes a model of the economy and climate (DICE-2007, Dynamic Integrated model of Climate and the Economy); and provides an analysis of Stern's 2006 Review using that model. The book includes a fierce criticism of Stern's approach to selecting a discount rate and of his estimates of the social cost of carbon.

Organization for Economic Co-operation and Development, "Cost-Benefit Analysis and the Environment: Recent Developments", Executive Summary, 2006

This book presents an in-depth assessment of recent conceptual and methodological developments in benefit-cost analysis, specifically in relation to environmental problems and environmental policy. Chapter 13 is entirely about discounting, an overview of which is provided in the book's executive summary. The overview emphasizes the limitations of the conventional approach (discounting at a constant rate), making reference to an alleged "tyranny of discounting."

Office of Management and Budget, Circular No. A-4, Regulatory Analysis, September 17, 2003, http://www.whitehouse.gov/omb/circulars_a004_a-4, last accessed 02/15/2011

This circular provides the OMB's guidance to Federal agencies on the development of regulatory impact analysis. It includes an excellent discussion on the rationale for discounting, and refers to OMB Circular A-94 for "basic guidance" on the discount rate. The document also addresses the issues of intergenerational discounting, and time preference for non-monetized benefits.

Office of Management and Budget, Circular No. A-94 Revised, Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs, October 29, 1992, http://www.whitehouse.gov/omb/circulars_a094, last accessed 02/15/2011

This circular provides general guidance for conducting benefit-cost analyses and cost-effectiveness analyses of federal programs and policies. It also provides specific guidance on the discount rates to be used in these evaluations.

Spackman, Michael, "Time Discounting and of the Cost of Capital in Government", *Fiscal Studies*, Vol. 25, No. 4, 2004, pp. 467–518

This paper reviews the main "conflicts" in the literature on public sector discounting and the reasons underlying them. It suggests practical procedures for discounting in government, which are consistent with most of the literature, but not with the "efficient market" hypothesis that financial markets provide all the information needed to define these procedures.

Spackman, Michael, "Social Discount Rates for the European Union: an Overview", Working Paper n. 2006-33, *Fifth Milan European Economy Workshop*, May 26-27, 2006

This paper is an augmented version of Spackman (2004), focusing on practices in the European Union and elaborating on some of the themes described in the earlier version.

Stern, Nicholas, "Stern Review on The Economics of Climate Change", HM Treasury, London, 2006, http://webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/sternreview_index.htm, last accessed 03/08/2011

This seminal review, headed by Sir Nicholas Stern, was commissioned by the UK Chancellor of the Exchequer. It examines the evidence on the economic impacts of climate change and explores the economics of stabilizing greenhouse gases. The review also considers the policy challenges involved in managing the transition to a low-carbon economy, and in ensuring that societies can adapt to the consequences of climate change. It includes a detailed discussion on discounting in the very long run, across generations; and adopts a very low discount rate in deriving an estimate for the social cost of carbon and assessing plans of actions.

Weitzman, Martin, "Gamma Discounting", *The American Economic Review*, Vol. 91, No.1, March 2001, pp. 260-271

This paper proposes a "new theoretical approach" to resolving the issue of selecting a discount rate for benefit-cost analysis. A numerical example is constructed from the results of a survey based on the opinions of 2,160 economists. The main finding is that even if every individual believes in a constant discount rate, the wide spread of opinion on what it should be makes the effective social discount rate decline significantly over time. Implications and ramifications of this proposed "gamma-discounting" approach are discussed.

Wikipedia, "Hyperbolic Discounting", http://en.wikipedia.org/wiki/Hyperbolic_discounting, last accessed 02/15/2011

This Wikipedia entry defines hyperbolic discounting and provides references to empirical evidence suggesting that people may discount at declining rates.