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APPROACHES TO MEASURING SOCIAL DISCOUNT RATE: A BANGLADESH PERSPECTIVE

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Abstract

Social discount rate reflects a society's relative valuation on today's well-being versus well-being in the future. This paper reviews various methods of measuring social discount rate, with particular emphasis on social rate of time preference and social opportunity cost of capital framework. Then Monte Carlo Simulation is conducted for Bangladesh to understand the optional social discount rate. The result suggests that the Government of Bangladesh should use a value between 9-11 per cent as optimal social discount rate for various long term projects. The discount rate is similar to the ones used by Pakistan, India and China.

1. Introduction

The government of any nation often come across various proposals that have costs and benefits accruing over a long period of time. They may cover a range of issues including investment in state-owned enterprises, departments, social, environmental, and regulatory policy choices, etc. Discounting enables different cost and benefit flows to be converted into a single net present value (NPV) number to ease decision-making. A social discount rate (SDR), albeit in theory at least, reflects a society's relative valuation on today's well-being versus well-being in the future. Therefore, a choice of an appropriate SDR is crucial for cost-benefit analysis (CBA), and has important implications for resource allocations. Setting the discount rate too high could exclude many socially desirable public projects from being implemented, while the reverse may result in economically inefficient investments. Furthermore, a relatively high SDR invariably favours projects which have benefits occurring at earlier dates as it attaches less weight to benefit and cost streams that occur in the distant future; while the opposite happens if SDR is too low. Historically, SDR entered the literature due to debates resulting from the rise of CBA in the 1950s and 1960s[1] although time preference

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in economic literature dates mainly to the 1920s with Ramsey's[2] model on saving. The need for discounting of social projects has been further reinforced because of its application to environmental economics.[3]

Economic efficiency requires that SDR measures the marginal social opportunity cost (SOC) of funds allocated to public investment. In a world with a perfectly competitive market, i.e., without any market distortions, the market interest rate is the appropriate SDR. However, in the real world where markets are distorted, this is not so and the market interest rate will no longer reflect marginal SOC of public funds. Economists have proposed several alternative approaches to the choice of the SDR in the presence of market distortions, but there has been no consensus on which is the most appropriate.[4] In the literature, the annual discount rate estimates vary from negative values to infinite.[5] The differences among these approaches reflect largely differing views on how public investment affects domestic consumption, private investment, and the cost of international borrowing.

Given this context, the paper has been structured as follows. After this introduction, Section 2 explains why it is rational or important to introduce SDR in calculating projects which have long temporal aspects. Section 3 describes the different economic approaches to the setting of discount rates and the two main methods of estimating SDR, i.e., social rate of time preference (SRTP) and SOC. The section discusses the theoretical foundation of these methods, albeit briefly. Section 4 tries to estimate the SDR for Bangladesh using aforesaid methods.

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[1] Michael Spackman, "Time discounting and of the cost of capital in government", *Fiscal Studies*, Vol. 25, 2004, pp. 467-518.

[2] Frank Plumpton Ramsey, "A Mathematical Theory of Saving", *Economic Journal*, Vol. 38, 1928, pp. 543-559.

[3] Robert S. Pindyck, "Uncertainty in Environmental Economics", *Review of Environmental Economics and Policy*, Vol. 1, 2007, pp. 45-65.

[4] For detail, see, Kenneth Arrow, "Intergenerational equity and the rate of discount in long-term social investment", *Department of Economics Working Papers,* Stanford University, 1995; Andrew Caplin and John Leahy, "The social discount rate", *National Bureau of Economic Research*, No. W7983, 2000; Martin S Feldstein, "The social time preference discount rate in cost benefits analysis", *Economic Journal*, Vol. 74, No. 294, 1964, pp. 360-379; George Loewenstein, Shane Frederick and Ted O'Donohue, "Time discounting and time preference: a critical review", *Journal of Economic Literature*, Vol. 40, No. 2, 2002, pp. 351-401; William D. Nordhaus, "A Review of the Stern Review on the Economics of Global Warming", *Journal of Economic Literature*, Vol. 45, 2007, pp. 606–678; R. S. Pindyck, *op.cit;* Amartya Sen, "On Optimizing the Rate of Saving.", *Economic Journal*, Vol.71, 1961, pp. 479-496; M. Spackman, *op.cit.;* Martin L. Weitzman, "On the Environmental Discount Rate", *Journal of Environmental Economics and Management*, Vol. 26, No. 2, 1994, pp. 200-209.

[5] Loewenstein et al., *op.cit.*

Section 5 tries to describe policy implications of the analysis. Finally, concluding remarks have been made.

2. A Review of Literature

So far optimum growth theory has concentrated mainly on maximisation of a utility function over an infinite time horizon, with a benevolent social planner typically discounts future utilities at a positive rate. There are those who are precisely opposed to discounting on the grounds that it unethical to attach a lower weight to the welfare of future generations and is irrational.[6] In the literature there are arguments in favour of discounting future utilities.[7] For example, when the discount rate is set equal to zero, the resulting inter-temporal consumption allocation excessively favours the future ones at the expense of the current one. The use of a positive discount rate in the social objective function is consistent with Koopmans[8] preference ordering over the set of well-being paths. They have noted that there is nothing irrational with positive time discounting and in fact has argued for it on both technical and philosophical grounds. Also, zero rate of pure time preference implies a savings rate excessively higher than what we normally observe and contradicts real world savings behaviour, which leads to other paradoxical results.[9]

There are considerable arguments that can be put forward to justify positive discounting.[10] First, individuals seem to have a preference for immediate rather than delayed gratification, and hence government, mindful of its citizen's preference, should discount the future costs and benefits associated

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[6] For details, see, William Stanley Jevons, *The Theory of Political Economy*, London: Macmillan, 1871; Frank Plumpton Ramsey, *op.cit.;* John Rae, *The Sociological Theory of Capital*, New York: Macmillan, 1905; Arthur C. Pigou, *The Economics of Welfare*, London: Macmillan, 1932; Colin Price, *Time, Discounting, and Value*, Oxford: Blackwell, 1993; Roy Forbes Harrod, *Towards a Dynamic Economics*, London: Macmillan, 1948.

[7] For details, see, Tjalling C. Koopmans, "Stationary Ordinal Utility and Impatience", *Econometrica*, Vol. 28, April 1960, pp. 287-309; Norman Henderson and Ian Langford, "Cross-disciplinary evidence for hyperbolic social discount rates", *Management Science*, Vol. 44, No. 11, Part-1, 1998, pp.1493-1500; Otto Eckstein, "A survey of the theory of public expenditure criteria", in *Public Finances: Needs, sources, and utilization*, Princeton University Press, 1961, pp. 439-504; Fisher Irwin, *The Theory of Interest*, London:Macmillan, 1930; Kenneth Arrow, *op.cit;* Derek Parfit, "Personal identity", *The Philosophical Review*, Vol. 80, 1971, pp. 3-27.

[8] Koopmans et al., *op.cit.*

[9] Kenneth Arrow, *op.cit.*

[10] Humberto Lopez, "The Social Discount Rate: Estimates for Nine Latin American Countries", *Policy Research Working Paper 4639*, The World Bank Latin America and the Caribbean Region Office of the Chief Economist, 2008.

to public projects. This kind of preference may be related to psychological factors such as impatience or mere myopia, to the fact that individuals do not have an infinity life span which in turn implies that rational individuals will prefer US$1 today than US$1 in the future because there is always a non-zero probability of not being able to enjoy the future income. In case of intergenerational projects, the use of pure time preferences may not be justified, since governments have responsibility for future generations. In that case, there would be good reasons for policy makers to be more patient than private citizens although the extent of the patience might be debatable. Koopmans[11] noted that without a positive time discount factor the integral of the utility of consumption over an infinite future may not converge most of the time. He also argued that a zero time discount factor would result in an unrealistically high savings to investment rate. Also, in line with Parfit[12], one could look at our future selves as different individual and hence what matters to an individual in the future is probably less important than what happens today.

As Lopez[13] points out, a second argument to discount future costs and benefits goes beyond pure time preferences. If one assumes that (i) the marginal utility of consumption declines with the level of income or consumption and (ii) future generations will benefit from increasing levels of income or consumption, then it would be inefficient to adopt an egalitarian approach. If the future generations are richer, then one would expect them to contribute more to their welfare, on philosophical and efficiency ground. The discount rate in this case will be contingent upon the social planner expectations regarding future growth, and on the elasticity of marginal utility of consumption. This is the foundation of the overlapping generation model.

Another argument for discounting future costs and benefits takes the perspective of a producer (or an investor). According to this, capital is productive and resources acquired for a particular project can be invested elsewhere, generate returns, and so have an opportunity cost. Therefore, to persuade an investor to invest in a project, the expected return from the investment should be at least as high as the opportunity cost of funding, which is the expected return from the next best investment alternative. Following this logic, the rate the investor should use in discounting benefits and costs of a project is the marginal rate of return on investment in the private sector. In the absence of market distortions, this is equivalent to the marginal social rate of return on private investment, also termed marginal SOC.

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[11] Koopmans *et al*., *op.cit.*
[12] Derek Parfit, *op.cit.*
[13] Humberto Lopez, *op.cit.*

In the following we will develop a simple model based on Ramsey growth model where the representative agent maximises its life-time welfare subject to inter-temporal constraints[14]:

Maximise $\int_0^\infty U(c_t)e^{-\rho t}\, d$

subject to $\dot{k}_t = f(k_t) - c_t$

where U(.) represents a time-invariant utility function with properties of U'(.)>0 (the marginal utility of consumption is positive) and U" (.)<0 (the marginal utility of consumption diminishes); ρ is SDR; c_t is consumption at time t; f(.) represents a production function; and $\dot{k}$ is net investment at time t .

Maximisation requires: $U'(c_t)f'(k_t) + U''(c_t)\dot{c_t} - \rho U'(c_t) = 0$

where c_t is change in consumption at time t. Above equation can be simplified to $r = f'(k_t) = \rho + \theta g$ where r is the rate of return to savings; $\theta = -(U''(c_t)/U'(c_t))c_t$ is the elasticity of marginal utility of consumption representing preference and is also known as the coefficient of relative risk aversion; and $g = \dot{c_t}/c_t$ is the growth rate of per capita consumption. We can further rearrange it and get

$$g = [\, f'(k_t) - \rho]/\,\theta$$

Maximisation of the optimality functional requires the SDR to be equalised to the marginal product of capital. Under the standard Inada conditions on $f'(k_t)$ positive discounting is therefore necessary according to a utilitarian criterion.

Now the golden rule criterion[15] with exogenous productivity growth requires $f'(kt) = \pi + n$, hence maximisation of long-run consumption per capita is achieved by setting $\rho = \pi + n$. Here π is the instantaneous rate of labour-augmenting productivity growth. The intuition for this result is as follows: Under constant productivity growth, aggregate output grows at the rate π + n. Thus, π + n measures the SOC of current relative to future consumption. The allocation of resources consistent with steady-state consumption maximisation requires that the marginal product of capital be equalised to π + n, which is achieved on the optimal time-consistent path when $\rho = \pi + n$, that is, when the SDR is equal to the opportunity cost of current consumption.

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[14] Frank Plumpton Ramsey, *op.cit.*

[15] Edmund S. Phelps, "The Golden Rule of Accumulation: A Fable for Growthmen," *American Economic Review*, Vol. 51, 1961, pp. 638-643.

The above result shows that a positive SDR is necessary in order to maintain constant consumption over time. A zero SDR implies an asymmetry across generations, with future generations enjoying higher average consumption levels than the current ones, which is essentially Lopez's[16] second argument mentioned above . Thus, far from leading to a fairer allocation of resources over time, the absence of a positive discount rate would favour future generations, at the expenses of the current ones. The aforesaid framework is actually one of the ways one can calculate SRTP, one of the mode of calculating social discount.

3. Methods and Data

This section briefly deals with the various methods of social discounting, for greater details the readers are suggested to look in to Young[17] and Zhuang *et.al*[18]. There are primarily four methods in social discounting, (i) SRTP, (ii) SOC of capital, (iii) weighted average approach, and (iv) shadow price of capital (SPC) approach. SRTP is the rate at which a society is willing to postpone a unit of current consumption in exchange for more future consumption. The use of SRTP as the SDR is based on the argument that public projects displace current consumption, and streams of costs and benefits to be discounted are essentially streams of consumption goods either postponed or gained; this idea is supported by many.[19] The proposal for using the marginal SOC of capital as the SDR, advocated by Mishan[20], Baumol[21] and Diamond[22] among others, is based on the argument that resources in any economy are scarce therefore government and private sector compete for the same pool of funds. Hence, public investment displaces private investment and those applied to public sector projects could have been invested in the private sector. Therefore, it follows that public investment should yield at least the same return as private investment. If not,

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[16] Humberto Lopez, *op.cit.*

[17] Louise Young, "Determining the discount rate for government projects." *Treasury Working Paper Series,* No. 02/21, New Zealand Treasury, 2002.

[18] Juzhong Zhuang, Zhihong Liang, Tun Lin, and Franklin De Guzman., "Theory and Practice in the Choice of Social Discount Rate for Cost-Benefit Analysis", Economics and Research Department, Working Paper Series No. 94, European Reports on Development, 2007.

[19] For details, see, Peter A. Diamond, "Opportunity Cost of Public Investment: Comment", *Quarterly Journal of Economics,* Vol. 84, 1968, pp. 682-688; John A. Kay, "Social Discount Rates", *Journal of Public Economics,* Vol. 1, 1972, pp. 359-378; Stephen A. Marglin, "The social rate of discount and the optimal rate of investment", *Quarterly Journal of Economics*, Vol. 77, No. 1, 1963, pp. 95-111; Amartya Sen, *op.cit.*

[20] Edward J. Mishan, "Criteria for Public Investment: Some Simplifying Suggestions" *Journal of Political Economy*, Vol. 95, No. 2, 1966, pp. 139-146.

[21] William Baumol, "On the Social Rate of Discount", *American Economic Review,* Vol. 58, 1968, pp. 788-802.

[22] Peter Diamond, *op.cit.*

total social welfare can be increased by reallocating fund or resources to the private sector, which will yield higher returns.

The problem with SRTP is that, it does not take into account impacts of public projects on funds available for private investment. Using SOC as the SDR, on the other hand, assumes that public investment only displaces private investment and not private consumption, which in reality may not always hold. The weighted average approach associated with contributions by, among others, Harberger[23], Sandmo and Drèze[24], and Burgess[25] attempts to reconcile the SRTP approach with that of SOC. However, Harberger argues that SOC may differ from one productive sector to another and SRTP could also vary among different groups of savers (reflecting, for instance, different tax brackets). Therefore, SOC and SRTP themselves should be the weighted average of those of various productive sectors or saver groups. In case of an open economy it is also suggested that in the presence of country risk premiums, the SDR should be a weighted average of SOC, SRTP, and the international borrowing rate inclusive of risk premiums.

A major criticism on the weighted average approach is that, while displacement of private investment by public investment can be a cost for the society, it erroneously assumes that benefits will be consumed immediately. Therefore, it ignores the fact that they could also be reinvested in the private sector, generate future consumption, and hence bring more social value than if they were consumed immediately. The following equation gives the basic formula for weighted average method:

$$\boldsymbol{\delta = \alpha SOC + (1 - \alpha - \beta) i_f + \beta SRTP}$$

where δ denotes the social discount rate, i_f is the government's real long-term foreign borrowing rate, α is the proportion of funds for public investment obtained at the expense of private investment, β is the proportion of funds obtained at the expense of current consumption, and (1 – α – β) is the proportion of funds from foreign borrowing. SRTP and SOC are measured, respectively, by the rate of real return on savings exclusive of (i_i) and investments inclusive of (r_i). Expressing the weights attached to different funding sources in terms of elasticities of demand and supply of funds with respect to changes in interest rates, the above equation becomes:

[23] Arnold C. Harberger, *Project Evaluation: Collected Papers*, University of Chicago Press, 1976.
[24] Agnar Sandmo and Jacques H. Dreze, "Discount rates for public investment in closed and open economies", *Economica*, Vol. 38, No. 152, 1971, pp. 395-412.
[25] David F. Burgess, "Complementarity and the Discount Rate for Public Investment", *The Quarterly Journal of Economics*, MIT Press, Vol. 103, No. 3, 1988, pp. 527-541.

$$\delta = \frac{\sum_i \varepsilon_i \left(\frac{S_i}{S_t}\right) i_i + \varepsilon_f \left(\frac{S_f}{S_t}\right) i_f - \sum_j \varepsilon_j \left(\frac{I_j}{I_t}\right) r_j}{\sum_i \varepsilon_i \left(\frac{S_i}{S_t}\right) + \varepsilon_f \left(\frac{S_f}{S_t}\right) - \sum_j \varepsilon_j \left(\frac{I_j}{I_t}\right)}$$

where ε_i, ε_f , ε_j are respectively elasticities of savings, supply of foreign capital, and private investment with respect to the interest rate. S_i/S_t and S_f/S_t are the shares to the total savings by various groups of domestic savers and foreign savers. I_j/I_t is the investment share of various business sectors.

The SPC approach, associated with contributions by Feldstein[26], Bradford[27], and Lind[28] among others, also attempts to reconcile the SRTP approach with that of SOC and, at the same time, addresses the limitation of the weighted average approach. One could look at the total cost of a public project as the sum of the current consumption that is directly displaced and those future consumption streams that are foregone due to the displacement of private investment. Similarly, the total benefit of a public project can be viewed as the sum of those immediately consumed and those future consumption streams generated from reinvestment.

Based on this aforesaid understanding, SPC approach involves four steps[29]. The first is estimating SPC, which is the present value of streams of future consumption foregone arising from displacing one unit of private investment or the present value of future consumption streams generated from reinvesting one unit of project benefits in the private sector. The second step involves, for each time period, converting all the costs and benefits that either displace or generate private investment into consumption equivalents by multiplying them by SPC. The third step is adding these costs and benefits to the other portions of costs (in the form of directly displaced consumption) and of benefits (in the form of immediate consumption), respectively. Finally, one has to discount the total cost and benefit streams at SRTP to calculate the NPV. We will briefly discuss in the following how SPC is derived mathematically.

Consider a project with a lifespan of n years, benefit streams, B_t, and cost streams, C_t . The net present value of the project will be:

$$\text{NPV} = \sum_{t=0}^{n} \frac{B_t^* - C_t^*}{(1+i)^t} = \sum_{t=0}^{n} \frac{B_t\left[\phi_b V + (1-\phi_b)\right] - C_t\left[\phi_c V + (1-\phi_c)\right]}{(1+i)^t}$$

[26] Martin S. Feldstein, "The inadequacy of weighted discount rates", in *Cost-Benefit Analysis*, Harmondsworth: Penguin, 1972.
[27] David F. Bradford, "Constraints on Government Investment Opportunities and the Choice of Discount Rate", *American Economic Review*, Vol. 65, No. 5, 1975, pp. 887-99.
[28] Robert C. Lind, "A Primer on the Major Issues Relating to the Discount Rate for Evaluating National Energy Option", in R. Lind (ed.), *Discounting for Time and Risk in Energy Policy*, Resources for the Future, Washington, DC, 1982.
[29] Zhuang *et al*. *op.cit.*

where B_t^* is the consumption equivalents of benefits at time t; C_t^* is the consumption equivalents of costs at time t; $\emptyset_b$ is the fraction of benefits that return to the private sector for investment; $\emptyset_c$ is the fraction of costs that displace private investment; i is SRTP; and V is SPC. Lyon[30] provides two alternative formulas to calculate V:

$$V = \frac{r - sr}{i + d - sr}$$

where r is the gross rate of return on private investment prior to depreciation, d is the depreciation rate, and s is the rate of savings from the gross return; and

$$V = \frac{\lambda - \sigma\lambda}{i - \sigma\lambda}$$

where λ is the rate of return from private investment net of depreciation, and σ is the rate of saving from the net return. The SPC approach, although theoretically attractive is difficult to implement. Also, like the weighted average method, the value of SPC is very sensitive to the values of SRTP and SOC. In addition it is very responsive to how depreciation and reinvestment are assumed, and to the length of life of a project. Lyon showed that the value of SPC could vary from about one to infinity, depending on different assumptions on the values of the various parameters. From these discussions it becomes clear that the major pillars of social discounting framework are SOC and SRTP.

Based on Feldstein,[31] Valentimy and Pradoz,[32] the derivation of the SRTP is made under four assumptions set by Feldstein. They are:

3.1. Individual consumption is distributed equally in the population, so that $c_{it} = c_{jt}$ for all i, j and t, where c_{it} is the consumption of individual i at period t. In order to make the model testable, the usual practice involve a departure from Feldstein by considering per capita income, y_{it}, instead. This implies that $\boldsymbol{Y_t = N_t y_{i,t}}$ (1)

where Y_t is total income (GDP, for example) and N_t is total population at time t. Feldstein's caveat about the distribution of consumption also follows through concerning the distribution of income. The choice of total income instead of total consumption is related to the fact that total income better reflects the wellbeing of a nation. In many modern economies, governments provide a lot of private goods, Nordic welfare states being a good example.

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[30] K. S. Lyon, "Why Economists Discount Future Benefits", *Ecological Modeling*, Vol. 92, No. 2-3, pp. 253-262.

[31] Martin S. Feldstein, *op. cit.*

[32] Valentim Joice and Mauricio Prado, *Social Discount Rates*, Italy: IMT Lucca Institute for Advanced Studies, 2008.

3.2. All individuals have the same utility function u_t over per capita income with a constant coefficient of relative risk aversion σ > 0 and marginal utility given by (where φ is constant) :

$$\boldsymbol{u_t' = \varphi y_t^{-\sigma}} \tag{2}$$

3.3. Social utility U_t is not necessarily the sum of individuals' utilities. Since we are in the case with equal distribution of income, Feldstein and also here we assume

$$\boldsymbol{U_t = N_t^{\alpha} u_t} \tag{3}$$

where α ε [0, 1] gives the weight of the population size N_t on the social utility.

3.4. Felicity F is the discounted sum of future social utilities:

$$F = \sum_{t=0}^{\infty} \beta^t U_t \tag{4}$$

where β ε (0, 1) is a pure time preference factor . With these assumptions we are ready to derive the SRTP rate; for further detailed explanations on the assumptions refer to Feldstein. So the SRTP rate between years t- 1 and t(d_t) is defined as

$$d_t \equiv \mathrm{MRS}_{t,t-1} - 1 \tag{5}$$

where $\mathrm{MRS}_{t,t-1}$ is the marginal rate of substitution of income between t-1 and t . By definition

$$\mathrm{MRS}_{t,t-1} = \frac{\partial F / \partial Y_{t-1}}{\partial F / \partial Y_t}$$

Using equation (4), we can derive $\boldsymbol{\frac{\partial F}{\partial Y_{t-1}}}$ and $\boldsymbol{\frac{\partial F}{\partial Y_t}}$:

$$\frac{\partial F}{\partial Y_{t-1}} = \beta^{t-1} \frac{\partial U_{t-1}}{\partial Y_{t-1}} \quad \text{and} \quad \frac{\partial F}{\partial Y_t} = \beta^t \frac{\partial U_t}{\partial Y_t}$$

Hence,

$$\mathrm{MRS}_{t,t-1} = \frac{\beta^{t-1} \partial U_{t-1} / \partial Y_{t-1}}{\beta^t \partial U_t / \partial Y_t} = \frac{\partial U_{t-1} / \partial Y_{t-1}}{\beta \partial U_t / \partial Y_t}$$

The first assumption and equation (1) imply that $\boldsymbol{\frac{\partial y_t}{\partial Y_t} = N_t^{-1}}$. Let us define π_t as the rate of population growth between period t-1 and t. Using equation (3):

$$\frac{\partial U_t}{\partial Y_t} = N_t^{\alpha} \frac{\partial u_t}{\partial Y_t} = N_t^{\alpha} \frac{\partial u_t}{\partial y_t} \frac{\partial y_t}{\partial Y_t} = N_t^{\alpha} u_t' N_t^{-1} = N_t^{\alpha - 1} u_t'$$

Similarly,

$$\frac{\partial U_{t-1}}{\partial Y_{t-1}} = N_{t-1}^{\alpha-1} u_{t-1}' = N_t^{\alpha-1} \left(1 + \pi_t\right)^{1-\alpha} u_{t-1}' \tag{6}$$

Then,

$$\text{MRS}_{t,t-1} = \frac{N_t^{\alpha-1}(1+\pi_t)^{1-\alpha}u'_{t-1}}{\beta N_t^{\alpha-1}u'_t} = (1+\pi_t)^{1-\alpha}\frac{u'_{t-1}}{\beta u'_t}.$$

Substituting the marginal utility in (2) at (6) and applying the result in (5) deliver the SRTP rate:

$$d_t = \frac{(1+\pi_t)^{1-\alpha}}{\beta}\left(\frac{y_{t-1}}{y_t}\right)^{-\sigma} - 1 \qquad (7)$$

If we further define γ_t as the growth rate of per-capita income between period t-1 and t and r as the pure time preference rate, where $\beta(1 + r) = 1$, then we can rewrite (7) as

$$\boldsymbol{d_t = (1+\pi_t)^{1-\alpha}(1+\gamma_t)^{\sigma}(1+r) - 1} \qquad (8)$$

The above equation is equivalent to Feldstein. Next we look at SOC discount rate, which can be estimated using number of different models. The models aim to identify what the market would expect to receive for a particular project. This is the rate of return to balance the SOC of undertaking the project in the public sector versus the next best alternative in the private sector where rates are observable.

The choice of underlying model can significantly alter the result obtained[33]. The main models to choose from include the Capital Asset Pricing Model (CAPM), the Arbitrage Pricing Theory (APT), and Fama and French's multi-factor model[34]. The expected return derived using CAPM assumes that all risks that can be removed by diversification are carried out. Arbitrage Pricing Theory, developed by Ross[35], is an alternative model to CAPM and uses an equilibrium-pricing factor model with multiple factors to determine the expected return. The APT theory does not specify exactly which factors determine the expected return or how many should be used. The application of the theory could include the use of the GDP or GNP, inflation or interest rates[36].

Fama and French have developed several multifactor models designed to predict the expected return of particular market investments. Their multi-factor model uses five specific factors to explain average market performance of particular stocks. There are three stock market related factors (overall market

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[33] Louise Young, "Determining the discount rate for government projects", *Treasury Working Paper Series*, No. 02/21, New Zealand Treasury, 2002.
[34] Eugene F. Fama and Kenneth R. French, "Common risk factors in the returns on stocks and bonds", *Journal of Financial Economics*, Vol. 33, No. 1, 1993, pp. 3-56.
[35] Stephen A. Ross, "The Arbitrage Theory of Capital Asset Pricing", *Journal of Economic Theory*, Vol. 13, 1976, pp. 343-362.
[36] Louise Young, *op.cit.*

performance, firm size, and book-to-market equity) and two-bond market related factors (default risk and effect of unexpected changes in interest rates).

The results from these models are then used in the standard weighted average cost of capital (WACC) formula to get a discount rate. The discount rate would be the weighted average cost of capital. The formula is

$$WACC = \{(1-T_c)\, k_b\, D/(D+E)\} + \{ k_e\, E/(D+E)\} \quad (9)$$

where T_c is the corporate tax rate, k_b is the return on debt calculated using CAPM, k_e is the return on equity calculated using CAPM, D is bonds or debt and E is equity (also called stock). This formula needs to be adjusted to reflect that the government does not pay tax or get a tax break on paying interest. This ensures the rate reflects the tax situation for a public sector project. This requires the formula to be divided by $(1-T_c)$, such that

$$WACC = [\, k_b D/(D+E)\,] + [\, K_e\, E/(D+E)] \quad (10)$$

where K_e is the return on equity calculated using the CAPM adjusted for the fact that the government does not pay corporate tax or algebraically as

$$K_e = k_e / (1 - T_c) \quad (11)$$

It is important to undertake sensitivity analysis, as any method of calculation of the discount rate will only provide an estimate and not the actual value. Here we will only briefly focus on CAPM model, as it one of most widely used method for calculating returns. The CAPM approach gives an expected return equal to the risk-free return (tax adjusted) plus a market related risk premium. This risk premium is based on how the security or investment moves in relation to the market. The way the security or investment moves in relation to the market is the β_e. The difference between the expected return on the market (R_m) and the after tax risk free rate $[R_f\,(1-T_c)]$ is the after tax market risk premium $[R_m - R_f\,(1-T_c)]$. The Equity beta β_e and the market risk premium are multiplied together to get the additional return for systematic risk. T_c is the corporate tax rate. As a formula this is

$$k_e = R_f\,(1-T_c) + [R_m - R_f\,(1-T_c)]\,\beta_e \quad (12)$$

CAPM is widely used in the private and public sector.

4. Social Discounting for Bangladesh: Results and Interpretation

Now that we have developed the theoretical foundation for calculating SDR, in this section we will try to estimate the SDR for Bangladesh, using SRTP, SOC and Weighted Average method. In case of SRTP and Weighted Average method, we will use Monte Carlo simulations as in some cases, especially for behavioural parameters (Risk Aversion, Time Preference, etc), theory gives us only permissible range of values rather than a point estimate. First we will try to estimate the SRTP and then SOC and Weighted Average method respectively.

4.1. Social Rate of Time Preference

In order to estimate the SRTP, we will use equation (8), which is reproduced below for reference.

$$d_t = (1 + \pi_t)^{1-\alpha}(1 + \gamma_t)^{\sigma}(1 + r) - 1$$

where π_t is the rate of population growth, α ε [0, 1] gives the weight of the population size, γ_t is the growth rate of per-capita income, $\sigma > 0$ is the coefficient of relative risk aversion and r is the pure time preference rate.

The rate of population growth rate is taken to be 1.35 per cent (2009 estimate) and this is based on the average of the estimate provided by World Development Indicators (WDI) of World Bank and CIA World Fact book. The rate of population growth positively affects the SRTP rate. The next parameter α works both as the curvature of the population growth on the SRTP rate, and also as the weight put on the size of the population according to (3). It can vary between zero and one. The effect of α on the SRTP rate is negative. In accordance to Feldstein, we take into account all the possible values within the entire admissible range. The effect of the per capita income growth rate on the SRTP rate is positive. In the present study it is taken to be 4.11 per cent which is average of annual per capita GDP growth rate over 2000-2008 periods. The data is taken from World Development Indicators (WDI) of World Bank. Now the coefficient of relative risk aversion σ or, equivalently, the marginal utility of income, is quite difficult to estimate. In macroeconomic models with standard preferences (constant relative risk aversion (CRRA) or Log utility) usually varies between one and four[37]. But essentially there is no consensus as to the value this parameter can take. Feldstein[38]argues that higher values of σ would seem less relevant for policy purposes and suggests values between 1 and 2. Others like Stern[39], Lanot *et.al*[40] and Blundell *et. al*[41] find that the estimate can vary between 1 and 10. However Evans[42], based on the structure of personal income tax rates, a study on 20 OECD countries suggests that on average for developed countries σ is close to 1.4.

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[37] Robert E. Lucas, "Macroeconomic priorities", *American Economic Review*, Vol. 93, No. 1, 2003, pp. 1-14.

[38] Martin S. Feldstein, *op. cit.*

[39] Nicholas Herbert Stern, *The Economics of Climate Change: The Stern Review*, London: Cambridge University Press, 2006.

[40] Gauthier Lanot, Roger Hartley and Ian Walker, "Who really wants to be a millionaire: estimates of risk aversion from game show data." *Warwick Economic Research Paper No. 719*, University of Warwick, 2006.

[41] Richard Blundell, Martin Browning and Costas Meghir , "Consumer demand and the life-cycle allocation of household expenditures" *The Review of Economic Studies*, Vol. 61, No. 1, 1994, pp. 57-80.

[42] David J. Evans, "The Elasticity of Marginal Utility of Consumption: Estimates for 20 OECD Countries", *Fiscal Studies*, Vol. 26, 2005, pp. 197-224.

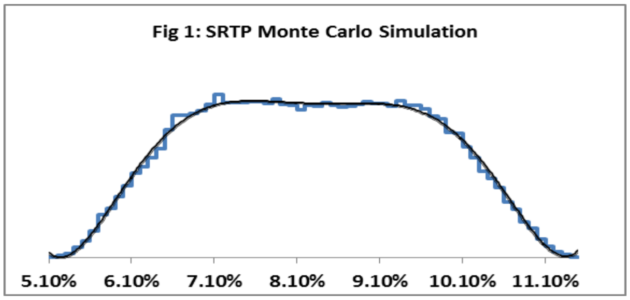
Layard et al[43] use data on different countries and time periods to estimate the marginal utility of income from direct measurement of experienced happiness in six major surveys instead of inferences from behaviour. Results were very similar among surveys, with a narrow range of 1.19-1.34. In view of these evidence Valentimy and Prado, use the average value of 1.26 for their computational purpose. In this paper the authors take in to account all the possible values within (1, 2). Since there is no theoretical foundation to choose a particular value within the 1-2 range, we will assume a uniform distribution during our simulation exercise. However it must be noted that we are restricting our parameter value within the 1-2 range, in view of the aforesaid literature. Finally, we look in to r, which is the pure time preference rate. Arrow indicates 1 per cent as a tentatively pure discount rate. Oxera[44] stipulated 1 per cent for UK. Stern uses 0.1 per cent per year. Nordhaus,[45] which he calls time discount rate, suggests 1.5 per cent. For the UK, HM Treasury selected a figure of 1.5 per cent. Evans also suggests that a figure close to 1.5 per cent is appropriate. In view of all these the present authors take in to account all the possible values within (1, 1.5) and as before we will assume a uniform distribution during the simulation exercise. The summary of the permissible range and estimated values for SRTP calculation is given below:

Table 1: Parameter Values for SRTP Monte Carlo Simulation

Population Curvature (α)	Rate of Population Growth (π_t)	Rate of Per Capita GDP growth (γ_t)	Risk Aversion (σ)	Pure time preference rate (r)
0-1	1.35%	4.11%	1-2	1-1.5%

Based on the aforesaid range and values we then perform Monte Carlo Simulation with 100,000 iterations and in each case the variable parameters are drawn from uniform distribution with the given range, as mentioned before. The following graph shows us the result of the simulation exercise.

[43] Richard Layard, Guy Mayraz and Stephen Nickell, "The marginal utility of income", *Journal of Public Economics*, Vol. 92, No. 8, 2008, pp.1846-1857.
[44] OXERA, "A social time preference rate for use in long-term discounting", a report for ODPM, *Dft and DEFRA*, mimeo, 2002.
[45] William D. Nordhaus, *op.cit.*

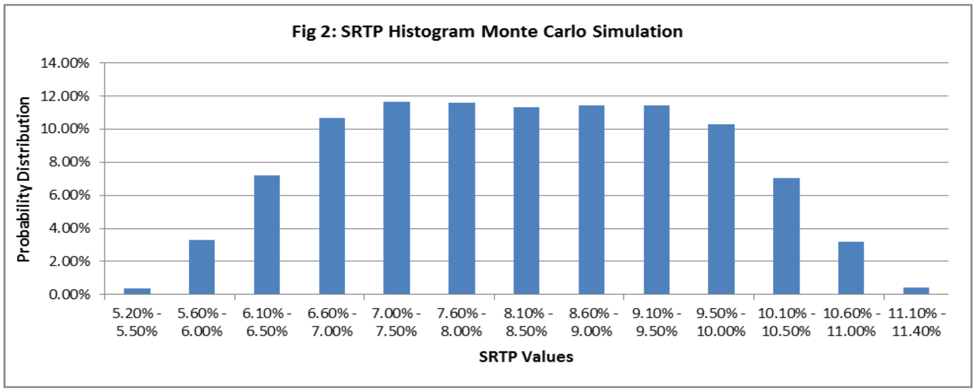


We added a sixth order polynomial as trend line, which seems to perfectly fit the distribution of the Monte Carlo Simulation. The descriptive statistics obtained from the simulation exercise is given below:

Table 2: Descriptive Statistics from Monte Carlo Simulation

Mean SRTP	8.30%
Standard Deviation	1.34%
Coefficient of variation	16.14%
Maximum Value	11.40%
Minimum Value	5.20%
Range	6.20%

The following histogram shows the distribution of SRTP values. As the table 2 and the histogram below shows, the data are indeed very widely spread. The range of the distribution is significant, 6.20 per cent and coefficient of variation is also very high, 16.14 per cent; however almost 55 per cent data are within SRTP values 7 per cent to 9.50 per cent. When Valentimy and Prado calculated SRTP value for 167 countries for the year 2006, for Bangladesh they got an average of 8.20 per cent very close to our average of 8.30 per cent. But their range was much tighter; it was between 7.20 per cent and 9.10 per cent. Considering the fact that they did not use any simulation exercise and had to make certain restrictive assumptions (e.g., risk aversion assumed to be 1.26 for all countries, time preference assumed 1 per cent for all countries), such results seem tenable. Even so their mean estimate for SRTP does seem to be in reasonable agreement with our estimate.



Next we will try to estimate the SOC of capital for Bangladesh using the CAPM framework discussed in the previous section.

4.2. Social Opportunity Cost of Capital

SOC calculation is contingent upon the nature of projects to be undertaken and in that sense is more restrictive than SRTP. As SOC estimation depends on the length, short vs. long term, and on the nature of risk of the project to be undertaken, we have to make certain assumptions. We will assume a long term cost recovery situation where the costs to be incurred are known with a high degree of certainty. We also assume that the costs will be recovered prior to any expenditure being incurred. This covers any circumstance where there is an ability of the Government to set the price to ensure cost recovery and there is no cross subsidisation between the users of the services and other taxpayers. The costs and benefits are occurring over a number of years. This is similar to situation when government tends to undertake large projects like Power Plants, major roads or bridge, etc.

Next we look at the weights for the debt and equity components of the project. This may depend on the type of agency within government that is undertaking the activity. For example, if the government is undertaking something directly through taxation or a subsidy, versus through a department or SOE. In the present case we assume that the project will be based on 100 per cent bond financing and no equity financing; this is a likely scenario for any large scale projects in Bangladesh where the government may issue bond or borrow money before commencing the project. If, however, the project was to be funded by an increase in general taxation then 100 per cent equity may have been appropriate. We will use equation (10) in order to calculate the SOC of capital or Weighted Average Cost of Capital, as it is called in CAPM framework.

$$WACC = [\, k_b D/(D+E) \,] + [\, K_e\, E/(D+E)]$$

where k_b is the return on debt calculated using CAPM, D is bonds or debt and E is equity (also called stock) and where K_e is the return on equity calculated using the CAPM adjusted for the fact that the government does not pay corporate tax. Now since we assume 100 per cent debt finance, the equity component drops out completely and we are left with WACC $= k_b$. Since we have no equity component, our measurement is simplified as we do not have to estimate the β coefficient, as this is only relevant if there is an equity component in the weighted average cost of capital. In order to calculate the nominal return on debt, k_b we need to calculate the debt premium and the risk free rate.

In this situation the assumed project is very long-term in nature and so the term of the risk-free rate should match this. Thus we should use a long term government bond rate to match this time frame. Therefore, in this situation the rate of recently introduced 10-year, 15-year and 20-year Bangladesh Government Treasury Bonds (BGTB) are the most appropriate choice. The 10-year Treasury bond was introduced in December 2005 and 15-year/20-year Treasury bond was introduced in December 2007. Since they are very long term bonds and have been introduced relatively recently, we use rate taken from the latest auction. We find that the nominal rate on 10-year and 15-year bonds was 8.77 per cent while the 20-year bond had a rate of 9.17 per cent. In view of this we can look at two scenarios, one very long term (using 20-year BGTB) and another medium to long term (using 10-year BGTB).

Next we need to estimate the debt premium but in the case of the government the risk-free rate is also its own bond rate. The government guarantee associated with government borrowing means the government does not pay a debt premium for the risk of default relative to other types of borrowers in Bangladesh; therefore we need to develop a proxy for this. One way to do is to estimate the debt risk premiums of high quality debt in the market, which are without a government guarantee. Hussain and Chakraborty[46] calculated the debt premium for twenty four commercial banks in Bangladesh that are listed in the Dhaka Stock Exchange for the three year period between 2006 and 2008 (see Appendix I). We used the average Debt premium of those 24 companies across the 3 year period. The results for our estimation are given below:

Table 3: Nominal Debt Return under Average Debt Premium

Project Span	BGTB used as Risk Free Proxy	Nominal Long Term Government Bond Rate	Average Debt Premium Before Tax	Nominal Debt Return
10 Year	10 Year T-Bill	8.77%	8.85%	17.62%
20 Year	20 Year T-Bil	9.17%	8.85%	18.02%

Now obviously not all of those companies are most reputable, although in Bangladesh the private commercial banking sector is a booming sector. Even so one could argue that they may not proxy well for the debt risk premiums of high quality debt. One of the lowest debt risk premium was observed for Rupali Bank Limited (RBL). This bank was established as a nationalised bank in 1972 under the Bangladesh Banks Nationalisation Order. The bank was denationalised in 1986, and reorganised as a limited company, with the Government of Bangladesh

[46] Tashfeen Hussain and Liton Chakraborty, "Is the cost of capital an important determinant of market performance of private commercial banks in Bangladesh?" Paper presented in *ASBBS Annual Conference*, Las Vegas, Vol. 17, No. 1, 2010.

holding majority share of 51 per cent. However, after the year 2000, the Government divested of its shares, and the privatisation of the bank was complete. Even so given that it was a nationalised bank for over 25 years, we can take its debt premium as a reasonable proxy for debt premium of high quality debt. Another proxy could be Pubali Bank limited (PBL), although it was nationalised at the same time as RBL but it was privatised back in 1983; it is one of the largest private bank in the country. Both RBL and PBL have similar debt premium and one of the lowest too. In view of this we repeat the previous estimation but now using RBL debt premium as proxy.

Table 4: Nominal Debt Return under RBL Debt Premium

Project Span	BGTB used as Risk Free Proxy	Nominal Long Term Government Bond Rate	RBL Debt Premium Before Tax	Nominal Return
10 Year	10 Year T-Bill	8.77%	8.36%	17.13%
20 Year	20 Year T-Bill	9.17%	8.36%	17.53%

All the above estimates are based on nominal return while we need to estimate the real return. In order to do this we will employ the simple formulation: Real rate = {[(1+ nominal rate) / (1 + inflation)] – 1}. Thus, we need inflation data for the calculation of real rate, but it has to match with the time frame we are considering. The inflation data was obtained from World Economic Outlook (2009) of International Monetary Fund; for 10-year time period we used 10 year average annual inflation rate, while for 20 year time period we used 20 year average annual inflation rate. Based on this, in the following we convert the nominal return on debt to real return.

Table 5: Real Debt Return

Project Span	Average Annual Inflation Rate	Debt Premium Before Tax	Nominal Return on Debt	Real Return on Debt
10 Year	5.63%	Average	17.62%	11.34%
		RBL	17.13%	10.89%
20 Year	6.12%	Average	18.02%	11.21%
		RBL	17.53%	10.76%

So from the above we can see that the SOC varies within 10.76 per cent to 11.34 per cent, which is less than 1 per cent; thus the variability is much lower than SRTP. The maximum value for SRTP, based on the simulation, was 11.40 per cent which also seems to be the upper bound for SOC, based on the average bank debt premium as benchmark. But if do take RPL debt premium as benchmark then as expected, for both 20-year and 10-year period it is almost half a percentage point lesser than the case with average debt premium.

We recall that 55 per cent of its data was within the range of 7.5-9 per cent, and here we see most data for SOC is around 11 per cent. Thus if the government of Bangladesh undertakes any project using complete debt financing then so long the return is above 11 per cent, it will take in to account both the opportunity cost of capital and citizens time preference, as the upper bound seems to be SOC. On the other hand if the project is more equity based so that the opportunity cost of capital is less than 11 per cent, then so long the project yield returns higher than 9 per cent, it seems viable under the SRTP framework too. So in essence the government of Bangladesh, in view of SOC of Capital and SRTP, should use a SDR of 9-11 per cent. We did a simulation exercise using different weights to calculate the weighted average SDR. The detail tables and graphs are presented in Appendix II but what we find is that the average value of SDR for Bangladesh is around 9-10 per cent and range is within 8-11 per cent in almost all cases.

It is worthwhile to look at SDR values of other countries in order to gauge whether our estimate for Bangladesh is reasonable. As there is no consensus as to what is the best approach to estimate SDR, it is not surprising that there are significant variations in public discount rate policies in different countries around the world. Many government agencies do not discount at all. Often the discount rate is prescribed by government review and monitoring agencies (e.g., OMB, CBO). In the U.S. and Canada, prescribed rates have been as high as 10 percent but have been trending lower. Zhuang *et. al*. provide a detail table, which gives an overview of the rates and methods used by different country in estimating their SDR.

We see in case of both India and Pakistan, the SDR is based on SOC framework and is 12 per cent, which is very close to our estimate based on the same framework. Pakistan and India both have similar institutional level of development as Bangladesh, especially in the financial sector and thus their SDR value gives credence to our estimate. China uses a weighted average method and gets a value 8 per cent, which is slightly lower than our range for weighted average SDR but even so is very much comparable. Philippines use SOC approach and set their discount rate at 15 per cent, which is comparably pretty high. Some of the European countries have very low discount rate, for instance Italy uses 5 per cent, Germany 3 per cent, both Norway and UK use 3.5 per cent. Both Australia and New Zealand use SOC approach to calculate their SDR and they stand at 8 per cent and 10 per cent respectively, which are relatively close to our findings.

5. Policy Implications

CBA based on high discount rates will have a tendency to favour projects with short-run benefits over those with payoffs in the long run. As the discount rate falls, we will find more and more projects with benefits emerging in the long run. Thus public investment programs can be dramatically different, both in terms of overall envelope and nature of projects depending on the specific discount rate used in practice. For instance the value of receiving BDT 1000 fifty years from now is worth less than BDT 90 today when evaluated at a 5 percent discount rate. On the other hand, if only a 1 percent discount rate is used, the same amount is worth over BDT 600 today. The present paper estimates for Bangladesh, based on simulation exercise and estimates, under both SOC and SRTP framework range between 9-11 per cent. The values seem very much probable in view of comparison with those of India, Pakistan and China. The government of Bangladesh is currently planning to undertake various long term projects, like open-pit mining at Barapukuria coal field in Dinajpur, Padma Bridge, Nuclear Power Plant in Rooppur Pabna or for that matter the currently under construction the flyovers in Dhaka city. In addition to these large scale infrastructural projects, the use of appropriate SDR is crucial for other long term projects. For instance Khan and Karim[47] use multiple SDR in a bioeconomic fishery model to evaluate the optimal fishing effort and harvest level of Bangladesh marine shrimp fishery over a span of 25 years. Similarly Khan[48] uses stochastic model and a range of SDRs to estimate water use decisions that maximise net social return in the Chandpur Irrigation Project (CIP) of Bangladesh for a 30 years period.

Raihan and Khondker[49] in their paper try to estimate the overall economic benefit of constructing Padma Bridge. They undertook simulation exercise using Social Accounting Matrix (SAM) multiplier model to estimate the overall impact. They used a discount rate of 12 per cent to estimate the NPV and benefit-cost ratio (B/C). In the following table NPV and B/C has been recalculated using the same benefit and cost steam as the paper but the choice of SDR is 9 per cent and 11 per cent; for comparison the original value using 12 per cent has also been provided.

Table 6: Benefit of Padma Bridge using different SDR values

		Model 1	Model 2
SDR at 9%	NPV (million USD)	$3,714	$3,604
	B/C Ratio	2.71	2.65
SDR at 11%	NPV (million USD)	$2,162	$2,089
	B/C Ratio	2.11	2.07
SDR at 12%	NPV (million USD)	$1,234	$1,184
	B/C Ratio	2.01	1.97

[47] Khan Mohammed Shamim Uddin and Mohammad Nesarul Karim, “The Control Path of Sustainable Marine Fisheries of Bangladesh”, *Thoughts on Economics*, Vol. 21, No. 03, 2011.
[48] Khan Mohammad Ismail, “Optimal water allocation for rice production under climate change”, School of Economics, La Trobe University, 2012.
[49] Selim Raihan and Bazlul Haque Khondker, *Estimating the Economic Impacts of the Padma Bridge in Bangladesh*, University Library of Munich, No. 37904, 2010.

The internal rate of return for the project was estimated to be 19 per cent and therefore it is a viable project under all three values of discount rate. Since the bridge is likely to be built under complete debt financing, an IRR of 19 per cent will take in to account both the opportunity cost of capital and citizens' time preference. Furthermore, since the bridge is likely to last over 30 years, it is probably more preferable to use the lower discount rate value of 9 per cent. Thus we can see that at a SDR value of 9 per cent, under both models, the net present value of benefit is roughly 3 times more than that which was estimated in the original paper.

6. Conclusion

In this paper we have undertaken a literature review of various techniques that are employed in determining the SDR and then estimated it for Bangladesh. Although from a theoretical standpoint various self-consistent measures of discounting have been developed, there is yet to be any broad based consensus in the academia and among policy makers regarding the best means of calculating the rate. As we have seen in this section various countries employ various methods of calculating discount rate and some even do not discount at all. This disparity in measurement technique is becoming a crucial issue now, as environmental concern is becoming a global phenomenon. How we should tackle pollution, global warming and other environmental issues, and to what extent government should invest in costly abatement technology is very much pertinent and contingent upon how one measure SDR. Hence, consensus in this arena is very much important at present for Bangladesh, especially considering the numerous upcoming high investment public projects. The present exercise can provide helpful insights in the decision making framework of future projects.

Appendix I: Debt Premium

Name of Bank	After Tax Cost of Debt (2006)	After Tax Cost of Debt (2007)	After Tax Cost of Debt (2008)	After Tax Cost of Debt Average
ABBL	0.026	0.025	0.027	**0.026**
CBL	0.061	0.031	0.002	**0.031**
IFICBL	0.035	0.036	0.034	**0.035**
IBBL	0.036	0.035	0.043	**0.038**
NBL	0.038	0.042	0.038	**0.039**
PBL	0.041	0.040	0.048	**0.043**
RBL	0.048	0.046	0.042	**0.046**
UBL	0.045	0.046	0.047	**0.046**
EBL	0.034	0.051	0.054	**0.046**
AABL	0.045	0.044	0.051	**0.047**
PMBL	0.046	0.046	0.049	**0.047**
SBL	0.049	0.049	0.045	**0.048**
DBL	0.050	0.048	0.051	**0.049**
NCCBL	0.046	0.053	0.054	**0.051**
SIBL	0.050	0.050	0.052	**0.051**
DBBL	0.051	0.050	0.053	**0.051**
MTBL	0.052	0.052	0.053	**0.052**
STDBL	0.057	0.050	0.056	**0.054**
OBL	0.050	0.060	0.058	**0.056**
BAL	0.055	0.058	0.061	**0.058**
MBL	0.058	0.060	0.064	**0.061**
EXMBL	0.063	0.064	0.060	**0.062**
ICBL	0.062	0.062	0.063	**0.062**
JBL	0.067	0.067	0.069	**0.068**
Average	**0.049**	**0.049**	**0.049**	**0.049**
Before Tax Average	***8.827%***	***8.830%***	***8.886%***	***8.847%***

Source: The table is adapted from T. Hussain, and L. Chakraborty, 2010, *op.cit*. They used a 45 per cent tax bracket to calculate after tax Debt Premium.

Appendix II: Monte Simulation Result for Weighted Average Method

In the following case we used the simple weighted average formula without foreign borrowing:

Weighted Discount Rate = β*SOC + (1- β)*SRTP where β ε **(0, 1).** The simulation exercised varied the different values of β and also simultaneously varied the SRTP values, which was estimated by simulation exercise. So both SRTP and β was varied during this Monte Carlo Simulation. The following gives us the summary results, we have derived four situations based on four different ways we measured SOC.

Four Variant SOC Measure	**Average Debt Premium & 10-Year Period (Case 1)**	**RBL Debt Premium & 10-Year Period (Case 2)**	**Average Debt Premium & 20-Year Period (Case 3)**	**RBL Debt Premium & 20-Year Period (Case 4)**
Average	10.27%	10.40%	9.07%	9.74%
SD	0.62%	0.28%	1.24%	0.59%
Max	11.34%	10.89%	11.21%	10.76%
Min	9.19%	9.91%	6.92%	8.71%

The graph from simulation exercise for each case is also given below: