The Social Rate of Time Preference and the Social Discount Rate

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ABSTRACT

This paper explains the conceptual basis for the social rate of time preference (STP) and why it is the appropriate method of choosing the social discount rate (SDR), compared to the most prominent alternative method: the social opportunity cost of capital (SOC). We recommend that for intragenerational projects in the United States, a rate of 3.5 percent is appropriate. For long-term intergenerational effects, we recommend using declining rates.

Obtaining the SDR is intrinsically a normative exercise in a second-best world. Policymakers should maximize a social welfare function that equals the present value of current and future utility from per capita consumption. In the presence of economic growth, there will be greater future consumption possibilities. Given the assumption of diminishing marginal utility of income, the consumption of a wealthier, future society should be discounted. Displaced private investment should be accounted for by first multiplying by the shadow price of capital, but this will not generally be necessary as most government interventions mainly affect consumption. Systematic risk should be handled by conversion of expected net benefits into certainty equivalents before discounting at the risk-free SDR, but empirically this effect is typically too small to matter.

Among governments there is increased adoption of both the STP method and the use of time-declining rates. Even governments using other approaches are lowering their rates, and most OECD countries now apply rates in the 3 to 5.5 percent range.

JEL codes: H43, H50, H54

Keywords: social discount rate, social rate of time preference, benefit-cost analysis, shadow price of capital, social welfare function

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In a benefit-cost analysis (BCA) of a potential public project or regulation, analysts must forecast the expected net benefits over some time horizon. To aggregate net benefits into a project's net present value (NPV), appropriate weights—social discount factors—must be applied to impacts that occur in different years. For intragenerational projects (defined as those with up to a 50-year horizon), it is standard practice to use weights that decline at a constant rate. The annual rate of decrease of these factors is the social discount rate (SDR).[1] A higher rate results in a lower present value of a future net benefit. This effect is magnified the further into the future an impact occurs. Lower rates favor projects with greater future net benefits, and higher rates favor those with more immediate net benefits, when comparing projects with the same initial investment profile and operational costs. Hence the selection of the SDR is a crucial determinant of whether a potential policy intervention has a positive NPV and of the relative merits of various interventions.

The main purpose of this paper is to explain the conceptual basis for the social rate of time preference (STP) and why it is the appropriate method of choosing the SDR. There are five related purposes: to explain how to obtain reasonable estimates of the underlying parameters of the STP; to propose an estimate of the SDR for the United States; to consider how to account for displaced private investment; to discuss how to incorporate risk into BCA; and to assess the role of time-declining discount rates in the evaluation of intergenerational projects. Several governments have moved in the direction of using the STP method. Regardless of method, government recommended rates are converging to a lower level. Estimates for most countries in the Organisation for Economic Co-operation and Development (OECD) now fall in the 3 percent to 5.5 percent range. We conclude that for intragenerational projects in the United States, a rate of about 3.5 percent is appropriate. For projects with long-term intergenerational

1. All rates and net benefits are assumed to be measured in real, inflation-adjusted units.

effects, we propose the use of declining discount rates. Finally, the paper briefly considers the relative merits of an alternative SDR method: the social opportunity cost of capital (SOC).

1. THEORETICAL BASIS OF THE SOCIAL RATE OF TIME PREFERENCE

Choosing a method for obtaining the SDR is intrinsically a normative exercise. If the economy were in a first-best equilibrium (i.e., a state of economic efficiency), the choice would be uncontroversial. In this world, there would be a complete set of perfectly competitive markets, no externalities or informational asymmetries, no demand for public goods, no transaction costs or taxes, and all individuals could borrow or lend at the same market interest rate. All rational, utility-maximizing people would equate their marginal rate of time preference (MRTP), or the rate at which they wish to trade current for future consumption, with this interest rate when determining their time path of consumption. Every profit-maximizing firm would invest until its private marginal return on investment (ROI) was equal to this rate. The SDR would equal "the" market interest rate.

Real economies, however, have taxes and transaction costs, as well as multiple market failures such as informational asymmetries, externalities, incomplete and missing markets, public goods, and monopoly rents. Pretax returns on private investment exceed after-tax returns to private saving, and the rates on government debt typically fall between pre and posttax returns. In this second-best world, the choice of the SDR is not obvious. However, if a government intervention reduces present consumption in order to increase future consumption, the SDR should reflect the rate at which "society" is willing to make this trade.[2]

One approach is to base the SDR on the (presumed common) rate of individual MRTP by equating it with the return to saving, measured by the expected after-tax return to holding government debt. However, there are serious problems with this approach. First, individuals differ in preferences and opportunities. Some individuals are reducing their debt; this form of saving results in a much higher after-tax return than that earned on government bonds. Second, market interest rates only reflect the MRTPs of living individuals who participate in financial markets, and their preferences are effectively weighted by

2. Investment is important because it is the means of transforming present into future consumption.

their wealth. Third, credit rationing prevents many individuals from borrowing. Fourth, individuals do not always make rational, consistent intertemporal choices.[3] Individuals display time inconsistency; their rates of time preference decline over the time horizon.[4] Individuals use different rates to discount different types of choices.[5] Many individuals simultaneously borrow and lend; they pay down mortgages, save for retirement, and borrow on their credit cards.[6] While such behavior is not irrational per se, it is unreasonable to assume that everyone can freely borrow or lend and to equate their MRTP with a single market rate. Finally, there are serious problems with the aggregation of individual choices into social choices.[7] All these second-best realities seriously undermine the rationale for using market after-tax returns to savings as the basis for the SDR.

An alternative approach is to use the STP method.[8] This method assumes that policymakers should evaluate government interventions with the goal of maximizing social welfare: the present value of the utility of society (or, in practice, of a representative individual). Utility depends on per capita consumption of all private and public goods and services, in present and future time periods. Although individuals do not make consistent, well-behaved intertemporal consumption choices, society should make public investments as though they do.

Policymakers should therefore maximize a social welfare function (W) that equals the present discounted value of current and future utility from per capita consumption:

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3. Shane Frederick, George Loewenstein, and Ted O'Donoghue, "Time Discounting and Time Preference: A Critical Review," *Journal of Economic Literature* 40, no. 2 (2002): 351–400.
4. David Laibson, "Golden Eggs and Hyperbolic Discounting," *Quarterly Journal of Economics* 112, no. 2 (1997): 443–77.
5. George Loewenstein and Drazen Prelec, "Anomalies in Intertemporal Choice: Evidence and an Interpretation," *Quarterly Journal of Economics* 107, no. 2 (1992): 573–97.
6. Robert C. Lind, "Reassessing the Government's Discount Rate Policy in Light of New Theory and Data in a World Economy with a High Degree of Capital Mobility," *Journal of Environmental Economics and Management* 18, no. 2 part 2 (1990): S8–S28.
7. Kenneth J. Arrow, *Social Choice and Individual Values*, 3rd ed. (New Haven, CT: Yale University Press, 2012 [1951).
8. F. P. Ramsey, "A Mathematical Theory of Saving," *Economic Journal* 38, no. 151 (1928): 543–59; Stephen A. Marglin, "The Social Rate of Discount and the Optimal Rate of Investment," *Quarterly Journal of Economics* 77, no. 1 (1963): 95–111; Martin S. Feldstein, "The Inadequacy of Weighted Discount Rates," in *Cost-Benefit Analysis*, ed. Richard Layard, 311–32 (Harmondsworth, UK: Penguin, 1972); Ian Malcolm David Little and James A. Mirrlees, *Project Appraisal and Planning for Developing Countries* (London, UK: Heinemann, 1974).

$$W = \int_0^\infty e^{-\rho t}\, U(c_t)\,dt \qquad (1)$$

where $U(c_t)$ represents the utility that society derives from per capita consumption during period t.[9] The discount factor, which is $e^{-\rho t}$, applies to the utility in period t (e is the exponential function).[10] The pure rate of time preference, ρ, reflects society's "impatience" and is the rate of decrease in the utility of incremental consumption purely because that utility occurs in the future. The solution yields the formula for the SDR:

$$\text{SDR} = \text{STP} = \rho + \eta g \qquad (2)$$

where $g = \frac{dC/dt}{c}$ is the rate of change in per capita consumption and $\eta = -\frac{dU'}{dc}\frac{c}{U'}$ is the absolute value of the elasticity of the marginal utility of consumption with respect to consumption.[11] Equation (2) assumes that there is no uncertainty with respect to the future growth rate.[12]

While ρ, g, or η could vary over time, we initially assume that they are constant. In the first-best world, investment continues until the return on investment (ROI) equals the STP, and the growth of consumption is socially optimal. However, in a second-best world, the ROI exceeds the STP, and there is too little investment relative to the welfare-maximizing amount. If a government intervention has a positive NPV when discounting at the STP, it improves social welfare by this measure (the "Ramsey rule").

The second term in equation (2) represents a normative social preference for more intertemporal equality in per capita consumption than would otherwise occur (i.e., consumption smoothing). With economic growth, there will be

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9. This incorporates the standard assumption that society can be represented by an infinitely lived, representative individual who consumes the average amount of consumption. Emmerling, Groom, and Wettingfeld argue that median consumption is a better proxy for the representative individual. Johannes Emmerling, Ben Groom, and Tanja Wettingfeld, "Discounting and the Representative Median Agent," *Economics Letters* 161 (2017): 78–81.

10. In discrete time, equation (1) would be written $W = \sum_0^\infty \left(\frac{1}{1+\rho}\right)^t U(c_t)$, and the discount factor for utility in period t would be $\left(\frac{1}{1+\rho}\right)^t$.

11. We drop the time subscript for simplicity. Equation (2) holds exactly for isoelastic utility functions, $U(c) = \frac{c^{1-\eta}}{1-\eta}$ *if* $\eta \neq 1$; $U(c) = \ln(c)$ *if* $\eta = 1$, and approximately for any time-separable utility function. Christian Gollier, *Pricing the Planet's Future: The Economics of Discounting in an Uncertain World* (Princeton, NJ: Princeton University Press, 2012).

12. Later we discuss the implications of risk for the STP.

greater consumption possibilities in the future. Given the standard economic assumption of diminishing marginal utility of income, the consumption of a future, wealthier society should be discounted to some degree. Thus, the second term in equation (2) is the product of g, the future growth rate of per capita consumption, and η, the percentage reduction in the marginal utility of per capita consumption as per capita consumption increases by 1 percent (i.e., the absolute value of the elasticity of the marginal utility of per capita consumption). If ρ and η are set to zero, society values each unit of consumption occurring in the future as equal to the value of a unit of consumption in the present, reflecting indifference to temporal inequality. In contrast, as η approaches infinity, society completely discounts future consumption.

2. ESTIMATES OF SDR PARAMETERS FOR THE STP METHOD

The STP method requires estimates for g, η, and ρ.

2.1. Estimates of the Expected, Future Growth Rate of Per Capita Consumption (g)

Most methods of forecasting the growth rate either rely on extrapolation from historical data or combine that extrapolation with expert judgment. Many researchers propose an estimate of 2 percent for the growth rate of US per capita consumption.[13] Drupp et al. survey 197 experts regarding the parameters in equation (2) for long-term discounting and find an average g of 1.7 percent.[14]

To predict g by extrapolating from historical, country-specific growth rates, one can regress the natural logarithm of real per capita consumption on time. Using annualized per capita quarterly data from the Bureau of Economic Analysis on real US consumption expenditures for 1947–2002, we estimate g for the United States at 2.3 percent.[15] Shiller's long-term data on US real per capita consumption yields an average annual growth rate of approximately 2.2 percent from 1947 to

13. Edward C. Prescott, "Prosperity and Depression," *American Economic Review* 92, no. 2 (2002): 1–15; David J. Evans and Haluk Sezer, "Social Discount Rates for Six Major Countries," *Applied Economic Letters* 11, no. 9 (2004): 557–60; William D. Nordhaus, "A Review of the Stern Review on the Economics of Climate Change," *Journal of Economic Literature* 45, no. 3 (2007): 682–702; Martin L. Weitzman, "A Review of the Stern Review on the Economics of Climate Change," *Journal of Economic Literature* 45, no. 3 (2007): 703–24.
14. Moritz Drupp et al., "Discounting Disentangled," *American Economic Journal: Economic Policy*, August 2018, https://assets.aeaweb.org/assets/production/files/6568.pdf.
15. Mark A. Moore et al., "'Just Give Me a Number!': Practical Values for the Social Discount Rate," *Journal of Policy Analysis and Management* 23, no. 4 (2004): 789–812.

2009, although it has trended downward.[16] Between 1999 and 2009, it averaged 1.63 percent per annum. Averaging 2.2 percent and 1.6 percent yields 1.9 percent as an estimate of g.[17] The most recent FRED data indicate a postwar average (1947–2018) of 2.24 percent.[18] Given these estimates, a growth rate of around 2 percent seems reasonable, with sensitivity analysis in the range of 1.75 to 2.25 percent.

2.2. Estimates of the Elasticity of the Marginal Utility of Consumption (η)

This parameter represents the degree of social aversion to intertemporal inequality in consumption.[19] There are at least four methods of estimating η.[20] The first method adopts a life-cycle model of household behavior; η is taken to be the inverse of the intertemporal elasticity of substitution.[21] The second method assumes that individuals have additively separable preferences for some commodity, usually food (so that the marginal utility of food consumption is independent of the consumption of other goods). With this method, η can be derived from estimates of the income elasticity, compensated price elasticity, and budget share of the additively separable commodity.[22] The third method directly esti-

16. These data can be downloaded from www.econ.yale.edu/~shiller/data/chapt26.xlsx. These data are an update of the data shown in chap. 26 of Robert J. Shiller, *Market Volatility* (Cambridge, MA: MIT Press, 1989), and Robert J. Shiller, *Irrational Exuberance* (Princeton, NJ: Princeton University Press, 2015).
17. Mark A. Moore, Anthony E. Boardman, and Aidan R. Vining, "More Appropriate Discounting: The Rate of Social Time Preference and the Value of the Social Discount Rate," *Journal of Benefit-Cost Analysis* 4, no. 1 (2013): 1–16.
18. See Federal Reserve Economic Data (FRED), https://fred.stlouisfed.org/series/A794RX0Q048SBEA.
19. In other contexts, it is also taken to represent aversion to inequality in consumption across states of nature (risk aversion) and among individuals at a moment in time (intratemporal inequality aversion). Atkinson et al. conclude that individuals are not equally averse to these different sources of consumption inequality. Giles Atkinson et al., "Siblings, Not Triplets: Social Preferences for Risk, Inequality, and Time in Discounting Climate Change" (Economics Discussion Papers, No. 2009–14, Kiel Institute for the World Economy, January 27, 2009).
20. Ben Groom and David Maddison, "New Estimates of the Elasticity of Marginal Utility for the UK," *Environmental and Resource Economics*, March 30, 2018, https://link.springer.com/content/pdf/10.1007/s10640-018-0242-z.pdf.
21. David Pearce and David Ulph, "A Social Discount Rate for the United Kingdom" (CSERGE Working Paper GEC 95-01, Centre for Social and Economic Research on the Global Environment, University College London and University of East Anglia, 1995).
22. Ragnar Frisch, "A Complete Scheme for Computing All Direct and Cross Demand Elasticities in a Model with Many Sectors," *Econometrica* 27 (1959): 177–96; Erhun Kula, "Derivation of Social Time Preference Rates for the United States and Canada," *Quarterly Journal of Economics* 99, no. 4 (1984): 873–82.

mates η by surveying individuals,[23] politicians,[24] or experts[25] regarding their aversion to intertemporal or intratemporal inequality. The fourth method estimates η from income tax schedules, using the degree of progressivity in the tax code to reveal society's preference for reducing inequality and assuming that this intratemporal aversion to inequality can be applied to intertemporal inequality.[26]

The first two methods of estimating η rely on measures of individual behavior in markets, and consequently we argue that they will not usefully reveal social preferences regarding intertemporal equality, as discussed above. Estimates based on these two methods vary, with most being in the range of 1 to 2.[27]

The STP method attempts to represent individuals' preferences for aggregate behavior as a society. So, we prefer to estimate η based on aggregated evidence of stated preferences for smoothing consumption. One means is to employ survey data. Layard, Mayraz, and Nickell use six surveys of experienced happiness as a function of income, covering more than 50 countries between 1972 and 2005.[28] They estimate that the marginal utilities of income or consumption are in a narrow range from 1.19 to 1.3, with an average of 1.26. Alternatively, one could survey the preferences of democratically elected politicians for consumption smoothing, under the assumption that they represent some aggregation of individual preferences for social intertemporal inequality aversion. A survey of Turkish politicians finds that their preferences are consistent with an isoelastic utility function and a value of 1 for η.[29] Finally, Drupp et al.'s survey of 197 experts finds an average value for η of 1.35.[30]

A fourth means of estimating η is based on the "equal absolute sacrifice" approach. This method assumes that a country's tax schedule is designed such that the marginal utility of the tax burden is the same for all individuals. A more progressive tax schedule implies a greater decrease in marginal utility at higher

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23. Richard Layard, Guy Mayraz, and Stephen Nickell, "The Marginal Utility of Income," *Journal of Public Economics* 92, no. 8–9 (2008): 1846–57.
24. David John Evans, Erhun Kula, and Yoko Nagase, "The Social Valuation of Income: A Survey Approach," *Journal of Economic Studies* 41, no. 6 (2014): 808–20.
25. Drupp et al., "Discounting Disentangled."
26. Nicholas Stern, *The Economics of Climate Change: The Stern Review* (New York: Cambridge University Press, 2007).
27. Kenneth J. Arrow et al., "Intertemporal Equity, Discounting, and Economic Efficiency," in *Climate Change 1995: Economic and Social Dimensions of Climate Change*, ed. James P. Bruce, Hoesung Lee, and Erik F. Haites, 128–44 (Cambridge, UK: Cambridge University Press, 1996); Groom and Maddison, "New Estimates of the Elasticity of Marginal Utility for the UK."
28. Layard, Mayraz, and Nickell, "The Marginal Utility of Income."
29. Evans, Kula, and Nagase, "The Social Valuation of Income: A Survey Approach."
30. Drupp et al., "Discounting Disentangled."

income levels, and therefore a larger value for η. Assuming an isoelastic utility function,

$$\eta = \frac{ln\left(1 - \frac{\delta T}{\delta Y}\right)}{ln\left(1 - \frac{T}{Y}\right)}, \quad (3)$$

where $\frac{\delta T}{\delta Y}$ = the marginal income tax rate and $\frac{T}{Y}$ = the average income tax rate. Interpreted strictly, this function implies a smoothly changing tax schedule, rather than one with a limited number of tax brackets. Progressive tax systems always yield estimates that exceed one. And it is not clear exactly which taxes to include, nor which taxpayers' rates to use. Nevertheless, taxation decisions in a democracy must be defended before an electorate and implicitly contain social values regarding (at least intratemporal) inequality in consumption. Using this approach, Stern finds a value of 1.97 for η in the United Kingdom.[31] Evans and Sezer find values for six countries ranging from 1.3 to 1.7, with 1.43 for the United States.[32] Evans provides estimates for 20 countries; these all lie in a range between 1 and 1.8, with 1.35 for the United States.[33] Moore, Boardman, and Vining average various estimates for the United States to derive a central estimate of 1.35 for η.[34]

Groom and Maddison reestimate η for the United Kingdom using each of the four methods and provide a meta-analysis of existing studies.[35] They cannot reject the hypothesis that all four methods of arriving at an estimate, and all three interpretations of the parameter, are the same. Their central UK estimate of η is 1.5.

Thus, the most reasonable estimates of η range between 1 and 2. We think that the use of the tax data is an appropriate, normatively grounded compromise that incorporates aggregate social views. The estimates using this method for the United States are tightly clustered, ranging between 1.35 and 1.43. We recommend a central US value of 1.35 for η, with sensitivity analysis at 1.0 and 1.7.

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31. Nicholas Stern, "Welfare Weights and the Elasticity of Marginal Utility of Income," in *Studies in Modern Economic Analysis: Proceedings of the Annual Conference of the Association of University Teachers of Economics*, ed. Michael J. Artis and Avelino Romeo Nobay (Oxford, UK: Blackwell, 1977).
32. Evans and Sezer, "Social Discount Rates for Six Major Countries."
33. David John Evans, "The Elasticity of Marginal Utility of Consumption: Estimates for 20 OECD Countries," *Fiscal Studies* 26, no. 2 (2005): 197–224.
34. Moore, Boardman, and Vining, "More Appropriate Discounting."
35. Groom and Maddison, "New Estimates of the Elasticity of Marginal Utility for the UK."

2.3. Estimates of the Pure Rate of Time Preference (ρ)

For intragenerational projects there is little disagreement that ρ should be positive, because those currently alive prefer to consume sooner rather than later. For intergenerational projects, there has been considerable debate about the value of ρ, because a positive number implies that the current generation is discounting the utility of future generations.[36] However, if ρ is set equal to zero—weighting each generation's utility equally—then optimal growth models imply implausibly high rates of savings.[37] Using an estimate for η of 1.35 with ρ equal to zero, for example, produces an implied savings-to-income ratio of almost 75 percent. These rates of savings vastly exceed any observed in reality. Arrow suggests ρ should be set at around 1 percent to resolve this dilemma.[38]

Drupp et al. yield an average estimate for ρ of 1.1 percent.[39] While the choice of the SDR and its parameters is fundamentally a normative exercise, we argue that proposed values should not be too inconsistent with observed, aggregate behavior.[40] Given these considerations, an estimate of 1 percent for ρ is reasonable, although others feel that it should be zero because it is unethical to treat the happiness of future generations as inherently less valuable.[41]

36. Kula and EC suggest that ρ can be inferred from the population's annual death rate, an estimate of a representative individual's instantaneous probability of death. Kula, "Derivation of Social Time Preference Rates for the United States and Canada"; EC (European Commission), *Guide to Cost-Benefit Analysis of Investment Projects* (Brussels: European Commission Directorate General Regional Policy, 2008), http://ec.europa.eu/regional_policy/sources/docgener/guides/cost/guide2008_en.pdf. While this may make sense for individuals, who discount the future since they may not be around to enjoy it, it is not compelling from a societal perspective. Others, such as Stern, interpret ρ as the annual risk of complete societal disaster or extinction. Stern, *The Economics of Climate Change*. But this risk is estimated to be very small, on the order of 0.1 percent.
37. Kenneth J. Arrow, "Inter-Generational Equity and the Rate of Discount in Long-Term Social Investment" *Contemporary Economic Issues* 4 (1999): 89–102.
38. Arrow, "Inter-Generational Equity and the Rate of Discount in Long-Term Social Investment."
39. Drupp et al., "Discounting Disentangled."
40. Mark A. Moore, Anthony E. Boardman, and Aidan R. Vining, "The Choice of the Social Discount Rate and the Opportunity Cost of Public Funds," *Journal of Benefit-Cost Analysis* 4, no. 3 (2013): 401–9; John Creedy and Hemant Passi, "Public Sector Discount Rates: A Comparison of Alternative Approaches," *Australian Economic Review* 51, no. 1 (2018): 139–57.
41. Ramsey "A Mathematical Theory of Saving"; Gollier, *Pricing the Planet's Future*. However, Marini and Scaramozzino show that, with population and productivity growth, ρ can exceed zero without implying that any future generation's utility is being discounted relative to that of the present generation. Giancarlo Marini and Pasquale Scaramozzino, "Social Time Preference," *Journal of Population Economics* 13, no. 4 (2000): 639–45.

2.4. Estimates of the STP for the United States

We propose estimates of 1 percent for ρ, 2 percent for g, and 1.35 for η. Following equation (2), this yields an SDR of around 3.7 percent. With sensitivity analysis at 1.75 and 2.25 for g, and 1.0 and 1.7 for η, the SDR could range from a low of 2.75 to a high of 4.83 percent. Rounding, a central value for the SDR of 3.5 percent with sensitivity analysis at 2.5 and 5.0 is reasonable.

Drupp et al. yield an implied average value of 3.4 percent for the STP, using equation (2).[42] However, when asked directly for estimates of the SDR, respondents' average value was 2.25 percent, indicating that most gave answers that are not completely consistent with the STP equation.

3. DISPLACED PRIVATE INVESTMENT AND THE SHADOW PRICE OF CAPITAL

A public investment that sacrifices current consumption and generates a greater return than the STP raises social welfare. If the project sacrifices current investment as well as current consumption, then the forgone investment would have yielded future consumption possibilities at the higher ROI rate. To ensure that society is better off, resulting private-sector investment changes should be converted into consumption equivalents by multiplying them by the shadow price of capital (SPC) before discounting at the STP.[43] To value that lost consumption, we initially assume that a dollar invested in the private sector earns a return (net of depreciation) of the ROI during each period and is consumed in perpetuity. To obtain the present value of this consumption stream, we discount the amounts received each period at the STP to obtain

$$\theta = \frac{\text{ROI}}{\text{STP}} \qquad (4)$$

θ represents the SPC: the present value of the consumption resulting from investing one dollar in the private sector. This formula is based on a simplifying assumption that the entire investment return is consumed during the period in

42. Drupp et al., "Discounting Disentangled."

43. Otto Eckstein, *Water Resource Development: The Economics of Project Evaluation* (Cambridge, MA: Harvard University Press, 1958); Feldstein, "The Inadequacy of Weighted Discount Rates"; David F. Bradford, "Constraints on Government Investment Opportunities and the Choice of Discount Rate," *American Economic Review* 65, no. 5 (1975): 887–99; Lind, "Reassessing the Government's Discount Rate Policy in Light of New Theory and Data in a World Economy with a High Degree of Capital Mobility."

which it occurs. It is more plausible that some would be consumed and some reinvested. Suppose a constant fraction f of the return is reinvested each period, while the fraction $1-f$ is consumed. The SPC is then the present value of this consumption stream discounted at the SDR, yielding the following value for θ:

$$\theta = \frac{(1-f)ROI}{(STP - fROI)} \tag{5}$$

Moore, Boardman, and Vining use US data for the parameters in equation (5) and estimate $\theta = 2.2$. However, shadow pricing is usually unnecessary.[44]

3.1. When Shadow Pricing of Capital Is Unnecessary

For regulations that primarily affect private consumption (e.g., through higher prices), discounting should proceed at the STP. For cost-effectiveness studies of policies with similar time-profiles of expenditures, shadow pricing does not affect the results. For projects that are self-funded, shadow pricing does not affect the go or no-go decision (although it might affect project ranking.[45] If public investments are tax financed, then income taxes primarily affect consumption (since most income is consumed), and most other taxes fall even more heavily on consumption.[46] The main effect of engaging in a government project is thus to reduce consumption rather than investment. Shadow pricing is only important if a project significantly crowds out private investment, which is most likely when a project is debt financed in a closed economy. But most economies are open to financial capital flows and most projects are tax financed, so displacement of private investment is unlikely.[47]

4. ADJUSTING FOR RISK

Thus far, we assume a certain future consumption growth rate. What difference would risk to consumption growth make? If per capita consumption growth is

44. Moore, Boardman, and Vining, "More Appropriate Discounting."
45. Bradford, "Constraints on Government Investment Opportunities and the Choice of Discount Rate."
46. Arrow et al., "Intertemporal Equity, Discounting, and Economic Efficiency."
47. Moore, Boardman, and Vining, "The Choice of the Social Discount Rate and the Opportunity Cost of Public Funds."

normally distributed with variance σ^2, then according to Gollier,[48] equation (2) becomes

$$SDR = STP = \rho + \eta g - 0.5\ \eta^2\sigma^2 \tag{6}$$

Using Shiller's long-term US data, the variance of the growth rate of per capita consumption from 1947 to 2009 is 0.033 percent.[49] Using our US estimate of $\eta = 1.35$, this would only reduce our SDR estimate by 3 basis points.

Next, consider project risk. Because of optimism bias, net benefits are often overestimated. This is best dealt with by correctly estimating expected net benefits and further adjusting them (if necessary) in light of historical evidence. Project risk refers not to overestimated net benefits but to the risk that actual net benefits differ from their expected values. This risk can be divided into nonsystematic risk (uncorrelated with consumption) and systematic risk (correlated with consumption). The former is spread over the population and is negligible for any individual.[50] Also, nonsystematic risk will be almost completely eliminated if the portfolio of government spending (and, *a fortiori*, overall consumption sources) is spread across many projects.[51] Systematic risk should be handled by discounting certainty equivalents of net benefits at the risk-free rate in equation (6). But for almost all projects, the difference between a certainty equivalent and its expected value is too small to matter.[52]

Some analysts use the capital asset pricing model (CAPM) to propose that the SDR should incorporate a sizable systematic risk premium. However, the conditions required for this to approximate the correct method of discounting certainty equivalents at a risk-free rate are implausible for most projects.[53] And, given reasonable estimates of the degree of risk aversion and the variance in the growth rate, the risk premium would be insignificant.[54]

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48. Gollier, *Pricing the Planet's Future*.
49. These data can be downloaded from http://www.econ.yale.edu/~shiller/data/chapt26.xlsx (see footnote 7).
50. Kenneth J. Arrow and Robert C. Lind, "Uncertainty and the Evaluation of Public Investment Decisions," *American Economic Review* 60, no. 3 (1970): 364–78.
51. Harry Markowitz, "Portfolio Selection," *Journal of Finance* 7, no. 1 (1952): 77–91.
52. Mark A. Moore, Anthony E. Boardman, and Aidan R. Vining, "Risk in Public Sector Project Appraisal—It Mostly Does Not Matter!," *Public Works Management & Policy* 22, no. 4 (2017): 301–21.
53. *Inter alia*, systematic risk must increase linearly with time in exact proportion to the decrease in the discount factors. Moore, Boardman, and Vining, "Risk in Public Sector Project Appraisal."
54. Gollier shows that the premium for systematic risk, $\pi(\beta) = \eta\beta\sigma^2$, should be added to the risk-free rate in equation (6), where β measures the correlation of the project's rate of return and the growth

The limited degree of individual risk aversion and historical volatility of growth also drive the "equity premium puzzle": that investors require a 4 percent to 6 percent premium to hold risky equities, rather than about 1 percent.[55] Investors may be more risk averse than estimates of η indicate. Alternatively, investors may fear a greater decrease in the growth rate than has been historically observed.[56] Gollier argues that fear of an economic catastrophe simultaneously explains large equity risk premiums and very low risk-free rates.[57]

While the equity risk premium puzzle is still unresolved, one possibility is that many private-sector firms face nonsystematic risk because owners or managers cannot fully diversify their wealth. If so, the private sector requires higher returns on investment (and uses higher discount rates) than the CAPM implies. Further, there is no reason to use private-sector risk premiums in public project evaluation. In a second-best world it is more appropriate for the government to derive shadow prices for risk and time based on social welfare maximization.

5. INTERGENERATIONAL SOCIAL RATES OF TIME PREFERENCE

Some government interventions, such as climate change mitigation, have very long-term effects. There are at least two arguments in favor of time-declining discount rates for intergenerational projects.[58] The first is based on an uncertain SDR. Even if one uses the SOC approach, future investment returns are uncertain. Allowing for this uncertainty means that increasingly lower discount rates should

rate. Gollier, *Pricing the Planet's Future*. Given an average β of 1 and our estimates for η and σ^2, this premium is only about 5 basis points.

55. Rajnish Mehra and Edward C. Prescott, "The Equity Premium: A Puzzle," *Journal of Monetary Economics* 15, no. 2 (1985): 145–61.

56. Robert J. Barro, "Rare Disasters and Asset Markets in the Twentieth Century," *Quarterly Journal of Economics* 121, no. 3 (2006): 823–66.

57. Gollier, *Pricing the Planet's Future*. This view determines the current French government–recommended SDR. Émile Quinet, *L'Evaluation Socioéconomique des Investissements Publics: Tome 1, Rapport Final* (Paris: Commissariat générale à la stratégie et à la prospective, 2013), http://www.strategie.gouv.fr/sites/strategie.gouv.fr/files/archives/CGSP_Evaluation_socio-economique_17092013.pdf. France proposes an SDR of 4.5 percent for a project with $\beta=1$, based on a risk-free rate of 2 percent and a risk premium of 2.5 percent. Norway proposes a risk-free rate of 2.5 percent and an average risk premium of 1.5 percent. Norwegian Ministry of Finance, *Cost-Benefit Analysis. Official Norwegian Reports NOU 2012:16* (Oslo: Norwegian Ministry of Finance, 2012), https://www.regjeringen.no/contentassets/5fce956d51364811b8547eebdbcde52c/en-gb/pdfs/nou201220120016000en_pdfs.pdf. These are not nearly as high as some of the rates proposed by other governments that advocate the SOC method (which implicitly contain risk premiums).

58. Kenneth J. Arrow et al., "Should Governments Use a Declining Discount Rate in Project Analysis?," *Review of Environmental Economics and Policy* 8, no. 2 (2014): 145–63.

be used to discount consumption flows that occur further into the future.[59] To calculate the expected net present value of a project, one must take expectations of the possible discount factors rather than of the possible discount rates.[60] This results in a certainty-equivalent discount rate that declines as the time horizon grows.[61]

The second argument for time-declining discount rates is that consumption growth is risky and displays positive, serial correlation, meaning that random shocks accumulate over time. Using the STP method, decision makers should be risk averse and therefore care more about negative shocks to consumption than about equal positive shocks. As equation (6) shows, this results in the "prudence term" $-0.5\eta^2\sigma^2$, lowering the SDR. As the variance of the growth rate increases over the time horizon, this results in a schedule of time-declining SDRs.[62] In developed countries, estimates of the uncertainty can be based on long-run (100 years or more) econometric data.[63]

6. CHOOSING BETWEEN THE STP AND THE SOC

The STP method derives an SDR that reflects a reasonable social aggregation of preferences over intertemporal inequality, given actual savings behavior and estimates of future growth rates. This is sometimes labeled the "prescriptive" approach, since it explicitly prescribes values for the parameters on the right-hand side of equation (2).[64] The alternative is to set the SDR equal to a (weighted) SOC, calculated as some weighted average of the ROI, the MRTP, and the marginal cost of foreign funds.[65] This has been referred to as the "descriptive" approach,

59. Martin L. Weitzman, "Gamma Discounting," *American Economic Review* 91, no. 1 (2001): 260–71.
60. This is because the expected value of a function of a random variable is found by taking expectations of the function, not of the random variable. That is, $E(f(X)) \neq f(E(X))$, where X is a random variable and E is the expectations operator.
61. One might think that time-declining discount rates would result in time-inconsistent social choices; society could regret a decision simply because of the passage of time. However, time-declining rates result from uncertain future parameter values, not from time-inconsistent preferences.
62. Gollier, *Pricing the Planet's Future*.
63. Richard G. Newell and William A. Pizer, "Discounting the Distant Future: How Much Do Uncertain Rates Increase Valuations?," *Journal of Environmental Economics and Management* 46 (2003): 52–71; Ben Groom et al., "Discounting the Future: The Long and the Short of It," *Environmental and Resource Economics* 32, no. 4 (2005): 445–93; Cameron J. Hepburn et al., "Social Discounting under Uncertainty: A Cross-Country Comparison," *Journal of Environmental Economics and Management* 57 (2009): 140–50.
64. Arrow et al., "Intertemporal Equity, Discounting, and Economic Efficiency."
65. Arnold C. Harberger, "The Discount Rate in Public Investment Evaluation," in *Conference Proceedings of the Committee on the Economics of Water Resource Development* (Denver, CO: Western

as it uses market rates of return as sources for the parameters of the SDR. This distinction is highly misleading, as both methods combine prescription with description. The choice of the SDR is a normative exercise. Both methods rely on value judgments and, to some extent, on observable economic behavior.[66]

One justification for the SOC approach is that it is consistent with BCA norms. But these norms require value judgments: accepting the status quo distribution of income, treating the social marginal utility of consumption as equal for all individuals, giving standing only to those living and participating in markets, embracing Pareto optimality as a social goal, and using the Kaldor-Hicks compensation test. Any of these could be questioned on normative grounds, as could the determination that the government ought to price time and risk in the same manner as private firms and individuals.

The use of the SOC method of choosing the SDR is fundamentally an "opportunity cost of public funds" argument.[67] SOC proponents argue that when a public intervention occurs, it diverts resources from private investment, so the social returns on this investment should be viewed as the time value of the money and used to discount net benefits. But this means that the counterfactual to a government project is an equally funded private investment, absent market failure.

There have been two such justifications for the SOC method. The first is that any government project should be treated as funded on the margin by the issuance of government debt, and that this increased debt raises interest rates and primarily crowds out private investment as well as some private consumption and net exports.[68] However, not every project can be assumed to be debt funded. While some projects may be funded by increasing the debt, others—e.g., road maintenance or federal R&D—would likely be part of a balanced budget. In our view, governments make decisions about the debt level and subsequently decide whether to undertake various projects.[69] To the extent that public goods

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Agricultural Economics Research Council, 1969); Agnar Sandmo and Jacques Drèze, "Discount Rates for Public Investment in Closed and Open Economies," *Economica* 38, no. 152 (1971): 395–412.

66. Seth Baum, "Description, Prescription, and the Choice of Discount Rates," *Ecological Economics* 69, no. 1 (2009): 197–205; J. Paul Kelleher, "Descriptive versus Prescriptive Discounting in Climate Change Policy Analysis," *Georgetown Journal of Law & Public Policy* 15 (2017): 957–77.

67. Moore, Boardman, and Vining, "The Choice of the Social Discount Rate and the Opportunity Cost of Public Funds."

68. David F. Burgess and Richard O. Zerbe, "Appropriate Discounting for Benefit-Cost Analysis," *Journal of Benefit-Cost Analysis* 2, no. 2 (2011): art. 2; David F. Burgess and Richard O. Zerbe, "The Most Appropriate Discount Rate," *Journal of Benefit-Cost Analysis* 4, no. 3 (2013): 391–400.

69. In a review of the United Kingdom history and policy of discounting, Spackman points out that "aggregate levels of public capital spending are in any case almost entirely macroeconomic and political decisions." Michael Spackman, "Government Time Discounting and Required Rates of Return: UK History and Current Issues," *Economic Affairs* 33, no. 2 (2013): 190–206.

are ultimately funded by tax dollars, the appropriate counterfactual to the government project is not lower debt and higher private investment, but lower taxes and more private consumption. Taxes primarily reduce current consumption rather than investment for the simple reason that consumption is a much larger share of total expenditure. Further, if some project is debt financed, then the STP method correctly accounts for any displaced private investment by shadow pricing. The SOC method tries to account for displaced investment by adjusting the discount rate. Since both the STP with the SPC and the SOC consider displaced investment, one might suppose that they would result in the same NPV. But this is not the case, except under very restrictive assumptions.[70] The second opportunity-cost justification for the SOC method is that private investment should be considered as the next best alternative to a government investment.[71] In a mixed economy, the government does not have the option to invest directly in the private sector.[72] But even if it does, the correct approach is to evaluate all possible government investments in both public and private sectors using the STP as the SDR, and then to invest in the highest-ranked projects first.

A final criticism of the SOC method is that private investment returns do not accurately measure the social marginal return to private investment. Private returns include monopoly and informational rents and do not net out negative externalities. Additionally, they are often estimated using the average rather than marginal returns on investment. Finally, private returns incorporate large risk premiums, but incorporating private-sector risk premiums in the SDR is incorrect for reasons discussed in section 4 and extensively in Moore, Boardman, and Vining.[73]

7. CONCLUSION

The method of obtaining a social discount rate is a normative choice. A government intervention that trades present for future consumption should reflect the rate at which society is willing to make this exchange. There is an increasing

70. Michael Spackman, "Time Discounting and of the Cost of Capital in Government," *Fiscal Studies* 25, no. 4 (2004): 467–518.
71. Peter Abelson and Tim Dalton, "Choosing the Social Discount Rate for Australia," *Australian Economic Review* 51, no. 1 (2018): 52–67.
72. Bradford, "Constraints on Government Investment Opportunities and the Choice of Discount Rate"; Richard C. Lind, ed., *Discounting for Time and Risk in Energy Policy* (Baltimore and Washington, DC: Johns Hopkins University Press and Resources for the Future, 1982); Arrow et al., "Intertemporal Equity, Discounting, and Economic Efficiency."
73. Moore, Boardman, and Vining, "Risk in Public Sector Project Appraisal."

academic consensus for the use of an optimal growth framework to derive the social rate of time preference as the SDR. We propose a rate of around 3.5 percent for the United States based on this STP method, given reasonable estimates of the underlying parameters.

Choosing interventions that pass an NPV test while discounting at this rate will improve social welfare, using a social welfare function that represents society as an infinitely lived agent that consumes the average amount of consumption in each period. The counterfactual to most interventions is higher current consumption, so this is the appropriate method. Any displaced private investment should be converted to consumption equivalents using a shadow price of capital (around 2 for the United States), although this will rarely be necessary. To account for systematic project risk, expected net benefits should be replaced by certainty equivalents before discounting at a risk-free STP, but this will hardly ever be required.

Using market-based interest rates as a basis for the SDR is inappropriate. Using private returns on investment as a measure of the opportunity cost of public projects is inappropriate mainly because investment in the private sector is not a reasonable counterfactual for most government interventions. This is particularly true for interventions with very long-term effects, as there are no private investments with maturities that match these time profiles. There are reasons to consider the use of time-declining SDRs for very long-term effects, although there is further work to be done in this area.

Current government practices vary, but there has been an increased adoption of the STP method and the use of time-declining rates.[74] Even governments using alternative approaches have been lowering their recommended rates, and most OECD countries now apply rates in a range of 3 percent to 5.5 percent.

74. See table 2 in Creedy and Passi for a summary of current government choices of method and proposed rates. Creedy and Passi, "Public Sector Discount Rates."

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