11-1-2001

Discounting in the Long Term

Coleman Bazelon

Kent Smetters

DISCOUNTING IN THE LONG TERM

Coleman Bazelon and Kent Smetters***

I. INTRODUCTION

Discounting addresses the problem of translating values from one time period to another. The larger the discount rate, the more weight an analyst places on costs and benefits in the near term over costs and benefits in the future. When evaluating policies that span generations, choosing a discount rate can have an overwhelming effect on the analysis. That choice, in turn, reflects the analyst's beliefs about the distant future.

This Article focuses on how to choose a discount rate for analyzing intergenerational public policy choices. These policies encompass issues such as global warming and nuclear waste disposal. The ongoing challenge is to characterize distant future costs or benefits in a way that is relevant for policy makers, who must evaluate trade-offs today. Unfortunately, the solution to that challenge lies in unknowable answers to what the world will look like in the deep future. For example, many analysts expect future generations to be wealthier than we are, but the degree of wealth can have a critical effect on our comparison of costs or benefits that future generations face in relation to ones we face.[1] We begin by discussing the underlying issues in choosing an appropriate discount rate for evaluating policies in the not-too-distant future. We then discuss the approaches used to discount distant future costs and benefits and how those approaches depart from the standard cost-benefit analysis.

---

* Vice President, Analysis Group/Economics. Internet: cbazelon@analysisgroup.com.

** Assistant Professor of Economics, Wharton School, University of Pennsylvania. Internet: Smetters@wharton.upenn.edu.

1. In this Article we adopt the nearly universal perspective of the economics profession of a Utilitarian ethical system.

II. DISCOUNTING IN THE NOT-TOO-DISTANT FUTURE

When future benefits or costs are completely certain, economic theory suggests discounting their values using a risk-free rate, which is typically taken as the return to some United States Treasury instrument.[2] However, when future benefits or costs are uncertain, the issue arises of how the calculation should be adjusted to take this uncertainty into account.[3]

Consequently, "[i]n private markets, investors demand a large premium to accept risky investments. Investments that are risky and whose outcomes are correlated with the investor's income should require an additional premium over a risk-free investment."[4] The premium represents compensation for taking on the risk. One example is the fact that unfavorable realizations of the risky investment are more likely when the investor's other income is down and the utility cost of a given loss of income is higher.

Moreover, "[t]he return to U.S. equities above U.S. government bills—known as the 'equity premium'—has averaged 6 percentage points per year during the past century, an astronomical difference when compounded over time."[5] In fact, this premium has been a puzzle because it is higher than can be explained by compensation for risk inside the standard neoclassical model.[6] Narayana Kocherlakota[7] and co-authors Jeremy Siegel and Richard Thaler[8] have written recent reviews of the equity premium puzzle in their respective articles. The puzzle humbles economists since it directly challenges our conventional understanding of how private agents respond to risk.

---

2. *See* Coleman Bazelon & Kent Smetters, *Discounting Inside the Washington D.C. Beltway*, J. ECON. PERSP., Fall 1999, at 213-14.
3. *See id.* at 214.
4. *Id.*
5. *Id.*
6. *See* Rajnish Mehra & Edward C. Prescott, *The Equity Premium: A Puzzle*, 15 J. MONETARY ECON. 145, 145 (1985).
7. *See generally* Narayana R. Kocherlakota, *The Equity Premium: It's Still a Puzzle*, 34 J. ECON. LITERATURE 42 (1996) (reviewing possible causes of the equity premium and concluding that various explanations seem insufficient).
8. *See generally* Jeremy J. Siegel & Richard H. Thaler, *Anomalies: The Equity Premium Puzzle*, J. ECON. PERSP., Winter 1997, at 191 (stating that the observed equity premium implies an extreme degree of risk aversion).

Beliefs about the cause of the equity premium can influence the appropriate choice of the risk premium used in policy analysis. On the one hand, if the equity premium is pure compensation for risk, then there would be little justification for the government to price its own risks at a rate different than the private market.[9] Of course, certain goods and services provided by the government (e.g., defense) might be fundamentally different than the *average* private market goods and services. It would not be correct, therefore, to simply incorporate the *average* equity premium when discounting risky public projects. But one could use valuation techniques to price public goods and services in the same way that private investors value new private goods and services. However, if the equity premium is, in part, due to inefficiencies in private markets, then a government policy that addresses those inefficiencies can possibly justify underpricing the risk relative to the private market.[10]

There is little evidence at this point to support the idea that the government should underprice risks relative to the private market.[11] Indeed, the costs of distorting taxation and the positive long-run correlation between stock and wage returns suggest that the government should possibly *overprice* risks relative to the private market.[12] Still, "existing models and empirical analysis are much too simple to show how the government might best exploit market imperfections."[13] Moreover, even if the government could exploit some market inefficiency and generate some "free wealth," the *opportunity cost* of using the "found wealth" for any particular purpose is not zero.[14]

A problem with using a single discount rate across all analyses is that this process considers each government program in isolation of the rest of the government's portfolio.[15] The correlation of a particular risk with the other risks that a taxpayer faces is

9. *See* Agnar Sandmo, *Discount Rates for Public Investment Under Uncertainty*, 13 INT'L ECON. REV. 287, 287 (1972).

10. *See, e.g.*, Henning Bohn, *Fiscal Policy and the Mehra-Prescott Puzzle: On the Welfare Implications of Budget Deficits When Real Interest Rates Are Low*, 31 J. MONEY, CREDIT & BANKING 1, 2 (1999).

11. *See* Bazelon & Smetters, *supra* note 2, at 213-16.

12. *See id.* at 216.

13. *Id.*

14. *See id.*

15. *See id.*

important.[16] Neither the government nor the private sector will need, in the language of insurance, a "risk load" to accept a large package of risks if all the risks are uncorrelated.[17] In many cases, however, the risks associated with government programs are correlated with each other, or with the other taxpayer resources such as their wage or capital income.[18] A risky government policy that posed a hazard of reducing a taxpayer's future disposable income presents relatively more hardship if the taxpayer's other income simultaneously declined. These risks would require a risk load.

A few very large risks—such as the Strategic Defense Initiative or demographic and economic risks facing Social Security and Medicare, as well as the risks in proposals to reform them—also pose a special problem.[19] This is because their returns cannot be adequately pooled with the risks of many smaller programs, even if they are uncorrelated.[20] When discounting for the very long term, this problem is only exacerbated: "For a single large risk, the proper discount rate is not only a function of the variation but it is also a function of the expected size and even sign of the expected net cost."[21] Furthermore, "the correct discount rate can even be negative!"[22]

Instead of calculating risk-adjusted discount rates, the proper approach to discounting is to take uncertainty directly into account by calculating a "certainty-equivalent" for the range of uncertain costs or benefits. The certainty-equivalent equals the amount of money that a person is willing to receive or pay to forego the uncertainty associated with the uncertain outcome. For example, the certainty-equivalent of a 50-50 gamble between winning $0 and $100 might be $40 for a risk-averse person.[23] In other words, such a person is indifferent between this gamble and receiving a guaranteed $40. Certainty-equivalence removes uncertainty from future values.

16. *See id.*
17. *See id.*
18. *See id.*
19. *See id.*
20. *See id.*
21. *Id.*
22. *Id.* at 217.
23. Technically, labeling an individual as risk-averse means that she would prefer some amount less than the actuarially fair value of the gamble of $50.

It is then proper to discount the stream of certainty-equivalent values at a risk-free rate.

Certainty-equivalent values can be computed with the aid of the options pricing technology pioneered by Fischer Black, Myron Scholes,[24] and Robert Merton.[25] An option can be viewed as a way of pricing downside or upside risk.[26] For example, a farmer who purchases an option to sell a future crop at a certain predetermined price is protected against a downturn in prices; that is, the option serves as insurance against a decline in crop prices, and the cost of the option is the associated "insurance premium" or the market-determined value of avoiding the associated risk. Conversely, stock options received by executives in the private sector offer the right to buy the stock at a prespecified price and date. The cost of such an option, if purchased on the open market, captures the upside potential of holding the stock. The Black-Scholes-Merton option-pricing technology is useful, since estimating option values depends only on price movements that are often observable for near-term analysis.[27] The genius behind option pricing is that observable market prices are assumed to reflect the market's underlying attitudes toward risk. Option pricing is especially useful if the policy change is assumed not to change observable market prices very much or complete a missing market that spans only to the near future. Unfortunately, these markets that make option pricing so useful and attractive for near-term policy analysis do not exist in the extremely long term.

III. DISCOUNTING IN INTERGENERATIONAL POLICY ANALYSIS

In the broadest sense, discounting over very long periods of time is no different than discounting over short periods. The basic rule—convert risky costs and benefits to certainty-equivalents and discount with a risk-free rate—still holds. But we do not have a developed

---

24. *See generally* Fischer Black & Myron Scholes, *The Pricing of Options and Corporate Liabilities*, 81 J. POL. ECON. 637 (1973) (presenting the theoretical valuation formula for pricing options).

25. *See generally* Robert C. Merton, *Theory of Rational Option Pricing*, 4 BELL J. ECON. & MGMT. SCI. 141 (1973) (discussing the Black-Scholes-Merton formula for option pricing and extending the theory).

26. *See id.* at 141.

27. *See id.* at 160-62.

market of government securities whose maturity spans two hundred or five hundred years, or other solid empirical evidence to apply the tools of near-term discounting to the deep future. As a result, our choices for the risk-free discount rate and for making adjustments for risk both unavoidably reflect the analysts' beliefs about the deep future. In what follows, we will provide a framework for identifying beliefs about the future and how they affect long-term discounting.

A. Long-Term Certainty-Equivalents and Consumption-Equivalents

All predictions about the values of economic variables in the deep future are inherently uncertain. For purposes of policy analysis, however, predictions about the deep future must be made, no matter how imprecise. Nevertheless, uncertain values should first be converted into their risk-adjusted certainty-equivalent before they are discounted. The bad news is that no serious work on making such adjustments has been done.

The approach to removing uncertainty from estimates used with near-term discounting—the Black-Scholes-Merton option pricing technology—typically cannot be directly applied to the very long-term. The reason is that no markets exist to estimate the relevant price moments in order to, for example, analyze the cost of a higher level of carbon dioxide (CO_2). Markets for certain types of risk do not exist, and even if they do, the contracts typically do not span many years. The option pricing technology can be used to calculate certainty-equivalents, but the calculations will be performed with parameter estimates reflecting an analyst's subjective beliefs rather than measurable estimates. Even basic information, including the long-run correlation between taxpayers' income and CO_2 levels, would be speculative at best.

A new issue arises when discounting over long time frames, which is often unimportant over shorter horizons, namely, the difference between a consumption discount rate and an investment discount rate. Taxes and other distortions drive a wedge between the lower marginal rate of substitution for consumers and the higher marginal rate of transformation in production. Simply put, a dollar diverted from investment costs the economy more, in terms of consumption, than a dollar diverted from consumption. In general, it is desirable to convert streams of benefits and costs to consumption-equivalents before they are discounted.[28]

B. The Social Rate of Time Preference (SRTP) or the Long-Term Risk-Free Rate

The appropriate risk-adjusted long-term stream of consumption-equivalent costs and benefits should be discounted at a risk-free rate. This rate, known in literature as the Social Rate of Time Preference (SRTP), can be decomposed into two parts.[29] The first part of the SRTP takes account of pure time preference.[30] The second part takes account of the idea that future generations are likely to be wealthier than us, making a given unit of consumption somewhat less valuable to them than it is to the current generation.[31]

It is a basic tenet of utility theory that individuals exhibit impatience. Treasury rates—taken as a proxy for the risk-free rate—are interpreted to represent the overall impatience of society. That exercise is unproblematic when the analysis covers a small number of years. Problems develop, however, when the analysis spans generations. While individuals certainly care about future generations, that concern may not be reflected in existing Treasury rates which are typically taken as reflecting the preferences of people currently living. For example, if people today care little about future generations, then existing Treasury rates would overestimate the weight that people today place on future generations.

---

28. *See* Robert C. Lind, *A Primer on the Major Issues Relating to the Discount Rate for Evaluating National Energy Options*, *in* DISCOUNTING FOR TIME AND RISK IN ENERGY POLICY 21, 36-39 (1982); *see also* K.J. Arrow et al., *Intertemporal Equity, Discounting, and Economic Efficiency*, *in* CLIMATE CHANGE 1995: ECONOMIC AND SOCIAL DIMENSIONS OF CLIMATE CHANGE 125, 130 (James P. Bruce et al. eds., 1996).

29. The SRTP is commonly expressed as SRTP = $\rho + \theta g$, where ρ is the pure rate of time preference, θ is the marginal utility of income, and g is the rate of growth of consumption. *See, e.g.*, William R. Cline, *Discounting for the Very Long Term*, *in* DISCOUNTING AND INTERGENERATIONAL EQUITY 131, 132 (Paul R. Portney & John P. Weyant eds., 1999).

30. *See* Arrow et al., *supra* note 28, at 131.

31. *See id.*

In practice, the discussion of long-term impatience in actual policy discussions is murky at best, as it tends to convolute the personal preferences of analysts with the more objective issue of trying to discover the rate of time preference held by society at large. For example, Frank Ramsey, the father of the neoclassical growth model, claimed that discounting future utility was unethical and lacked imagination.[32] To be sure, many analysts in academics and environmental groups might agree with Ramsey's sentiment (including both authors). However, some people in society, including those whose income would be significantly affected by a proposed policy change benefiting future generations, may not. Nevertheless, not incorporating pure impatience into long-term analysis may be the best baseline assumption, but it is ultimately a choice for the analyst.[33]

As noted in *Discounting Inside the Washington D.C. Beltway*, a zero discount rate raises a practical problem: "No discounting of future consumption flows means that consumption at some far-distant date can be just as valuable as consumption today."[34] Moreover, "since there are an infinite number of tomorrows but only one today, consumption from public goods might be postponed indefinitely with the government always investing for future consumption. Modern policy analysts and academics typically discount future utility to some degree in their analyses. In fact, so did Ramsey!"[35]

Positive discounting, however, comes not solely from the ethically questionable practice of positing an underlying preference for current generations over more distant ones, but from the assumption that future generations will likely be better off. Consequently, the second part of the SRTP accounts for the fact that, if later generations will enjoy a higher level of consumption, then they will attach less value to a marginal unit of consumption.[36] Just as a wealthy person today would value an extra dollars worth of consumption

32. *See* Frank P. Ramsey, *A Mathematical Theory of Saving*, ECON. J., Dec. 1928, at 543.
33. This assumption formalizes the Utilitarian ethical viewpoint.
34. Bazelon & Smetters, *supra* note 2, at 218.
35. *Id.* at 218-19.
36. The following discussion will assume that future societies are richer than our current society, a general trend in human history. The basic logic—if not sign—of the analysis, however, is unaffected if future generations are expected to be poorer.

somewhat less than a poor person today would, a richer society in the future would value an extra dollar of consumption somewhat less than today's society. The measure of this accounting for future societies' greater wealth is the growth of the rate of consumption scaled by the elasticity of marginal utility or, more plainly, how much utility fluctuates with changes in consumption.

C. Long-Run Productivity Growth

Even if we decide that the utility of each generation should be weighted equally, long-term discounting will typically be positive because of the second part of the SRTP construction just noted; in essence, current generations will want to leave relatively less to future generations who will enjoy more consumption. The estimation of the quantity of consumption future generations will enjoy relative to us today is rather tricky. In the long run, consumption growth must be determined by productivity growth. Consequently, beliefs about the long-term prospects for productivity growth are integral to the SRTP. Over the past 150 years since the industrial revolution, consumption has grown at an average annual rate of approximately 3%.[37] Looking back over a longer time frame of a thousand years or more brings the Middle Ages and even Dark Ages into the analysis and, therefore, lowers the annual average growth of consumption. What, then, is the right assumption about the distant future?

One school of thought, characterized by Partha Dasgupta et al., believes in limits to growth.[38] They begin by noting that consumption growth over the last few thousand years has barely been positive.[39] Looking forward, they believe that technological change will not overcome the constraint of a fixed ecology of the planet.[40] Even if measured income growth is positive going forward, negative environmental externalities can drive the social consumption growth rate

---

37. *See* Robert G. King & Sergio T. Rebelo, *Transitional Dynamics and Economic Growth in the Neoclassical Model*, AM. ECON. REV., Sept. 1993, at 908, 915.

38. *See generally* Partha Dasgupta et al., *Intergenerational Equity, Social Discount Rates, and Global Warming*, *in* DISCOUNTING AND INTERGENERATIONAL EQUITY 51 (Paul R. Portney & John P. Weyant eds., 1999) (discussing social discount rates).

39. *See id.* at 65.

40. *See id.*

to zero, or even to a negative rate. If future growth is indeed quite limited in this way then the appropriate discount rate is quite low, maybe even zero. This view leads to the proscription that current generations carefully limit their consumption in order to prevent the risk of leaving future generations in a world worse than the one we inherited.

Another school of thought, characterized by Martin Weitzman, believes productivity growth will continue to grow at a robust pace.[41] According to him, "[e]verything, then, comes down to estimating the deep-future effectiveness of human ingenuity to come up with new recipes of production for new circumstances."[42] The "endogenous growth" model by Paul Romer, in particular, argues that future productivity will mainly be determined by future ideas, which feed off of previous ideas.[43] In this sense, future growth is essentially limitless.[44] Under this view, current generations do not have to worry much about the consumption of future generations since they will, in any case, be much wealthier than us. The appropriate discount rate, therefore, would be positive, and possibly quite large.

However, given the uncertainty of the future, a precautionary approach suggests using a moderate discount rate. Indeed, this approach is roughly consistent with the Weitzman gamma discounting approach (a survey of economists' beliefs about long-term discount rates nicely fits a gamma distribution, hence the name "gamma discounting").[45] In particular, uncertainty about future discount rates causes the effective discount rate used in policy evaluation to decline over time.

The idea behind gamma discounting is to attempt to directly take into account the uncertainty in future discount rates. The central insight comes from taking the expected value of discounted net benefits calculated from a distribution of uncertain discount rates. An

---

41. *See* Martin L. Weitzman, *"Just Keep Discounting, But. . .", in* DISCOUNTING AND INTERGENERATIONAL EQUITY 23, 23-29 (Paul R. Portney & John P. Weyant eds., 1999) [hereinafter *Just Keep Discounting*].

42. *Id.* at 25-26.

43. *See* Paul M. Romer, *Increasing Returns and Long-Run Growth,* 94 J. POL. ECON. 1002, 1002-08 (1986).

44. *See id.*

45. *See* Martin L. Weitzman, *Gamma Discounting,* AM. ECON. REV., Mar. 2001, at 260, 269 [hereinafter *Gamma Discounting*].

example of a characterization of uncertain discount rates would be the following question: Will the discount rate in the year 2501 be 1% or 5%? The ultimate contribution to the expected value from the lower discount rate part of the distribution will be greater than the contribution from the present values calculated with the higher discount rates. Even if the chance that the discount rate will be low is the same as the discount rate being high, the magnitude of the present values calculated with the low rate will be much larger than the present values calculated with the higher rate. Indeed, Weitzman argues that "the high-rate believers discount away the relevance of their own scenario, leaving the future ultimately to the low-rate believers."[46] Consequently, as the time frame of analysis increases, uncertain beliefs about future discount rates will result in lower discount rates.

Gamma discounting has two important implications for long-term discounting. First, the discount rate declines over time at a hyperbolic rate. Second, the rate of decline in the discount rate is a positive function of the amount of uncertainty in the discount rate.

D. The Role of Correlation

Imagine for a moment that the threat of global warming did not possess the intergenerational long-time dimension. Standard cost-benefit analysis would suggest comparing the present value of the benefits of mitigation with the costs to determine whether or not carbon emission mitigation is worth it. One part of that analysis would convert the expected benefits from mitigation to certainty-equivalents. The certainty-equivalents of the benefits from mitigation would likely be higher than the expected value of the benefits from mitigation for several reasons. First, mitigation has an aspect of insurance value that is added to the expected benefits to calculate the certainty-equivalent. In addition, the likelihood of a negative correlation between global warming and society's income (e.g., a higher *stock* of pollution reduces production)[47] enhances that insurance value. Consequently, the *value of mitigation* is positively

46. *Id.*

47. Of course, the *flow* of pollution and income is likely to be positively correlated.

correlated with a nation's income. The properly calculated certainty-equivalents would then be discounted at a risk-free rate.

But global warming does have a long time frame that adds another dimension to the analysis. The risk-free discount rate for the long term, the SRTP, is proportional to consumption or income growth. Therefore, beliefs about the discount rate appropriate for long-term discounting are reflective of beliefs about how well off future societies will be. But, how well off future societies will be can affect how they value the benefits of a policy such as global warming mitigation. Unlike the near term discounting case, adjustments to calculate certainty-equivalents are not independent of the level of the discount rate.

The correlation between the future value of a policy variable and the discount rate used to translate that value back to the present has an important implication: the uncertainty underlying Weitzman's gamma discounting very likely is not independent of what is being discounted. That means that the effective discount rate should be higher in cases where future income and benefits are positively correlated and lower in cases where future income and future benefits are negatively correlated. But the degree of that correlation is likely unknowable and, again, subject to an analyst's prior beliefs.

E. Other Issues

The above narrowly focused economic analysis assumes away many other very important issues. A strong tension, in particular, exists between *inter*generational distributional fairness and *intra*generational distributional fairness. For example, one way to help future generations would be to leave them more trees. But this results in a loss of income to loggers.

Intragenerational distributional issues have made reaching a global agreement on greenhouse emissions all the more difficult. Carbon dioxide, in particular, is sometimes referred to as the "perfect externality." The reason is that, unlike some other greenhouse gases, CO_2's damage to the environment is, for the most part, independent of where in the world it is produced. As a result, it is important to think about reducing the *global* level of CO_2 emission, and to think about the *global* cooperation that is necessary to achieve this result. To be sure, a unilateral reduction in CO_2 emission by the United

States would benefit future generations if developing countries (in particular, China and India) maintain their current production levels. More realistically, however, the production of CO_2-intensive goods would probably migrate to developing countries, reversing much of the salutary outcome of a unilateral move. Convincing developing countries to maintain, and even reduce, their CO_2 emission in order to help future generations is a hard sell when production of CO_2-intensive goods puts food on the table for current generations.

Of course, according to the classic Coase theorem, an intergenerational and intragenerational trade-off need not exist if richer people simply pay poorer people to reduce the negative externality that they create.[48] The Coase theorem, however, strictly deals with efficiency and not distributional fairness.[49] For example, plans to reduce pollution, including the global CO_2 level, do not include enough financial incentives to entice developing countries to participate. Moreover, some developing countries appear reluctant to agree to the outside monitoring that would be necessary to verify domestic production levels of pollution. But the major stumbling block is primarily the reluctance of richer countries to pay developing countries not to pollute, even though such payments would make both countries better off relative to the status quo.

IV. PUTTING THE PIECES TOGETHER: A MODEST SUGGESTION

Despite the uncertainty and subjectivity of very long-term economic and policy analysis, it is still needed for the purpose of planning for the future. To that end, we suggest following the advice offered by Weitzman using gamma discounting, but with two caveats.[50] First, depending on the specifics of the policy under consideration, some small positive discount rate should be used in calculating the present value of events that occur in the very distant future. Second, thought should be given to the correlation between future incomes and the policy under study.

Based on a survey of Ph.D. economists, Weitzman recommends

48. *See* Ronald H. Coase, *The Problem of Social Cost*, J.L. & ECON., Oct. 1960, at 1, 1-2.

49. *See id.* at 18.

50. *See Gamma Discounting, supra* note 45, at 270.

a sliding scale of discount rates (see Table). Those discount rates are consistent with declining certainty equivalents for consumption growth, as reported in the last column of the table. Those rates are the certain growth rates of consumption (calculated using a value of the marginal utility of income of 1.5) that correspond to the discount rates reported in the middle column of the table. Interestingly enough, these rates are not far from the rates experienced historically over similar time periods.

TABLE 1

Time Period (years)	Recommended Discount Rate	Implied Certain Growth Rate of Consumption (ρ=0, θ=1.5)
1 to 5	4%	2.67
6 to 25	3%	2.00
26 to 75	2%	1.33
76 to 300	1%	0.67
more than 300	0%	0.00

First, note that the effective discount rate calculated by Weitzman approaches zero asymptotically. Since small differences in the discount rate can be significant when the analysis covers centuries or even millennia, using a zero discount rate for the distant future of over three hundred years is probably inappropriate. For analysis that spans more than three hundred years into the future, it is probably advisable to accurately calculate the effective discount rate instead of using the rounded recommendations in the table above.[51]

Moreover, careful thought should be given to the correlation of the future costs and benefits with future income or consumption. Ideally, that correlation would be taken into account when calculating certainty-equivalents. However, for most analysts simply calculating expected values may be a courageous enough act. In that case, sensitivity analysis of the discount rate in line with the correlation may be the best an analyst can do. Ignoring that correlation will

51. For a general discussion on the proposal of a new theoretical approach to the proper discount rate in cost-benefit analysis, see *Gamma Discounting*, *supra* note 45.

create a bias in the estimates. Even in the unlikely case of zero correlation, it is important to explore the sensitivity of the discount rate assumed.

One final thought on very long-term discounting: any present values calculated would have significant uncertainty bounds around them rendering only relatively blunt conclusions valid.