1 The concept of discounting in cost-benefit analysis

Cost-benefit analysis is a tool to improve decision-making. Identifying and measuring costs and benefits encourages close examination of the factors that influence them and assists in minimising costs and maximizing benefit, helping decision makers increase net benefits to society.[1]

1.1 Introduction

Cost-benefit analysis uses willingness to pay to measure benefits and opportunity cost to measure costs.[2] The opportunity cost of resources is their value in the alternative use to which they would have been put.[3] Identifying the costs and benefits of a policy change involves comparing outcomes with the proposed change to outcomes without the change. Analysts can measure the value people place on something by observing how much they are willing to pay. Market behaviour often reveals people's valuations, or is at least a guide to them. Wherever possible, money values of benefits and costs should be based on tradeoffs that individuals would make in markets.[4]

Most government policies give rise to a stream of costs and benefits over time. To evaluate them requires us to compare costs and benefits received in different time periods. That requires choosing a discount rate, which determines the value of future costs and benefits relative to current ones. The choice of discount rate can make a huge difference to the desirability of government projects, especially when their costs and benefits occur over long periods.

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1 See Australian Government (2007, p. 115) for the benefits of using cost-benefit analysis.

2 See Department of Finance and Administration (2006); Australian Government (2007, appendix B, pp. 115–34); and Weimer (2008).

3 Not the best alternative use to which they *could* have been put, which is how opportunity cost is sometimes defined in textbooks. The two definitions only coincide in a perfectly functioning economy, where if resources are not used in one activity they *would* be used in the most valuable alternative they *could* be used, but that is not generally true in a distorted economy. See Feldstein (1972, pp. 319–320).

4 Arrow et al. (1996, principle 15, p. 11).

Yet there is little agreement about the appropriate discount rate, with cost-benefit guides, academics and textbooks giving conflicting advice. What influences discount rate choice? Should we use the same discount rate in all applications? If not, what factors make a higher or lower rate appropriate for particular uses? But first, what is a discount rate? Why is it used? Why is it important?

1.2 The discount rate in cost-benefit analysis

How do we weigh future costs and benefits against current costs and benefits? A convenient way to compare, and add up, costs and benefits that accrue at different times is to calculate their present value, which expresses them as an equivalent amount of today's dollars.

Discounting converts the dollar value of costs and benefits received in different time periods to present value. The term discounting refers to the fact that a dollar received in the future is worth less than a dollar now. The value of future dollars relative to current dollars is expressed in terms of a time preference rate or a discount rate and is usually expressed as a percentage rate for a period of one year. If the discount rate were constant at ρ per cent per year, a benefit of B_t dollars received in t years has a present value of $B_t/(1+\rho)^t$ dollars.[5] To calculate a project's net present value, we add up all the present values of all its costs and benefits over time, which measures how much the project increases wealth — how much extra consumption it generates for society. The higher the net present value, the more valuable the project.

Any evaluation of policies with future costs and benefits must specify a discount rate. Choosing a discount rate is the same as choosing the value of future dollars. Failure to discount implies a discount rate of zero, which means a future dollar, however distant, counts as much as one received immediately.

Cost-benefit analysis presents estimates of the costs and benefit of a policy in dollar terms. Choosing a discount rate is about putting relative values on estimates of costs and benefits received in different time periods. This paper is not about whether cost-benefit analysis is reasonable or how well costs and benefits can be quantified. It is

[5] More generally, if the discount rate in period j is r_j then a benefit of B_j dollars received at the end of period j is worth $B_j/[(1+r_1)(1+r_2)(1+r_3) \ldots (1+rj)]$ at the beginning of period 1. There is no problem with having discount rates varying over time: we can have a term structure of interest rates (see, for example, the appendix to Harberger 1969). In fact, if credit market conditions are temporarily unusual (or likely to change), it is desirable to have the discount rate changing towards its normal (or predicted) level over the next few years (Harberger 1969, p. 117).

about discount rate choice: how to discount the estimates that are made. Whether cost-benefit analysis should be used is a separate debate.

Putting a dollar value on a project's costs and benefits may be a difficult task — it is not easy to estimate the benefits flowing from a public good, environmental improvements or safety measures that that save lives. There may be considerable uncertainty about predicted impacts and their appropriate monetary valuation. But that is a reason for conducting sensitivity analysis with the disputed variables and improving the estimates, and does not affect the case for discounting.

The discount rate should not be adjusted because of defects in the measurement of costs and benefits. A better approach is to directly adjust the cost and benefit estimates. A change in the discount rate will have a larger effect the further into the future the cost and benefits are received, which generally would not be the appropriate adjustment for measurement problems.

1.3 Why discount?

An important distinction in economics is between investment and consumption. Investment activities primarily affect future well-being; the main impact of consumption activities is in the present. An investment project involves bearing a current cost that is expected to give future benefits. That is, current output is directed to producing future benefits rather than current benefits. Investment is any expenditure on increasing, maintaining and improving capital. Capital is an asset that produces future benefits.

Although the common view of capital is confined to physical capital, such as buildings and machines, this accounts for a small part of the total stock of capital in countries that have achieved a high level of average income. Other forms of capital include the stock of skills and productive knowledge embodied in people (known as human capital) and the framework of laws and regulations (sometimes referred to as institutional capital).

The term government project, therefore, is a broad one that applies to any government decision or policy that affects future consumption. It may be providing a public good, building infrastructure or the introduction of a new regulation. It may involve public investment or it may be a regulation that requires the private sector to invest, with government costs being limited to monitoring and enforcement costs. For example, hiring labour to build a stadium is an investment in a capital good. Requiring more scaffolding to reduce future deaths or injuries or equipment to reduce future pollution emissions is also an investment. So is spending time training to learn new skills that increase future productivity or resources spent implementing or complying with a regulation that increases future safety or prevents an endangered species being wiped out. All involve current costs, borne for expected future benefits.

The case for discounting depends on opportunity costs. The cost of investing funds in a project is what it would have produced in its alternative use. Because capital is productive, an extra dollar invested in the private sector will (on average) grow to more than a dollar. A future dollar, therefore, is worth less than a current dollar, a fact reflected in positive market interest rates. For example, if $1 invested in the private sector would grow to $1.07 next year, the annual rate of return to investment (the marginal rate of return to capital) is 7 per cent.[6] One dollar received in one year's time is worth $1/1.07 = $0.93 now. A public project would only cover its opportunity cost if it earned an annual rate of return of at least 7 per cent.

Equivalently, if a project's net benefits had a positive net present value using a discount rate of 7 per cent, then its benefits are greater than its costs and the project would increase wealth.[7] For example, if a project cost $50 and produced benefits of $60 in one period (a rate of return of 20 per cent), its net present value is $60/1.07 – $50 = $6.07. If the $50 was left in the private market it would produce $50*1.07 = $53.50 of benefits in period 2 dollars. The project produces enough benefits to fully compensate people for the cost of the resources it uses and have $6.50 (= $60 – $53.50) left over (which has a present value of $6.50/1.07 = $6.07).

The analysis generalises to any stream of costs and benefits from a project. If the net present value is positive using a discount rate that reflects the return capital would have earned in the private sector, the project covers its opportunity costs: the benefits from using capital in the project are greater than from leaving it in the private sector. When a government project draws on savings to make an investment, it is sometimes loosely said that it uses capital, because capital can refer to the asset created by investment or the savings that finance it.

Cost-benefit analysis converts all costs and benefits to money equivalents based on willingness to pay. The project is exactly equivalent to receiving that flow of dollars over time. The benefit estimates represent the sum of money those who would benefit from the policy are willing to pay to receive the benefits. The cost estimates are the amount of money that needs to be paid to compensate for the costs the

6 If the rate of return on an asset is i, then the return on the asset is $1+i$. If the rate of return is taxed at rate τ then the after-tax rate of return on the asset is $i(1-\tau)$ and the after-tax return is $1+ i(1-\tau)$.

7 A project produces a stream of costs and benefits. The project's benefit less cost in period t is the net benefit in period t. The net benefit produced in any period may be positive or negative.

project imposes. It is argued here that these streams of money payments should be discounted using a rate derived from the return in the private sector. That compares project benefits with the benefits the capital invested in the project would have produced if left in the private sector.

1.4 Real and nominal discount rates

The discount rate should be consistent with the dollar flows that are measured. If costs and benefits are measured in nominal (or current) dollars, they should be discounted with a nominal discount rate. Costs and benefits measured in real terms (that is, adjusted for inflation), should be discounted with a real discount rate. Both methods should result in the same net present value.[8]

Market interest rates are usually nominal rates — showing the rate at which dollars today are traded for dollars in the future, revealing how savers and investors value future dollars. If savers are willing to lend *$1* in return for $\$1+\rho$ next year, then the annual nominal interest rate is ρ per cent.

Market interest rates are usually positive, indicating people generally value a dollar in the future less than a dollar now. When money is given up now for money one period from now (the act of saving), you give up the right to use or consume the money during the period, which could include investing it. That right is valuable, so dollars today are worth more than dollars tomorrow.

Dollars are valuable for what they can buy. Inflation is one reason a dollar in the future is worth less than a dollar now. A general rise in the price level means a dollar buys fewer goods. Future costs and benefits can be valued in nominal or real dollars. In the nominal (or current) dollars approach, the impact of expected inflation is explicitly reflected in the projections (the cost and benefit streams grow faster when expected inflation increases). The real (or constant price) approach expresses all variables in terms of the price level of a given year, usually the present year. A real dollar has the same purchasing power at any time (can buy the same bundle of goods).

The usual approach in cost-benefit analysis is simply to express all costs and benefits in real dollars, which avoids having to estimate the future course of inflation. But that requires the analyst to convert past nominal flows into real dollars and to specify a real discount rate.[9]

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[8] See appendix A, section A.1.

[9] See appendix A, section A.2.

The real interest rate is the rate at which real dollars (or goods) today are traded for real dollars (or goods) tomorrow — either directly or through converting goods into money, trading money this year for money next year (through lending it at the nominal interest rate) and then buying goods next year.[10]

As people consume — and get utility from — goods, not dollars, it is the real interest rate that is relevant when people decide how much to consume now and in the future.

Again, because present command of resources expands opportunities, people are willing to pay for that command, and people who give it up need to be compensated for doing so.[11] The real interest rate, therefore, is usually positive — goods received now are worth more than goods to be delivered in the future.

Expressing cost and benefit estimates in terms of constant purchasing power does not mean pricing individual products and factors at current prices. Anticipated changes in the relative price of important outputs and inputs into the project, as distinct from general price level changes, should be reflected in the estimates of future costs and benefits.[12] For example, cost-benefit studies that deal with environmental and safety issues need to account for the changing value of non-marketed goods and amenities and of the value of statistical life. Both are likely to grow at least as fast as average incomes. For example, if climate change damages the environment, the relative price of environmental amenities will increase, raising the value placed on marginal units. When the relative price of an important output or input (including the discount rate) is currently out of line with its long-term norm, this should be identified, and the path by which the price is expected to move back to its norm should be specified.[13]

1.5 The discount rate's impact on project viability

The net present value of any project with future costs and benefits crucially depends on the discount rate chosen, especially when the costs are borne in a different time frame than the benefits are received. As illustrated in table 1.1, when the discount rate is higher, future costs and benefits count for less. A high discount rate favours projects with benefits that accrue early.

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[10] See Friedman (1990, pp. 333–37) for a discussion of real and nominal interest rates.

[11] See Heyne (2002)

[12] Harberger (1969, footnote 16, p. 122).

[13] Harberger (1992, p. 14).

The discount rate has an important effect on investment decisions. A typical project involves upfront costs, with the benefits coming later. If so, the lower the discount rate, the more attractive is the project (the higher its net present value). If the discount rate is set too high, desirable projects may be rejected. If it is set too low, undesirable projects may be approved. The size of the discount rate makes a huge difference to policies where benefits occur in the distant future, such as many environmental policies. Lower discount rates encourage investors to adopt projects that offer returns at distant dates. It was a lower discount rate that drove the differences between the policy conclusions of the Stern report and the consensus view of previous cost-benefit analyses of global warming. Stern's cost-benefit analysis of global warming assumed a real discount rate of 1.4 per cent and concluded there was a case for an immediate imposition of a high, and increasing, carbon price. Nordhaus assumed a 5.5 per cent discount rate, and favoured a modest carbon price, increasing over time. The recommended polices differed because of the different discount rate assumptions. When Nordhaus ran his computer model using Stern's discount rates, he got similar results to Stern.[14]

The difference is not surprising because most of the effects of global warming take place decades in the future. At Stern's discount rate of 1.4 per cent per year, $1 grows into $4 in 100 years and $16 in 200 years. At Nordhaus's 5.5 per cent, it would grow to $211 in 100 years and $44 719 in 200 years. Put differently, the present value of $1 of damages in 100 years with Stern's discount rate is 25 cents, more than 50 times greater than with Nordhaus's. A dollar in 200 years is valued at 6 cents now, almost 2800 times more than Nordhaus's value.

[14] See Nordhaus (2007, pp. 694, 698-700); Baker et al. (2008, pp. 63-64) and Weisbach and Sunstein (2008, p. 11).