

# Resolving the discounting dilemma: Social time preference vs. social opportunity cost

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**ABSTRACT:** Because discounting both imputes the capital costs of investment projects and intertemporally weighs their benefits, no project-independent discount rate can perform both functions to everyone’s satisfaction. Discounting using the Social Time Preference Rate (STPR) results in undervalued capital costs, while discounting with the Social Opportunity Cost Rate (SOCR) may undervalue future benefits – at least in the eyes of those making the opposite choice, as STPR is generally smaller than SOCR. This article proposes a two-rate discounting method that uses SOCR only to compute capital costs but not to discount future benefits and uses STPR to discount future benefits but not to compute capital costs. There is no need to choose between the STPR and the SOCR; both are needed to reach correct benefit-cost analysis conclusions. If there is agreement on the value of the SOCR, there will be agreement on which projects are feasible because, regardless of the value of the STPR, the SOCR is the hurdle feasibility rate. Two-rate discounting is a more accurate correction to single-rate social time preference (STP) discounting than the shadow price of capital (SPC) or the marginal cost of funds (MCF) approaches.

**KEYWORDS:** Social discount rate; STP discounting; SOC discounting; Two-rate discounting; Shadow Price of Capital; Marginal Cost of Funds.

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# 1. Introduction

Referring to the familiar descriptive and prescriptive classification of approaches to discounting in benefit-cost analysis (BCA), William Nordhaus (2019) observed that the debate about discounting is “just as unsettled as it was when first raised three decades ago.” The prescriptive approach proposes a social time preference rate (STPR) based on ethical considerations, while the descriptive approach seeks to measure the social opportunity cost rate (SOCR) based on observed market data. The above classification, coined by Arrow et al. (1995), was common shorthand in the literature for a long time, but more recently the competing approaches have been referred to as social time preference (STP) discounting and social opportunity cost (SOC) discounting, after the names of their preferred social discount rates.

The dilemma is significant because discounting using the alternative rates may lead to very different conclusions. Because discounting performs two functions (the imputation of capital costs and establishment of intertemporal weights), discounting at low rates undervalues the cost of capital, to which adherents of the SOC approach object, while discounting at high rates attaches less value to future benefits, to which adherents of the STP approach object. High stakes are associated with the choice of discount rate, and advocates of both approaches often hold strong views. Freeman and Groom (2010) felt that these disagreements “raise the spectre of the near impossibility of reconciling” the STP and the SOC approaches to discounting. Spackman (2020) was blunter: “The divide between advocates of social opportunity cost and social time preference (STP) frameworks seems unbridgeable.”

A review of the literature by Groom et al. (2022) shows that both methods of discounting are used. Many have adopted the practice of using some version of STP discounting, which, coupled with the failure to make adjustments for the understatement of the opportunity cost of capital, results in incorrect BCA conclusions. This makes addressing the dilemma not just of academic interest but also of significant practical consequence.

To bridge this divide, this paper shows how the two functions of discounting should be achieved in two steps. In the first, the SOCR is used to calculate the opportunity cost of capital (which a project incurs until it fully amortizes the capital it uses), but it is not used to discount future benefits. Adjusting the primary net flow of projects by the costs of the capital used results in a net flow after capital costs that leaves only positive net benefits (in the case of feasible projects) that need to be assigned intertemporal weights. As the SOCR reflects the opportunity cost of capital, this step brings adherents of the two approaches closer together because there will be no disagreement concerning the cost of capital and agreement on which projects are feasible (i.e., generate net benefits after all costs, including those of capital).

In the second step, the STPR is used to discount future net benefits, but not to compute capital costs, since these have been accounted for in the first step. The question that remains for the second step is what rate should be used to assign intertemporal weights to net benefits? This paper suggests that the choice of rate depends on the purpose of the analysis. If the objective is to measure the welfare impact of projects as perceived by consumers (following the principle of willingness to pay), the appropriate STPR should be used. If the objective is to maximize the welfare impact of a given budget, then the SOCR should be used as the STPR. If the objective is to maximize another objective, an STPR that measures it should be used. Two-rate discounting using the appropriate STPR and SOCR will yield the BCA result suited to the objectives of the analysis

The paper is framed in the context of efficiency analysis, in which benefits are defined by willingness to pay, and costs by willingness to supply. The analysis does not consider income distribution effects, secondary effects, or other preferences of social planners. These considerations could be included in the specification of project flows if required. In any case, the question of how to account for the opportunity cost of capital when it differs from the rate of decline of the numeraire in the analysis will remain, and is the focus of this paper.

The analysis follows the conventional BCA assumption that the public sector is risk neutral. Risk neutrality does not disregard risk. It just allows calculations to be based on the expected values of the variables of interest as if they were deterministic.

The paper has eight sections. Section 2 shows that the two functions of discounting (imputation of the opportunity cost of capital and intertemporal weighing of remaining net benefits) can be performed as separate steps using the appropriate rate for each, and that this will measure the welfare impact of projects accurately. Section 3 shows why a generic shadow price of capital (SPC) cannot correct the understatement of capital costs that conventional STP discounting entails. Section 4 describes how the SOCR is generally defined. Section 5 explains why the adjustment for marginal cost of funds (MCF) is also unable to correct the error in STP discounting. Section 6 deals with the classification of ways of defining the STPR. Section 7 explains the proposed resolution of the dilemma. Section 8 presents conclusions.

## 2. Two-rate discounting

The meaning of the word “capital” can be ambiguous. For instance, when discussing production functions of capital and labor, it refers to durable goods such as machinery and equipment that are used in production. But it also refers to a stock of money used to finance the acquisition of durable goods, sometimes

called capital equipment. The acquisition of these goods in project analysis is a part of investment. This semantic ambiguity may lead to the confusion of capital with capital goods, which in turn leads to ambiguity about what is meant by the term “cost of capital.”

In this paper, the term “capital” will be used to denote stocks of money made available to projects, which typically have negative “primary flows” – net flows of benefits less all costs, except interest. (Interest costs are excluded to avoid double counting with the interest costs imputed by discounting.) The reason primary flows are initially negative is that capital equipment needs to be acquired and other costs incurred before sufficient benefits begin to be generated. We call these negative values “investments.” Investments are a flow, financed from capital, which is a stock. While the primary flow is negative, the stock of capital increases to cover the shortfall. Capital earns interest, however, which cannot be paid before benefits begin to be generated, so interest costs (a flow) are capitalized, that is, added to the capital stock used by the project. In BCA, instead of using a market interest rate to quantify the earnings of capital, we use the SOCR, which is a shadow price in the sense that it is the welfare cost of using a \$1 stock of capital for one year. Total capital costs are a combination of investments and the accumulated and compounded earnings of the capital stock committed to the project. The latter, which we call the opportunity cost of capital, is a flow, whereas the acronym SOCR always refers to the rate used to calculate it.

Discounting does not modify the investment flow; it keeps track of the required capital stock and automatically imputes the interest earned by that stock, using the discount rate as the interest rate. When a discount rate other than the SOCR is used, such as the STPR, the opportunity cost of capital is incorrectly calculated. As  $STPR < SOCR$ , the opportunity cost of capital is undervalued by STP discounting. More specifically, what is understated is not the value of investments, but the earnings of the capital stock. These foregone earnings are a function not only of investments and the SOCR but also of the timing and amount of project benefits. The lower the benefits, the longer it will take to amortize capital and the higher the opportunity cost of capital incurred in the meantime.

Marglin (1963) devised a correction to the undervaluation of the opportunity cost of capital that STP discounting entails, which will be discussed in Section 3 below. At this point, as an introduction to the concept of two-rate discounting, the following quote from Marglin (1963) is germane. It shows that two rates are needed to correctly compute the NPV of investment projects. “The answer is remarkably straightforward. [...] we plan public projects to maximize their net present value at the marginal social rate of discount, but, in evaluating the social cost of public investment, an opportunity cost reflecting the social value of utilizing resources in private investment *replaces* the money cost of the portion of the resources that comes from the private investment sector.” (Emphasis added.)

As the SOCR measures the opportunity cost of capital, the following example shows why both the STPR and the SOCR are needed to define a project's NPV. Take a project with infinite life that has capital costs  $K$  and yearly net operational benefits  $b$  accruing in perpetuity. In computing the present value of this project, Marglin's key insight was to "replace the money cost"  $K$  of the project by its future yearly opportunity cost  $K \times \text{SOCR}$ . The project's NPV therefore is:

$$NPV = -\frac{K \times \text{SOCR}}{\text{STPR}} + \frac{b}{\text{STPR}} \quad (1)$$

This expression reflects the assumption that, in the context of infinitely lived assets, committing capital  $K$  forever to the project incurs an opportunity cost of  $K \times \text{SOCR}$  every year, forever. It also shows that both STPR and SOCR are needed to calculate the NPV of the project. Neither rate can do it by itself.

The condition for NPV being positive is:

$$\frac{b}{\text{STPR}} > \frac{K \times \text{SOCR}}{\text{STPR}} \quad (2)$$

which reduces to  $b > K \times \text{SOCR}$ . This means that the feasibility hurdle rate of return for projects is the SOCR. The STPR is irrelevant. This is logical, as projects that fail to cover the opportunity costs of the capital used are welfare-destroying, a fact that is unaffected by the value of STPR. But meeting or exceeding the hurdle rate only ensures that the project is worth undertaking; to measure the present value of its welfare impact, however, we need the intertemporal weighing implicit in the STPR.

Using two interest rates to compute NPV is commonly used in financial analysis to assess how a project affects equity holders. The problem in that case is analogous to the one we face. A firm borrows to finance an investment. To calculate the return to the owners of the firm, we must convert the project flow into the flow to equity, namely the cash flow of the owners. For simplicity, assume that the owners finance the entire capital expenditure. To convert the project flow, we *replace* the initial capital expenditure with the debt service flow of the loan that finances it. The result is the flow to equity, which contains no initial investment but has net benefits reduced by the debt service of the loan. It is the project flow plus the funding flow (where disbursements are positive). This result is the equity holders' cash flow – undiscounted up to this point – from which a present value can be computed using the equity holders' opportunity cost of funds, which is different from the interest rate on the loan. With the proposed two-rate discounting method, the equity holders' role is played by society, which finances its capital requirements at the SOCR and discounts its cash flow at the STPR.

The first step in two-rate discounting requires computing the capital needs and opportunity costs of the project. This is done directly from the project's pri-

mary flow that we assume to be initially negative and positive thereafter. Capital finances negative project flows. The earned opportunity cost of capital is capitalized. Once the primary flow turns positive, all benefits are fully devoted to amortizing the capital allocated to the project until all of it has been repaid. This process defines the financing flow. Before full amortization is achieved, the financing flow is the negative of the primary flow: when the primary flow is negative, the financing flow exactly covers the shortfall; when the primary flow is positive, the financing flow is its negative because all benefits are devoted to the amortization of capital costs. Once these are fully amortized, we have reached the full payback period; the qualifier “full” added to indicate that not only have investments been amortized, but also the accrued opportunity cost of capital. The financing flow will be zero thereafter. Adding the financing flow to the primary flow yields the flow of net benefits. Before the full payback period, the flow of net benefits will be zero because project benefits have not yet covered all costs (see Appendix for an illustrative example). When net benefits are positive, this indicates that the project is feasible because it generates benefits after all costs. If the project is unable to amortize capital cost within the life of the project, it will not generate any net benefits. The residual value will be the unamortized balance of capital costs. Such projects are welfare-destroying.

The second step in two-rate discounting is to discount the flow of net benefits at the STPR to obtain the two-rate NPV.

An alternative and easier way to compute a two-rate NPV is by compounding the primary flow forward at the SOCR while the previously compounded value is negative. When it becomes positive, we have reached the full payback period. By this point, capital costs have been fully paid off, and the current compounded value is equal to that period's remaining benefit after final amortization. This value and all subsequent primary benefits are net benefits after capital costs. Compounding continues, but at the STPR rather than the SOCR, until reaching the time horizon of the analysis. The last compounded value is the future value (FV) of the project. Notice that only net benefits after all costs have been compounded forward. Discounting that FV at the STPR yields the project's two-rate NPV.

This process makes it clear why the SOCR is the feasibility hurdle rate of return. If the project's  $IRR < SOCR$ , the benefits of the project are insufficient to amortize capital costs.<sup>2</sup> The FV at the time horizon will be negative, equal

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<sup>2</sup> Projects that display multiple changes in sign will have multiple IRRs, so the comparison of the SOCR with the various IRRs is more complex. The two-rate NPV that is computed will always be unambiguous, however. In such cases, when using the shortcut method, the rate of compounding forward will revert to the SOCR if, after the primary flow's second change of sign, the compounded amount becomes negative, and returns to the STPR when it turns positive again. In this way, multiple changes in the sign of the primary flow can be handled. The fundamental principle is always the same: no project is economically feasible that is unable to cover all of its costs, including the opportunity cost of capital quantified by the SOCR.

in absolute value to the unamortized capital costs. The PV of that future value will be negative at any nonnegative STPR. This is why the STPR is irrelevant to the question of feasibility.

Formally, the recursive process described above operates as follows.  $C_i$  is the cumulative compound value of the project primary net flow for period  $i$ :

$$C_i = C_{i-1} (1+r_i) + b_i \quad (3)$$

where  $i$  is the time-period index ranging between 0 and time horizon  $t$ .

$$\begin{aligned} b_i &= \text{primary net flow for period } i \\ r_i &= \text{SOCR if } C_{i-1} < 0 \\ r_i &= \text{STPR if } C_{i-1} \geq 0 \\ r_0 &= 0 \\ C_{-1} &= 0 \end{aligned}$$

The FV of the project is  $C_t$ , which is obtained by recursively applying expression (3) from years 1 to  $t$ . A project will have a positive welfare impact if its FV is positive, or, equivalently, if the PV of this FV is positive.

Two-rate discounting accurately splits conventional single-rate discounting into its two components: imputation of capital costs and intertemporal weighing. We can show that this is true by computing the two-rate NPV when SOCR = STPR =  $r$ . In this case, the FV of the primary net flow can be calculated using recursive expression (3) as follows:

$$C_0 = b_0 \quad (4)$$

$$C_1 = C_0 (1+r) + b_1 = b_0 (1+r) + b_1 \quad (5)$$

$$C_2 = C_1 (1+r) + b_2 = [b_0 (1+r) + b_1] (1+r) + b_2 \quad (6)$$

$$C_2 = b_0 (1+r)^2 + b_1 (1+r) + b_2 \quad (7)$$

Following this series through period  $t$ , we have

$$C_t = \sum_{i=0}^t b_i (1+r)^{(t-i)} \quad (8)$$

Since  $C_t = FV$ , we can compute  $NPV = FV / (1+r)^t$ . Dividing each term of expression (8) by  $(1+r)^t$ , yields the following:

$$NPV = \sum_{i=0}^t b_i / (1+r)^i \quad (9)$$

which is the conventional NPV using  $r$  as a discount rate. Thus, when STPR = SOCR, the two-rate NPV is identical to the conventional single-rate NPV. The

separate effects of two-rate discounting add up to the entire discounting effect of conventional discounting.

The shortcut method for computing two-rate NPVs is very convenient if, instead of using constant values, the analyst wishes the SOCR and the STPR to change over time. All that would need to be done is to use the varying values that correspond to each year in expression (3). This would make it possible to handle some of the normative STPRs that have been proposed for very long-horizon projects. The same could be done with the SOCR, although it should be noted that the SOCR is only used until the full payback period is reached, which is not likely to be distant in time for feasible projects, given the range in values of the SOCR that are commonly used

Another adjustment that this calculation method makes very easy to implement is valuing savings and consumption from project benefits differently. To accomplish this, net benefits after the full payback period should be split. The consumed part should be compounded forward at the STPR as in the standard case, while the saved part should be compounded forward at the SOCR, which values savings. The FV of this portion will be higher per unit than the consumed fraction and therefore will increase the project's NPV.

### 3. The shadow price of capital

Marglin (1963) proposed using the shadow price of capital (SPC) to solve the problem of how to discount project flows at the STPR while accounting for the true opportunity cost of capital. The necessary SPC correction factor, assuming perpetual capital commitment, is SOCR/STPR as defined in expression (1), which becomes:

$$NPV = -K \times SPC + \frac{b}{STPR} \quad (10)$$

But even if the capital asset is infinitely lived, the project does not need the allocated capital forever. Capital can be amortized sooner if the project's benefit stream allows, and doing so makes an important difference in the computed NPV. The difference will be illustrated with a simple numerical example by assigning values to expression (1). Let SOCR= 5%; STPR = 2%;  $K=1$  and  $b = 0.07$ .

If we assume that capital is committed forever, then  $NPV = - (0.05/0.02) + (0.07/0.02) = 1$ . Then  $SPC = (0.05/0.02) = 2.5$ , which is the present value of only the opportunity cost of capital discounted at the STPR, because in this case the amortization of the initially allocated capital occurs at time  $t = \infty$ , the present value of which is zero.

Alternatively, let us consider the case of the fastest possible amortization. Using standard continuous compounding formulas, we find that  $K$  can be amortized in 26.64 years. This leaves an after-capital-costs net flow of zero during the first 26.64 years and of \$0.07 thereafter. Discounting this benefit flow at the STPR, we get  $NPV = (0.07/0.02) / \exp(26.64 \times 0.02) = 2.05$ , which is much higher than the result obtained under the assumption of perpetual capital allocation. Knowing what the NPV is, we can calculate a project-specific SPC by solving for it in expression (10). We find that in this case  $SPC = 1.45$ .

This value is equal to the present value of the fastest possible capital amortization, discounted at the STPR:

$$\int_0^{26.64} 0.07 e^{-0.02 t} dt = 1.45 \quad (11)$$

The two-rate NPV with the data of this illustrative example equals 2.05. The primary flow and the funding flow cancel out during the first 26.64 years, leaving a net benefit flow thereafter that has  $NPV = 2.05$ , as already calculated. In two-rate discounting, capital is amortized as quickly as possible, as all benefits are devoted to capital cost amortization until full payback is achieved. This must be so because it is the assumption implicit in conventional discounting. It is true for two-rate discounting by construction, which is the equivalent of conventional discounting, as shown in expressions (4)-(9).<sup>3</sup>

We can see from the preceding that attempting to define a generic SPC correction based on the idea of an infinitely lived alternative investment is not the solution that BCA needs. This was recognized by Cline (1992), who developed an elegant method for computing a correction that accounts for the useful lives of projects. The following expression, cited in the OECD CBA Manual (2018:207), calculates the present value of the capital costs of \$1 invested for  $t$  years as a function of the assumed social discount rate (SDR) values:

$$SPC = \frac{SOCR}{STPR} \cdot \frac{1-(1+STPR)^{-t}}{1-(1+SOCR)^{-t}} \quad (12)$$

But as this expression implies a constant annuity over the life of the project, the resulting correction is not exact because the amortization of capital is not the fastest possible.

Generic SPC factors, such as the one proposed by Newell et al. (2023), are not useful for quantifying the opportunity costs of capital for specific projects because they cannot account for the actual capital usage of those projects.

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3 Whether, in fact, projects amortize capital in financial terms is immaterial to BCA. Amortization can be virtual. Without the assumption of amortization, NPVs could not be computed for non-revenue-generating projects, such as freeways or environmental projects.

According to the cited study, “the SPC is defined as the change in immediate consumption equivalent to the present value of the stream of consumption losses associated with the immediate displacement of \$1 of capital, discounted at the consumption discount rate. Computing this requires considering the effect that such an immediate displacement of capital would have on consumption over time, given savings rates, investment returns, and depreciation.” “The degree of the displacement’s persistence is determined by broad economic equilibrium dynamics, including depreciation and savings, suggesting that the SPC should be guided by macro-derived models of savings and investment.”

The conceptual problem with this approach is that it is based on tracing a fictitious alternative investment that has a time profile of capital commitment that is different from that of the project being appraised, which makes the two incomparable. The Newell et al. (2023) method is complicated and fraught with estimation problems. Perhaps it is for this reason that we can read the following in the OECD CBA Manual (2018: 221): “Using the Shadow Price of Capital approach (SPC) is advisable when using the [STPR], so that the opportunity cost of public capital can be reflected in the NPV calculation. This rarely happens in practice due to onerous informational requirements”.

Estimation problems aside, it should be clear that multiplying investments by a generic SPC factor cannot compensate for the error in estimating the opportunity costs of capital, which are not exclusively a function of investments. Project-specific SPCs can be calculated from the NPVs computed using the two-rate discounting method, but since no additional information would be gained, this is unnecessary.

## 4. The SOCR

Harberger (1972), in writing on measuring the social opportunity cost of public funds, defined what we call the SOCR as the weighted average of the net-of-tax yield on savings and the cost of borrowing borne by investors, with the weights proportional to their respective elasticities of supply and demand. The welfare cost of funding a public sector project through borrowing can be calculated using the SOCR. Burgess and Zerbe (2011) expanded Harberger’s formulation by adding foreign borrowing as a third source of funds, thereby adding a third rate and a third weight to the formula.

Harberger (2007) pointed out that while the SOCR measures a welfare cost, this happens to coincide with the direct and indirect borrowing costs of the public sector. The direct cost is the interest actually paid, while the indirect cost consists of tax revenues forgone from displaced activities. This finding is cor-

roborated experimentally by an agent-based capital market model developed by Szekeres (2022). Therefore, the SOCR measures a very tangible cost indeed.

Because Harberger defined the SOCR as a weighted average of two rates, some might think that the two-rate discounting method proposed in this paper creates a weighted average rate. That is not the case. Two-rate discounting differs from Harberger's weighted average in three ways: (1) the two-rate discounting procedure does not define an invariant weighted average rate; (2) while two rates are used in both procedures, they are not the same ones: two-rate discounting uses the STPR and the SOCR, whereas Harberger computes the SOCR from before and after-tax market rates; and (3) two-rate discounting computes the NPVs of projects, whereas Harberger's average rate is the SOCR, one of the inputs of two-rate discounting.

For BCA analysts, as well as for this paper, the SOCR is a given. Estimates for some countries do exist. One was presented for the US by Burgess and Zerbe (2011). The World Bank prepared one following Harberger's methodology for Mexico in 2014 (see Coppola et al. 2014). In reviewing current discounting practices, Groom et al. (2022) listed several countries that have established SOCRs for use in BCA. The adopted values range from 2.25% to 10%.

## 5. The marginal cost of public funds

There is a large body of literature devoted to the opportunity cost of public funds (OCPF) that focuses on the costs of taxation. This is also called the marginal cost of public funds (MCF). This literature, which is distinct from the literature on the choice of social discount rate, largely ignores the opportunity cost of capital. In a survey article, Massiani and Picco (2013) listed twenty articles on the subject, of which only five mentioned the crowding out of private investments. In commenting on this, they added: "Eventually, this implies that the question about crowding out is not to know how much it counts but whether it should be taken into account. [...] Generally, the actual relevance of the crowding out in the OCPF's analysis has to be carefully questioned."

In contrast, Burgess and Zerbe (2011) stated that "according to the SOC approach, the marginal source of funding for all projects is the capital market, thus keeping the issue of tax reform separate from project evaluation. If a particular tax is being proposed to finance a particular project, the revenue from the tax could be used to pay down the debt instead of funding the project, so an alternative use of funds for any project is to pay down the debt." This is a strong argument, considering that all governments carry debt. Despite this, Groom et al. (2022) reported that "another way in which the STP approach can be augmented is via the MCF. This method adjusts public investment costs in any [BCA]

to reflect the welfare cost of raising public funds using a different shadow price. The adjustment reflects the economic impacts of raising public funds, e.g., the distortionary effect of income tax on labor supply.”

But could taking the MCF into account correct the understatement of the opportunity cost of capital that STP discounting implies? Harberger (2007) explained how the MCF adjustment should be applied in BCA. “The cleanest, most straightforward way to take tax financing and the excess burden associated with it into account is to apply an extra charge or benefit of  $\lambda$  to each and every cash outflow or cash inflow from and to the public treasury, over the life of the project.” In other words, whenever appropriate, cost and benefit flows of projects should be multiplied by  $(1 + \lambda)$ . An example of when the costs of a project should be adjusted occurs when its benefits are not collected in fees, and consequently its costs must be funded by taxes. An example of when benefits should be so adjusted occurs when the project generates revenues for the public treasury.

The MCF approach measures the welfare costs of raising tax revenues, so the MCF correction applies to flows. In contrast, the opportunity cost of capital measures the benefit forgone when a stock of capital is allocated to a particular project. Investment flows determine additions to the required capital stock. The opportunity cost of capital is the cost of employing the committed stock of capital, the magnitude of which is not just a function of the size of the stock, but also of the length of time that the stock is in use. Even if tax revenues were the marginal source of capital for a project, all that augmenting investments by  $(1 + \lambda)$  would do is to add an extra cost to incrementing the capital stock. When the capital stock is amortized later in the life of the project, multiplication by  $(1 + \lambda)$  would be required to measure the benefit of incrementing government revenues, if germane. But this adjustment is unrelated to the opportunity cost of the committed capital stock. To measure that, a rate like the SOCR is needed, not a factor like  $(1 + \lambda)$ .

The MCF adjustment is therefore not an alternative to measuring the opportunity cost of capital. If the project is such that the MCF adjustment is warranted, project flows should be appropriately adjusted, as Harberger (2007) explained. An important caveat must be added: we assume that the MCF reflects only welfare losses that are contemporaneous with raising taxes. Capitalizing the future effects of taxation into the MCF is best avoided. To obtain a clean analysis, the contemporaneous welfare loss of taxation should be measured by the MCF, while the opportunity cost of capital should be measured by the SOCR.

## 6. The STPR

Harberger (1972) assumed that “the ‘social rate of time preference’ refers to an appropriately weighted average of the different marginal rates of time prefer-

ence applicable to the individuals who compose the society.” The STPR so calculated could be called the revealed preference STPR.

This is not how Arrow et al. (1995) defined the STPR, however. They based their STPR on normative or ethical considerations. Perhaps all definitions that depart from Harberger’s (1972) description should be called normative, because they replace the revealed preferences of individuals by the preference of someone with authority. The reader is referred to two extensive survey articles on the subject: Greaves (2017) and Groom et al. (2022).

The distinction between revealed preference and normative STPRs is important, for it affects how NPVs should be interpreted. Szekeres (2022) contains an agent-based capital market model which demonstrates that when the STPR corresponds to the MRS between present and future consumption of the representative consumer, two-rate discounting correctly computes the welfare impact of projects: it equals the value of the equivalent compensating lump sum. Discounting with normative STPRs yields NPVs that fail this test.

Two-rate discounting will work with any STPR but will only measure the welfare impact of projects measured by willingness to pay if a revealed preference STPR is used, estimations for which are scarce in the literature. Otherwise, it will measure changes in the social planner’s objective function. According to Groom et al. (2022), countries use STPR values in a range between 1% and 3.5%. For BCA analysts, as well as for this paper, the STPR is a given.

## 7. The proposed resolution of the dilemma

As described in the Introduction, the choice of discount rate has been an unsolved dilemma for a long time, at least since Baumol (1968) wrote that “we see now that no optimal rate exists. The rate that satisfies the one requirement cannot possibly meet the conditions of the other.” This is true because conventional discounting performs both the imputation of the opportunity cost of capital and the intertemporal weighing of remaining benefits using the same rate. Discounting at the STPR reflects the desired intertemporal welfare weights but fails to correctly measure the opportunity costs of capital, while discounting at the SOCR defines the correct opportunity costs of capital but may fail to reflect the desired intertemporal welfare weights.

Two-rate discounting resolves the dilemma of the choice of discount rates not by devising an optimal rate – an impossibility, as Baumol (1968) correctly pointed out – but by showing that the two functions of discounting can be performed at different rates and that each rate can be used for the function in which it performs best. There is therefore no need to choose between the

SOCR and the STPR because both are required to account for the opportunity cost of capital and to reflect the desired social time preference.

The first step in two-rate discounting establishes the opportunity costs of capital without any discounting. This makes capital just another resource, the cost of which is added to the project flow whenever incurred. After this step, we have the flow of net benefits after all costs. This is what the project yields from all resources allocated to it. At this point, the feasibility of the project can readily be ascertained, even before any discounting. The presence or absence of benefits reveals it. If the project data and the SOCR are accepted as valid, there should be universal agreement on which projects are feasible and which are not.

It is only in the second step that the STPR plays a role by discounting the net benefit flow to obtain the NPV of the project. After the identification of feasible projects by reference to the SOCR, projects need to be ranked by virtue of the application of the desired intertemporal weights. To this end, an STPR should be selected that is congruent with the objective of the BCA being conducted.

- If the objective of BCA is to select projects that maximize the present value of aggregate future benefits, then net benefits after capital costs should be discounted at the SOCR, because that is the opportunity cost of public funds. This is the method to be used by public entities interested in optimizing the allocation of a given investment budget. In this case, conventional SOC discounting will compute correct NPVs. Notice that this discounting method measures the cost of matching the net benefits of projects through alternative investments. This is BCA conducted with a *cost of public funds numeraire*.
- Alternatively, if the objective of BCA is to measure the impact of projects on consumers' welfare, then net benefits after capital costs should be discounted at the *revealed preference STPR* because that is what quantifies consumers' intertemporal time preference. In this case, there is no shortcut; two-rate discounting *must* be used, first to measure the opportunity cost of capital correctly and then to value net benefits in a way that reflects willingness to pay. This is the correct way of conducting BCAs with a *consumption numeraire*.
- Choosing a normative STPR likewise *requires* two-rate discounting to correctly account for the opportunity cost of capital. Computed NPVs will measure the degree of fulfillment of social planners' objectives.

Thus, the selection of the STPR used to rank feasible projects depends on the purpose of the analysis being performed.

SOC discounting is consistent with the definition of present value because the computed NPVs compound back to the project's net benefits at the SOCR, which is the public sector's opportunity cost of funds. Two-rate discounting, which is effectively STP discounting applied to net benefits after the appropri-

ately calculated opportunity costs of capital have been considered, is internally consistent if the STPR reflects the revealed preferences of the representative consumer. Computed NPVs will compound back at the STPR to the quantified benefits. However, the method will not be consistent from the point of view of the resource-allocating authority, because the NPVs thus obtained will overstate the amounts that are necessary to match project benefits through alternative investments at the authority's opportunity costs of funds, which is the SOCR. This also applies to discounting with normative STPRs, in which case the results that are obtained are only consistent with the preferences of the social planner.

## 8. Conclusions

Conventional STP discounting understates the opportunity cost of capital, while the SOCR may understate the present value of future benefits. The two-rate discounting method proposed here offers a way out of this dilemma. The main insight is that the two functions of discounting (imputation of capital costs and intertemporal weighing of benefits) can be performed separately, using different rates. The SOCR is used to compute capital costs correctly, and the STPR is used to express the desired intertemporal weights. Therefore, it is not necessary to choose between the two rates. Both must be used.

Computing the capital costs of projects involves no discounting. Instead, it requires compounding. In the first step of two-rate discounting, the simple rules of finance define the evolution of the necessary capital stock, its remuneration quantified by the SOCR, and the pace of its fastest possible amortization. When the financing flow so constructed is added to the project's primary flow, the result is the undiscounted flow of net benefits. Conceptually, this first step is the internalization of the opportunity cost of capital into the project's flow and its pricing at the corresponding shadow price, the SOCR.

If the resulting net benefit flow is positive, the project is feasible. In the case of unfeasible projects, there will be no net benefits, just the unamortized capital balance at the time horizon. As only the SOCR is used up to this point, it is clearly the feasibility hurdle rate. The STPR plays no role in this determination.

The net benefits identified through this process measure the welfare impact of undertaking the project. In the second step, the net benefit flow is discounted at the STPR that expresses the desired social intertemporal preferences to obtain the project's NPV.

Many ways of formulating the STPR have been proposed. Choosing one involves a policy decision by the appropriate authority of each jurisdiction. We have found it useful to classify the possible STPR choices depending on the objective of the BCA:

- If the objective is to select projects that maximize aggregate future benefits attainable from a given capital budget, then net benefits after capital costs should be discounted at the SOCR, because that is the opportunity cost of public funds.
- If the objective is to measure the impact of projects on consumers' welfare, then net benefits after capital costs should be discounted at the *revealed preference* STPR because that is what quantifies consumers' intertemporal time preferences.
- If the objective is to attain some other goal, then the appropriately chosen normative STPR will serve to rank projects.

The choice of objective will unambiguously determine the choice of STPR.

Discounting a project's primary flow at the STPR will overstate the benefits of the project. Part of the estimated net benefits will be fictitious, like the consequence of underestimating any other input, be it labor, raw materials, or capital equipment. The SPC cannot correct this shortcoming because no generic SPC factor multiplying investments will accurately correct the understatement of the opportunity cost of capital, which is only partially a function of investments. Likewise, the MCF adjustment will fail to do so. Adjusting the value of a project flow item cannot exactly offset the understatement of the costs of the capital stock used by the project.

Two-rate discounting easily and accurately measures the NPV of projects in a manner that is consistent with the values of the SOCR and the STPR, a set of social parameters that can be chosen unambiguously if the objectives of the BCA are clear. Obtaining correct BCA results through this method will help avoid undertaking projects that diminish future generations' welfare. As Becker, Murphy and Topel (2011) stated: "Future generations would not thank us for investing in a low-return project."

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## Appendix

In this Appendix, the two-rate discounting method is illustrated with data from a real-life project. The data come from a feasibility study performed by Information for Investment Decisions, Inc., of Washington, DC, in August 1979. The project was the development of the Cerro Colorado copper mine. The plan was to exploit copper deposits found in the Chiriquí province of Panama that were estimated to contain 1.4 billion tons of ore with a tenor of 0.785%. The project included the following components: mine development, ore concentration plant, smelter and sulfuric acid plant, in addition to infrastructure such as roads, a seaport, and a water collection dam. Total capital requirements were estimated to reach nearly \$2 billion. The study was conducted using Monte Carlo simulation to quantify uncertainty about the yield of the mine, investment and operating costs, and the forecast of copper prices. Values of the primary project flow shown in this Appendix are expected values obtained from the Monte Carlo simulations that were undertaken. An Excel file with the data is available for download at <https://doi.org/10.3886/E244982V1>.

**Table A1. NPV calculation for the Cerro Colorado project**

| Years | Primary Flow | Opening Balance | Oppty. Cost | Delta Capital Stock | Closing Balance | Financing Flow | Net Benefits after CC | Two-rate shortcut method |
|-------|--------------|-----------------|-------------|---------------------|-----------------|----------------|-----------------------|--------------------------|
| 1     | -183.0       | 0.0             | 0.0         | 183.0               | 183.0           | 183.0          | 0.0                   | -183.0                   |
| 2     | -327.9       | 183.0           | 14.6        | 327.9               | 525.5           | 327.9          | 0.0                   | -525.5                   |
| 3     | -447.8       | 525.5           | 42.0        | 447.8               | 1 015.4         | 447.8          | 0.0                   | -1 015.4                 |
| 4     | -301.5       | 1 015.4         | 81.2        | 301.5               | 1 398.1         | 301.5          | 0.0                   | -1 398.1                 |
| 5     | -87.5        | 1 398.1         | 111.8       | 87.5                | 1 597.4         | 87.5           | 0.0                   | -1 597.4                 |
| 6     | 54.7         | 1 597.4         | 127.8       | -54.7               | 1 670.5         | -54.7          | 0.0                   | -1 670.5                 |
| 7     | 47.1         | 1 670.5         | 133.6       | -47.1               | 1 757.1         | -47.1          | 0.0                   | -1 757.1                 |
| 8     | 108.1        | 1 757.1         | 140.6       | -108.1              | 1 789.5         | -108.1         | 0.0                   | -1 789.5                 |
| 9     | 174.6        | 1 789.5         | 143.2       | -174.6              | 1 758.1         | -174.6         | 0.0                   | -1 758.1                 |
| 10    | 352.0        | 1 758.1         | 140.6       | -352.0              | 1 546.7         | -352.0         | 0.0                   | -1 546.7                 |

| Years               | Primary Flow | Opening Balance | Oppty. Cost | Delta Capital Stock | Closing Balance | Financing Flow | Net Benefits after CC | Two-rate shortcut method |
|---------------------|--------------|-----------------|-------------|---------------------|-----------------|----------------|-----------------------|--------------------------|
| 11                  | 354.5        | 1 546.7         | 123.7       | -354.5              | 1 316.0         | -354.5         | 0.0                   | -1 316.0                 |
| 12                  | 165.4        | 1 316.0         | 105.3       | -165.4              | 1 255.8         | -165.4         | 0.0                   | -1 255.8                 |
| 13                  | 74.9         | 1 255.8         | 100.5       | -74.9               | 1 281.4         | -74.9          | 0.0                   | -1 281.4                 |
| 14                  | 81.5         | 1 281.4         | 102.5       | -81.5               | 1 302.5         | -81.5          | 0.0                   | -1 302.5                 |
| 15                  | 125.0        | 1 302.5         | 104.2       | -125.0              | 1 281.7         | -125.0         | 0.0                   | -1 281.7                 |
| 16                  | 318.9        | 1 281.7         | 102.5       | -318.9              | 1 065.3         | -318.9         | 0.0                   | -1 065.3                 |
| 17                  | 279.0        | 1 065.3         | 85.2        | -279.0              | 871.5           | -279.0         | 0.0                   | -871.5                   |
| 18                  | 309.0        | 871.5           | 69.7        | -309.0              | 632.2           | -309.0         | 0.0                   | -632.2                   |
| 19                  | 306.7        | 632.2           | 50.6        | -306.7              | 376.1           | -306.7         | 0.0                   | -376.1                   |
| 20                  | 226.4        | 376.1           | 30.1        | -226.4              | 179.8           | -226.4         | 0.0                   | -179.8                   |
| 21                  | 219.5        | 179.8           | 14.4        | -194.2              | 0.0             | -194.2         | 25.3                  | 25.3                     |
| 22                  | 240.1        | 0.0             | 0.0         | 0.0                 | 0.0             | 0.0            | 240.1                 | 265.9                    |
| 23                  | 272.9        | 0.0             | 0.0         | 0.0                 | 0.0             | 0.0            | 272.9                 | 544.1                    |
| 24                  | 276.5        | 0.0             | 0.0         | 0.0                 | 0.0             | 0.0            | 276.5                 | 831.5                    |
| 25                  | 284.1        | 0.0             | 0.0         | 0.0                 | 0.0             | 0.0            | 284.1                 | 1 132.2                  |
| 26                  | 281.2        | 0.0             | 0.0         | 0.0                 | 0.0             | 0.0            | 281.2                 | 1 436.1                  |
| 27                  | 294.0        | 0.0             | 0.0         | 0.0                 | 0.0             | 0.0            | 294.0                 | 1 758.8                  |
| 28                  | 295.7        | 0.0             | 0.0         | 0.0                 | 0.0             | 0.0            | 295.7                 | 2 089.7                  |
| 29                  | 452.4        | 0.0             | 0.0         | 0.0                 | 0.0             | 0.0            | 452.4                 | <b>FV</b> 2 583.9        |
| <b>IRR</b>          | 10.3%        |                 |             |                     |                 | 8.0%           |                       |                          |
| <b>NPV @SOCR</b>    | 365.5        |                 |             |                     |                 | 0.0            | 365.5                 |                          |
| <b>NPV Two-rate</b> | 1 484.1      |                 |             |                     |                 | 0.0            | 1 484.1               | 1 484.1                  |
| <b>NPV @STPR</b>    | 2 615.7      |                 |             |                     |                 | -1 131.5       | 1 484.1               |                          |

Note: values in \$ million.

The second column of Table 1 shows the primary flow of the project given in millions of dollars for years 1-29. The primary flow is negative for the first five years, which represents sums that need to be financed. The following four columns describe the financing mechanism. The first column of this block is the Opening Balance of capital employed at the beginning of the period in question. The next column shows the Opportunity Cost of the outstanding capital balance. It is calculated using  $\text{SOCR} = 8\%$ . The following column, labeled Delta Capital Stock, shows the change in the capital stock that occurs in the given year. For Year 1, since the primary flow is  $-\$183\text{m}$ , the capital stock increment is a positive value of this magnitude. The following column contains the Closing Balance for the year, which is simply the sum of the values of the three preceding columns in the same row.

From here on we proceed recursively. The Opening Balance of Year 2 is the Closing Balance of Year 1. This balance incurs opportunity costs of \$14.6m and the negative primary flow of Year 2 is also added to the capital stock, leading to a Closing Balance of \$525.5m for Year 2. This procedure is repeated for the following years.

Notice that in Year 6 the Primary Flow becomes positive, and we can see in the Delta Capital Stock column that this positive flow of \$54.7m is entirely devoted to amortizing the capital stock, which is reduced by this amount. However, the closing balance in Year 6 does not diminish because the opportunity cost of the opening balance exceeds the positive net flow for this year. Looking at the Closing Balance column, we can see that its values keep growing because of the accruing opportunity costs of capital. This process continues until Year 21, in which capital is finally fully amortized. This is the full payback period. From here onwards, there are no further capital costs.

The column labeled Financing Flow contains financing proceeds and the amortization of the capital stock. Notice that its values are identical to those of the Delta Capital Stock column. By adding this flow to the primary flow, we obtain Net Benefits after Capital Costs, shown in the next column. We can see that there are no net benefits until capital is fully amortized in Year 21. That year, the amortization of capital is concluded, and the small residual of \$25.3m that remains after final amortization becomes a net benefit. Thereafter, net benefits coincide with the values of the primary flow.

We now proceed to discuss the financial performance indicators that can be derived from these flows. The IRR of the primary flow is 10.3%. The IRR of the financing flow is 8%. This is so by definition, given that the interest rate is the SOCR = 8%.

The NPV of the primary flow discounted at the SOCR is \$365.5m. The NPV of the financing flow at the same rate is 0. Again, this is so by definition, given that the SOCR was used to compute the opportunity costs of capital. We can see that the NPV of the primary flow is the NPV of Net Benefits after Capital Costs less the NPV of the Financing Flow. In keeping with the interpretation of NPV, this is the PV of benefits after all costs, including those of capital.

The two-rate NPV of the project is obtained by discounting net benefits after capital costs at the STPR, which we have assumed to equal 2%. The NPV has a value of \$1,484.1m.

The conventional NPV of the primary flow discounted at the STPR is \$2,615.7m. It is interesting to see what this amount consists of. Part of it is the same \$1,484.1m PV of net benefits that we computed for the two-rate NPV, minus the NPV of the Financing Flow, discounted at the STPR, which is - \$1,131.5m. This is by how much the cost of capital has been underestimated by STP dis-

counting, and it is therefore the amount by which unadjusted conventional STPR overestimates the welfare impact of the project.

The objective of two-rate discounting is to avoid this overestimation, while keeping the PV of future benefits the same as with STP discounting.

The last column of Table 1 shows how the shortcut method used to compute a two-rate NPV works. As described in the main text, this column contains the compounded accumulation of the primary net flow values using the SOCR as the compounding rate while the accumulated total is negative and using the STPR thereafter. Notice that this flow is identical to the values of the Closing Balance column in Table 1 during the capital amortization period. These balances diminish until we reach the full payback period. Thereafter, the primary net flow values are compounded forward using the STPR until reaching the time horizon in Year 29. The last value in this series is the FV of the project, \$2,589m in this case. Discounting this value to Year 1 using the STPR, we obtain the same two-rate NPV of \$1,484.1m that we obtained before, much more laboriously.

The example presented is that of a feasible project, because its  $IRR > SOCR$ . Should it be that  $IRR < SOCR$ , the project would be unfeasible, the full payback period would not precede the time horizon, Delta Capital Stock would never cease to be negative, the Closing Balance would keep growing, the Financing Flow would not cease to be negative, and there would be no net benefits. Using the shortcut method, the values compounded forward would remain negative and grow in absolute value. The FV would be the negative of the Closing Balance column.<sup>4</sup> Could a SPC correction remedy the understatement of the opportunity cost of capital implicit in conventional STP discounting? Yes, a project-specific SPC factor can be found to accomplish this. Using the Goal Seek feature of Excel, we find that if the initial investments in the project, that is, the negative values of the primary flow, are multiplied by 1.87, then the NPV of the thus modified primary flow conventionally discounted at the STPR will yield the same result as that obtained by two-rate discounting.

Another project-specific SPC calculation was mentioned in the main text, based on the present value of the amortization payments. It cannot be expressed as a factor in this case, because investments are spread over 5 years, but the concept can be illustrated. The PV of capital amortization (negative values of the Financing Flow in Table 1) discounted at the STPR is - \$2,431.3m. If we modify the Primary Flow by putting this value in Year 1, set the values of Years 2-5 to zero, and then conventionally compute the NPV of the modified flow at the STPR, we get a value of \$1,484.1m, the same as with two-rate discounting.

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<sup>4</sup> Readers who download the Excel file will see an illustration of this by setting SOCR to a value higher than the IRR of the primary flow.

But to make either project-specific SPC correction, we first had to compute a two-rate discounting NPV. Therefore, finding the SPC factor adds no new information and is unnecessary. It should be noted that no generic SPC factor will ever be appropriate except by pure chance. The following table will help explain why.

**Table A2. Composition of the Capital Costs of the Cerro Colorado project**

|                     |            |
|---------------------|------------|
| Total investments   | \$1 347.7m |
| Opportunity cost    | \$1 824.3m |
| Total capital costs | \$3 172.0m |

The values in Table 2 are undiscounted. Total investments is the sum of the negative values of the primary flow during its first five years. This is the amount that the SPC factor multiplies. But initial investments are not the sole determinant of total capital costs. The opportunity cost is another important component that is a function of two other factors as well: the SOCR and the timing of project benefits. It is these, along with the total investments, that determine the time profile of the project's capital needs, and hence the derived opportunity cost of capital. No generic SPC correction, which necessarily ignores two key determinants of the opportunity cost component of total capital costs, can effect an accurate correction by multiplying one of the components of total capital costs.

The MCF correction is not illustrated with this project, even though it could be. Data exist to show the project's incremental impact on public finances, in the form of increased tax revenues. The way to effect the correction would be to add the product of the incremental tax revenues by the appropriate factor  $\lambda$  as an extra benefit, which would result in changes in the project's primary flow. This type of adjustment has no conceptual bearing on the opportunity cost of capital.