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COMMENTS AND OPINIONS

Project Evaluation Decision Rules: A Reply to W.R. Cook

W.R. COOK'S (1989) article "Using the Internal Rate of Return in Public Sector Project Evaluations" in the October 1989 issue of *The Canadian Journal of Program Evaluation* recommends using internal rate of return (IRR) in place of net present value (NPV) as the decision rule for assessing the economic desirability of alternative public investments. The original article, the reply by Watson (1990), and the response by Cook (1990) do not fully address the reasons for which the NPV decision rule has been consistently recommended as the formulation for use in financial analysis (Canada & White, 1980; Clark, Hindelang, & Prichard, 1984; Copeland & Weston, 1980; Herbst, 1982; Levy & Sarnat, 1986; Quirin & Wiginton, 1981; Viscione, 1984; Wilkes, 1983) and public-sector cost-benefit evaluation (Broadway & Bruce, 1984; Dasgupta & Pearce, 1972; Mishan, 1971; Quirin & Wiginton, 1981; Schofield, 1987; Sugden & Williams, 1978). This reply will briefly discuss these reasons in the context of the three types of decision making: single project accept/reject, the ranking of independent projects, and selection from mutually exclusive projects.

Although the NPV and IRR decision rules are related, these formulations differ in their approaches to discounting future net-benefits (benefits less costs). The NPV rule assumes the social discount rate (r) in order to directly calculate the absolute incremental change in *sign and magnitude* of social welfare (i.e. NPV, the surplus of discounted future net-benefits over initial costs); the IRR rule calculates the relative *direction* of incremental change in social welfare by solving for the discount rate (IRR) for which NPV is zero.

Dr. Cook explains that although the NPV decision rule is widely used in public-sector decision making because of its ease of calculation, project selection is suspect because the calculation of NPV (a) assumes *r* and (b) is affected by the monetary dimensions of the project. Hence, the NPV decision rule can incorrectly rank projects and potentially inefficiently allocate scare capital funds. In contrast, the IRR decision rule avoids serious bias by calculating (rather than assuming) the discount rate. Because the historic limitations on the use of the IRR decision rule (the analytical difficulties in solving for IRR and interpreting multiple IRRs) have been resolved, the barriers to the widespread use of the IRR decision rule have been removed, and the rule, if used, could help decision makers to allocate capital funds efficiently.

This reply argues that (a) the interaction of the discount rate and the timing of flows of net-benefits, (b) the "reinvestment" assumption, (c) the interpretation of multiple roots, (d) the dependence of the calculated IRR on the monetary dimensions of the project, and (e) the inability of the method to include intangible costs and consequences may severely compromise decision making based on the IRR decision rule. Although the social discount rate must be assumed, the NPV rule avoids the above limitations and is consistent with underlying welfare economic theory (the theoretical basis of cost-benefit analysis; see Broadway and Bruce [1984], and Winch [1972]).

SINGLE PROJECT ACCEPT/REJECT SELECTION

Both the NPV and IRR decision rules reach equivalent accept/reject decision when projects have conventional streams of costs and benefits (i.e., an initial investment followed by a series of positive net-benefits: –, +) (Dasgupta & Pearce, 1972; Levy & Sarnat, 1986; Quirin & Wigington, 1981). However, contrary to Dr. Cook's assertion, the IRR decision rule depends on the value of *r* ; decision makers must specify a cut-off *r* below which they will not adopt projects. The incorrect specification of *r* will bias decision making using either the IRR or NPV decision rules.

Projects having nonconventional streams of net-benefits will generate multiple IRRs. Multiple IRRs are associated with stream sign changes (e.g., simple –, +, – or complex –, +, –, +, – sign changes). Sign reversals arise from periodic major equipment overhauls or replacements, project termination costs (e.g., salvage or site cleanup), and other investments and expenditures. Dr. Cook (1989, 1990) argues that the concern about multiple IRRs is a "red herring." Citing Sugden and Williams (1978), he suggests that a sinking fund could be used to convert simple nonconventional streams of costs and benefits (–, +, –) into conventional ones (–, +, +). In my reading of Sugden and Williams, I did not find this suggestion; however, Sugden and Williams do state that:

> the open-cast mining project, for instance, had early costs followed by later returns followed by still later costs. In such a case it is not immediately obvious how to interpret the critical value of the interest rate . . . It is not even obvious in such cases that there will be only one critical value. (p. 21)

Sugden and William then conclude that:

> in this book we shall continue to use the concept of present value because of its simplicity, its generality, and its intuitive appeal. Further discussion of the limitations of the "internal rate of return rule" and of ways of revising some of its limitations can be found in other works. (p. 21)

Although methods have been proposed to convert nonconventional streams into conventional ones (e.g., Dasgupta & Pearce, 1972; Quirin & Wiginton, 1981), these methods impose additional constraints on the IRR decision rule and apply only to simple nonconventional streams (Dasgupta & Pearce, 1972). The motorway example used by Cook (1990) is misleading; not all projects having intermediate (as opposed to terminal) negative net-benefits can be correctly separated into two distinct projects, each with conventional flows of net-benefits. Converting several intermediate negative net-benefits into equivalent annuities is both complicated and unnecessary. The NPV decision rule always generates a unique solution regardless of the number of sign changes (Dasgupta & Pearce, 1972).

RANKING INDEPENDENT PROJECTS

It is well known that NPV and IRR decision rules can inconsistently rank independent projects when inputs (e.g., funds for capital investments in equipment and other resources) are constrained (Dasgupta & Pearce, 1972; Quirin & Wiginton, 1981; Sugden & Williams, 1978). In Figure 1 from Cook (1989, p. 16), using the NPV decision rule, project A is preferred to project B in the region $0 < r < d^*$, project B is preferred to project A in the region $d^* < r < ra$, and project B is the only viable project in the region $ra < r < rb$. Also from Figure 1, using the IRR decision rule, project B is preferred to project A throughout the region $0 < r < rb$. The factors responsible for inconsistent rankings include (a) the different weights (or relative importance) assigned to future net-benefits by r or IRR, and (b) the assumption that intermediate net-benefits are "reinvested" in other projects that also have returns equal to r or IRR (Canada & White, 1980; Herbst, 1982; Levy & Sarnat, 1986; Quirin & Wiginton, 1981).

The calculated value of NPV depends on r and the distribution (i.e., the timing and magnitude) of the project's net-benefits. For example, in Figure 1 from Cook (1989, p. 16), the nondiscounted sum of the project A net-benefits less the initial investment is greater in magnitude than that of project B; however, the incidence of project A net-benefits trails that of project B (e.g., the comparison of preventive health programs to acute medical interventions). Therefore, the discounted value of the project A net-benefits will be lower than that of project B for high discount rates (r or IRR); similarly, the discounted value of project B net-benefits will be higher than that of project A for low discount rates. All other things being equal, the IRR decision rule has greater bias than NPV (i.e., IRR > r) against projects whose benefits are deferred. The ranking of projects A and B is different for lower/higher rates of discount.

If the IRR of the next best project were the shadow price of capital, it could be used to rank alternative investments when the capital budget is the binding constraint. However, the IRR is not the shadow price of rationed capital; as explained earlier, the IRR is the rate of discount at which the project NPV is zero (i.e., initial investment is equal to the discounted net-benefits). The marginal value of capital is the opportunity cost of using this scare input for alternative uses; it is a function of the total capital available for investment and the amount of capital required by the proposed investments (Sugden & Williams, 1978). Ordering projects by the size of their IRR in order to "maximize the return subject to a budget constraint" can result in incorrect rankings. Sugden and Williams (p. 79) show how using IRR as the shadow price of capital can incorrectly rank projects. Although Watson's (1990) suggestion of ranking projects in terms of NPV per unit investment is questioned by Cook (1990), Sugden and Williams (1978) recommend this approach. Birch and Donaldson (1987), building on earlier work by Mishan (1967), recommend using integer programming to select the set of projects that maximize total NPV subject to the constraints of the capital budget.

The underlying error of using IRR to rank projects is that it confuses the two distinct concepts of time preference and opportunity cost (Sugden & Williams, 1978). Economic evaluation using the NPV formulation makes these distinctions: The rate of discount reflects the social marginal time preference rate (MTPR), and the opportunity costs of resources utilized/saved (i.e., their value in the next best use) are valued in terms of competitive market prices or appropriate shadow prices.

Although the social MTPR cannot be directly measured or inferred (Sugden & Williams, 1978), an extensive literature debating the relative merits of using alternative social discount rates as shadow prices of the MTPR has emerged (see Dasgupta & Pearce, 1972; Mishan, 1971; Sugden & Williams, 1978). Because the MTPR shadow prices are ambiguous, a strong case can be made for decision makers to specify a social MTPR that is consistent with explicit social objectives (Sugden & Williams, 1978). Although setting r too high or too low may bias decision making (Dr. Cook's concern), the sensitivity of project NPV to changes in r can be examined. When the NPV is sensitive to r, decision makers must specify a discount rate that reflects social objectives. Although the discount rate can be mis-specified in both decision rules, it is not clear that substituting the implicit bias of the IRR formulation for the explicit recognition of bias by the NPV formulation will improve decision making.

A problem related to the specification of the social rate of discount is the "reinvestment" assumptions. Both the NPV and IRR formulations implicitly assume that all intermediate net-benefits are reinvested at the discount rate used (r or IRR). This assumption is clearly inappropriate if opportunities to invest are not available at the assumed discount rate (Mishan, 1967; Quirin & Wiginton, 1981). The NPV decision rule assumes that intermediate net-benefits are reinvested in other social programs generating r ; the IRR formulation assumes that intermediate net-benefits are reinvested in other social programs generating IRR. This assumption is incorrect if IRR is higher than rates provided by the available investment opportunities. Although Cook (1989) expressed concern about the reinvestment assumption, the suggestion to set aside an unspecified amount of money to adjust the net-benefits in order to reduce the IRR is arbitrary potentially and misleading.

The interpretation of multiple IRRs is a serious concern that can influence the ranking of independent projects. Although methods have been proposed for converting nonconventional streams of costs and benefits into conventional ones, the IRR calculated from such a stream is neither mathematically nor economically equivalent to the IRR derived from a conventional stream (Quirin & Wiginton, 1981). It may not be meaningful to compare projects having nonconventional streams of net-benefits with those having conventional ones.

SELECTION AMONG MUTUALLY EXCLUSIVE PROJECTS

When only one project of a set of mutually exclusive alternatives can be selected, it can be shown that the IRR decision rule may generate incorrect rankings (Dasgupta & Pearce, 1972; Quirin & Wiginton, 1981; Sugden & Williams, 1978). When choosing among mutually exclusive alternatives, the IRR decision rule (IRR > r) must be supplemented by the rule that the IRR for the stream of incremental investments and net-benefits (e.g., the arithmetic difference between project A and B costs and net-benefits) for each pair of projects should also be greater than r. Using the combined rule, the binary comparison of all projects will ultimately select the project generating the greatest increase in social welfare. The correct mutually exclusive alternative may be discriminated against by the IRR decision rule because of the size of the initial financial investment (Dasgupta & Pearce, 1972; Levy & Sarnat, 1986). This is a cumbersome process; the NPV decision rule, in contrast, always yields correct rankings of mutually exclusive projects (Dasgupta & Pearce, 1972). Furthermore, the stream of incremental net-benefits of the combined mutually exclusive projects may be nonconventional (+, –, + or +, –, +, –) even though the two source streams were both conventional (–, +). The above concerns about multiple IRRs apply.

OTHER CONCERNS

Dr. Cook (1989, 1990) notes that the final ranking of projects requires judgment by decision makers about the nonquantifiable factors not included in the IRR formulation. Changes in intangible outcomes (e.g., changes in health status) whose valuation in monetary units is controversial (e.g., the monetary value of life and suffering [see Jones-Lee, 1976; Mishan, 1971; Mooney, 1978; Sugden & Williams, 1978; Viscusi, 1986]) may be the goal of many public-sector investments (e.g., health care programs). Excluding such outcomes from decision-rule formulations will severely limit the role and relevance of economic evaluation in much public-sector decision making (e.g., health care expenditures in Ontario were 34% of the provincial budget). Although valid methods measuring willingness-to-pay for improved health status (independent of any income implications) are emerging, such techniques are preliminary and have not been widely used (Drummond, 1990).

Cost-effectiveness analysis is one form of economic evaluation that can be used to evaluate alternative courses of action in terms of their incremental monetary costs and benefits to produce an incremental intangible outcome (e.g., the change in patient health status valued in terms of Quality Adjusted Life Years; see Drummond, Stoddart & Torrance, 1987; Torrance, 1986; Torrance & Feeny, 1989; Warner & Luce, 1982). Because the IRR decision rule is restricted to evaluations in which all relevant costs and benefits are valued in monetary units (i.e., cost-benefit analysis), this rule has limited application in many important areas of public-sector decision making (e.g., health care and social services).

The key concern of analysts undertaking policy-relevant economic evaluation of public-sector projects is the comprehensive and accurate identification, measurement (in physical units), and valuation (in monetary units) of all relevant costs and benefits. The analytical formulation used must address the policy question. Given the current limitations of willingness-to-pay methods, it is appropriate to value many policy-relevant outcomes using nonmonetary units. Willingness-to-pay methods may enable analysts to "look forward to a time when all public investment, and ultimately, all public programs are routinely subject to a proper cost-benefit analysis" (Cook, 1990, p. 81). However, until such methods are further developed, economic evaluation of health care programs will continue to shift away from cost-benefit analysis (Drummond, 1990; Drummond, Stoddart, & Torrance, 1987; Evans, 1984; McGuire, Henderson, & Mooney, 1988). Furthermore, for the above reasons, when cost-benefit analysis is routinely performed, the IRR decision rule should not be the formulation used.

SUMMARY AND CONCLUSIONS

The NPV decision-rule is (a) easy to calculate, (b) straightforward to interpret for all three types of decision making, and (c) consistent with the principles of welfare economics. In contrast, the IRR decision rule (a) is complex to calculate (even for accept/reject decisions), (b) requires supplemental rules to ensure the correct ranking of independent projects having simple nonconventional flows of costs and benefits, (c) may give ambiguous rankings when projects have complex nonconventional flows, and (d) is not always consistent with the principles of welfare economics.

The arguments that personal computers remove the burden of calculating IRR is irrelevant, that "red herring" multiple IRRs can be avoided by using sinking funds is limited, and that the IRR is the opportunity cost of rationed capital is incorrect. These arguments fail to address the well-known methodological concerns about using the IRR decision rule for public-sector project evaluation. Hence, the conclusion derived from over 20 years of thoughtful discussion stands: The NPV decision rule is the correct formulation for the economic evaluation of public-sector projects; when capital is rationed, integer programming should be used to select the set of projects that maximize NPV subject to capital budget constraints.

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REFERENCES

Birch, S., & Donaldson, C. (1987). Applications of cost-benefit analysis to health care: Departures from welfare economic theory. *Journal of Health Economics*, *6*, 211–225.

Broadway, R., & Bruce, N. (1984). *Welfare economics*. Oxford: Basil Blackwell.

Canada, J., & White, J. (1980). *Capital investment decision analysis for management and engineering*. Englewood Cliffs, NJ: Prentice Hall.

Clark, J., Hindelang, T., & Prichard, R. (1984). *Capital budgeting: Planning and control of capital expenditures*. Englewood Cliffs, NJ: Prentice Hall.

Cook, W.R. (1990). Cook replies. *The Canadian Journal of Program Evaluation*, *5*, 79–82.

Cook, W.R. (1989). Using the internal rate of return in public sector project evaluations. *The Canadian Journal of Program Evaluation*, *4*, 11–22.

Copeland, T., & Weston, J.F. (1980). *Financial theory and corporate policy*. Reading, MA: Addison-Wesley.

Dasgupta, A., & Pearce, D. (1972). *Cost-benefit analysis: Theory and practice.* London: MacMillan.

Drummond, M. (1990). Allocating resources. *International Journal of Technology Assessment in Health Care, 6,* 77–92.

Drummond, M., Stoddart, G., & Torrance, G. (1987). *Methods for the economic evaluation of health care programmes.* Oxford: Oxford University Press.

Evans, R. (1984). *Strained mercy: The economics of the Canadian health care system.* Toronto: Butterworths.

Herbst, A. (1982). *Capital budgeting: Theory, quantitative methods, and applications.* New York: Harper & Row.

Jones-Lee, M.W. (1976). *The value of life: An economic analysis.* London: Martin Robertson.

Levy, H., & Sarnat, M. (1986). *Capital investment and financial decisions.* Englewood Cliffs, NJ: Prentice Hall.

McGuire, A., Henderson, J., & Mooney, G. (1988). *The economics of health care.* London: Routledge & Kegan Paul.

Mishan, E. (1971). *Cost-benefit analysis.* London: George Allen & Unwin.

Mishan, E. (1967). A proposed normalization procedure for public investment criteria. *Economic Journal, 77,* 777–796.

Mooney, G. (1978). Human life and suffering. In D. Pearce (Ed.), *The valuation of social cost* (pp. 120–139). London: George Allen & Unwin.

Quirin, G.D., & Wiginton, J. (1981). *Analyzing capital expenditures: Private and public perspectives.* Georgetown, ON: Irwin-Dorsey.

Schofield, J. (1987). *Cost-benefit analysis in urban & regional planning.* London: Allen & Unwin.

Sugden, R., & Williams, A. (1978). *The principles of practical cost-benefit analysis.* Oxford: Oxford University Press.

Torrance, G. (1986). Measurement of health state utilities for economic appraisal: A review. *Journal of Health Economics, 5,* 1–30.

Torrance, G., & Feeny, D. (1989). Utilities and quality-adjusted life years. *International Journal of Technology Assessment in Health Care*, *5*, 559–575.

Viscione, J. (1984). *Financial analysis: Tools and concepts*. New York: National Association of Credit Management.

Viscusi, W.K. (1986). The valuation of risks to life and health: Guidelines for policy analysis. In J. Bentkover, V. Covello, & J. Mumpower (Eds.), *Benefits assessment: The state of the art* (pp. 193–210). Boston: D. Reidel.

Warner, K., & Luce, B. (1982). *Cost-benefit and cost-effectiveness analysis in health care: Principles, practice, and potential*. Ann Arbor, MI: Health Administration Press.

Watson, L. (1990). Comments and opinions. *The Canadian Journal of Program Evaluation*, *5*, 73–77.

Wilkes, F. (1983). *Capital budgeting techniques*. New York: John Wiley & Sons.

Winch, (1971). *Analytical welfare economics*. London: Penguin Books Limited.