1. Decision rules

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ABSTRACT

Benefit-cost analysis is the cornerstone of the economic analysis of public policy, and is closely aligned with basic rational choice and market concepts from microeconomics. Information and other constraints often block the direct application of marginal decision rules for policy decisions, but the conceptual role of marginalism can still be useful in interpreting benefit-cost analysis. While all policy analysis texts that emphasize the economic dimensions of policy cover the basics of marginal analysis, the sources of market inefficiency, and basic decision rules for policy analysis, the connections between marginal and non-marginal policy decision rules are seldom emphasized. This chapter limits its discussion of marginal analysis to the concepts of optimal quantity and optimal allocation rather than the market-based concepts of surplus, equilibrium and elasticity which are discussed in later chapters. This chapter begins by reviewing marginal and non-marginal concepts and measures for policy decisions, and then discusses a set of basic decision rules that can be informed by these concepts. Student exercises are included and answered in the appendix to the chapter.

MARGINAL AND NON-MARGINAL FUNDAMENTALS

There are two marginal concepts that inform common policy decision rules. The first defines the optimal quantity of any activity as the point where marginal benefits equal marginal costs, given that net benefits are decreasing in the neighborhood of the equality. If these conditions apply, one should continue to invest in a project as long as the marginal benefits of the project are greater than its marginal costs, and should choose one's scale for the project where the marginal benefits and marginal costs are equal.

The other fundamental marginal decision related to policy analysis involves allocating resources across a set of policies, with or without a budget constraint. Ideally, one should allocate resources so that the marginal benefit of the last dollar spent on one project equals the marginal benefit per dollar for all others. In equation form, for any three projects X, Y and Z, the ideal allocation of funds between the projects would occur where:

$$\frac{MBx}{MCx} = \frac{MBy}{MCy} = \frac{MBz}{MCz}, \tag{1.1}$$

where *MB* refers to marginal benefits and *MC* to marginal costs. This rule is analogous to various tangency conditions that define optimal choice for the individual, including the equal marginal utility per dollar rule that defines utility maximization in introductory microeconomics texts.[1] If one has no budget constraint, each of these projects should be funded until its marginal benefits equal its marginal costs, as in Figure 1.2. If each project's marginal benefits equal its marginal costs, each ratio in equation (1.1) will equal 1. We later refer to this option as an optimal budget. When an effective budget constraint exists, the ratios will be larger than 1 and some projects may not be funded at all, a case which will be covered in more detail further on.

For truly marginal analysis one would have to be able to costlessly compare a large number of policy options. If one could arrange these options in order of declining net benefits one would have a problem similar to Figure 1.1. Accurate marginal analysis requires complete and costless information and highly divisible units of measurement. A more realistic scenario involves comparing the net benefits of a much more limited set of policies with alternative budgets and/or designs. Comparing these policy options in order of budget size or quantity would involve a type of quasi-marginal analysis, but none of the mathematics of marginal economics would directly apply. However, there are lessons from marginalism in most comparisons of alternative policies.

The most fundamental non-marginal principles for analyzing the efficiency of policy alternatives are the Pareto improvement principle (a corollary to Pareto optimality), and the Kaldor-Hicks criterion or fundamental rule of policy analysis.

Definitions:

Pareto improvement: An action leads to a Pareto improvement if it makes at least one person better off without making at least one person worse off. A Pareto improvement can also be achieved if anybody who

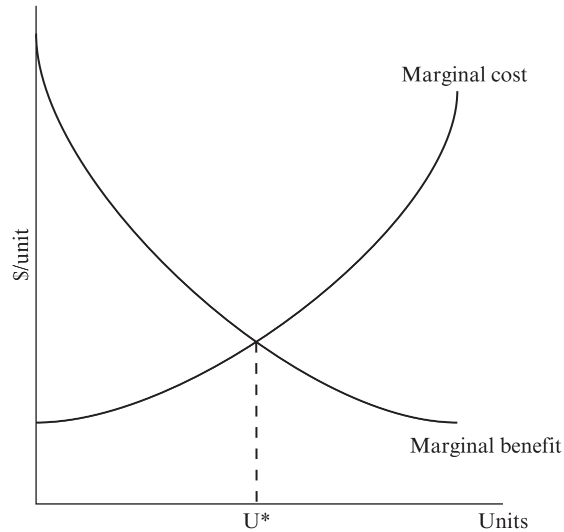

Figure 1.1 Optimal scale for one project

would otherwise lose due to a policy is fully compensated for his or her losses. Therefore a Pareto improvement requires that total benefits outweigh total costs, and that any losers be fully compensated.

The Kaldor-Hicks principle states that a policy should be adopted if the winners could *in principle* compensate the losers. This rule requires only that the total benefits outweigh the total costs.

NON-MARGINAL MEASUREMENTS

The Kaldor-Hicks principle can be applied to several different types of decisions, all of which are informed to some degree by the basic concepts of marginalism. These decisions can be made using one or more of the following measurements of benefits and costs. The three most common of these measurements are net benefits, the benefit/cost ratio and the rate of return. These three concepts are defined below:

Definitions:
Net Benefits = Total Benefits – Total Costs
Benefit/Cost Ratio = Total Benefits/Total Costs
Rate of Return = 100 percent • (Total Benefits-Total Costs)/Total Costs

In some situations, these measurements are consistent, but in others they can produce different rankings for alternative projects. In cases where these measurements are not consistent, a clear preference exists in economics for the net benefits measure. These measures will first be applied to an example.

Student Exercise 1: One design for a new windmill-based electricity complex costs $9 million to construct, will produce $15 million worth of power, and will require $2 million in operating and maintenance costs. A second design will cost $6 million to construct, produce $10 million worth of power, and will require $2 million in operating and maintenance costs. Find the net benefits, benefit/cost ratio, and percentage rate of return on each of these two projects. Answers are provided at the end of the chapter.

Project 1:
net benefits = ____ benefit/cost ratio = ____ rate of return = ____
Project 2:
net benefits = ____ benefit/cost ratio = ____ rate of return = ____

If you can only recommend one choice, which option is best according to each measure?

Every policy analysis text recommends the net benefit measure over the benefit/cost ratio. The primary reason for this preference is that net benefits are more consistent with the Kaldor-Hicks criterion. Net benefits attempt to directly measure the total net gain for society whether or not losers are compensated. There are also technical problems with the benefit/cost ratio and rate of return measures. For example, the benefit/cost ratio and rate of return measures are sensitive to how one categorizes operating expenses. One can include operating expenses as part of total cost, making the total revenue for the first windmill project in the previous example $15 million and the total costs $11 million. One may also define benefits as net operating revenue, or total revenue minus operating costs. Under this interpretation the benefits of the windmills would equal $13 million and the total costs $9 million. Both interpretations of operating costs produce net benefits of $4 million, but they produce different benefit/cost ratios and rates of return.

TYPES OF POLICY DECISIONS

Benefit-cost analysis is interpreted somewhat differently for different types of decisions. Among the types of policy decisions an analyst may be required to investigate are the following:

1. Should a single program be accepted or rejected?
2. Which one, at most, of a set of alternatives should be approved?
3. What is the optimal size of a budget covering multiple projects?
4. Which one or more projects should be approved within a fixed budget?
5. What is the ideal scale or scope of a particular project or program?
6. If multiple groups will receive benefits, how should the benefits be allocated?

Each decision will be considered below.

Accepting or Rejecting a Single Project

The decision rule when analyzing a single project is very simple. Approve the project if the net benefits are greater than zero, so that society experiences a net gain in well-being. If total benefits are greater than total costs, then the benefit/cost ratio will be greater than one and the rate of return will be greater than zero. All these outcomes will lead the analyst to recommend approval of the program.

Choosing One of Several Possible Projects

The second type of decision requires the analyst to choose at most one project among multiple alternatives. This type of situation occurs when determining the best use of a plot of land or a particular choice among competing designs for a building or highway project. The recommended rule for this decision is to **choose the project with the highest net benefits, assuming that at least one alternative has positive net benefits.**

Student Exercise 2: See Table 1.1. Assume that a particular plot of land could be developed as residential housing, an industrial park or a factory outlet mall. Only one alternative (at most) can be approved. Assuming that all relevant costs including opportunity costs are included, the ideal choice

Table 1.1 Real estate alternatives

	Housing	Industrial Park	Outlet Mall	Vacant Lot
Benefits	$1,000,000	$1,250,000	$1,600,000	$1,000
Costs	$1,100,000	$900,000	$1,200,000	$1,000
Net Benefits				
B/C Ratio				
Rate of Return				

in this simple case is to find the policy that will provide the highest net benefits to society. Students can be asked to rank these choices in terms of their net benefits, and choose the one that places first. Then they should calculate the benefit/cost ratio and rate of return for each alternative. Note that the benefit/cost ratios for the industrial park and the outlet mall are not consistent with the net benefit ranking. Given this information, which project should be approved?

Choosing an Optimal Budget

An optimal budget is an intriguing concept, but may be less impressive in political terms once it is defined.

> **Definition: An optimal budget** is one that maximizes possible net gains to society as a whole. Therefore an optimal budget will fund all projects with positive net benefits for society. If marginal analysis is possible, an optimal budget would be sufficient so that each project or department is funded to the point where its marginal benefits equal its marginal costs.

Student Exercise 3: What is the optimal budget for the set of projects in Table 1.1?

Choosing Which One or More Projects to Fund Given a Fixed Total Budget

If a person runs a charitable institution that funds health research or a transportation agency that allocates a fixed budget for highway repairs, she will face this kind of decision on a regular basis. The efficiency goal of this decision rule is to maximize the net benefits of a fixed budget.

Marginal analysis would suggest allocating funds so that the marginal benefit/marginal cost ratios are equal for all funded projects. Linear programming or other mathematical programming techniques may be used if sufficient production information exists or if multiple constraints are in force.[2] Assuming that information is too limited for marginal analysis and that only the budget is constrained, a viable method for making this choice involves the following steps:

1. Calculate the benefit/cost (B/C) ratio for each choice. Immediately reject any project which does not have a B/C ratio greater than one.
2. Rank the projects according to their B/C ratio.
3. Choose the highest B/C ratio, then the next highest, and so forth until you cannot go further without breaking your budget. This step is simi-

lar to moving from left to right on the basic marginal benefit-marginal cost graph in Figure 1.1.
4. If you must skip one or more projects due to budget considerations, choose the remaining programs with the highest B/C ratios that fit into the budget.

Because of the limited choices in such cases, the budget constraint is likely to not be fully spent, creating a case of complementary slackness in the budget constraint. The predetermined scale of each project also may imply a degree of inefficiency.

Student Exercise 4: See Table 1.1.

1. Assume that you have plenty of available land but only $3 million to spend. Following the four steps above, choose the projects from the table that should be approved within this budget. Then verify that these projects provide the greatest total net benefits.
2. Now assume that your budget has not been determined. Calculate the optimal budget for land development given this set of projects.

Choosing the Ideal Scale of a Project

A common question associated with many different types of policies is how large the policy or project should be. For social policies such as housing assistance or a job training program, the program's scale determines number of dollars spent and the number of people served. For an infrastructure project, the physical size as well as the cost of the project may be an issue. For example, the number of lanes in a new road is very much an issue of scale. Using marginal analysis, scale is simply a matter of finding the quantity of goods or services for which marginal benefits equals marginal cost. When information is not adequate for marginalism, exploring the net benefits of a finite number of production levels, and choosing the level with the highest net benefits, may partially serve the same purpose. This approach is a type of sensitivity analysis. If one orders the production scales by size, the comparison of each successive size is somewhat marginal in nature.

A scale example with limited information

In 1942 the US federal government established a 50 parts per billion (ppb) standard for the allowable amount of arsenic in drinking water. A 1999 report by the National Academy of Sciences concluded that the 50 ppb standard did not adequately protect public health, and provided a set of

Table 1.2 Alternate arsenic standard benefits and costs

Arsenic Standard	3 PPB	5 PPB	10 PPB	20 PPB
Compliance Costs (millions of 1999 $)	$698–792	$415–472	$180–206	$67–77
Estimated Health Benefits (millions of 1999$)	$214–491	$191–356	$140–198	$66–75
Cancer Cases Avoided	57–138	51–100	37–56	19–20

Source: US Environmental Protection Agency (2001).

estimated costs and benefits for a range of possible standards to replace the original.

Student Exercise 5: See Table 1.2. In 2001 the Environmental Protection Agency (EPA) chose one of the following maximum allowable levels of arsenic. Which one would you choose, if any, and why? EPA policy at that time was to assign a value of $6 million per life saved. If half of these cancer cases would result in death, what would the value of lives saved be worth in dollar terms? Use the high estimate of cancer cases avoided as an example.

Choosing an Optimal Scale and Allocation Among Different Programs: Marginal Analysis

Another common administrative decision involves determining both the total size of a program and how much funding should go to various agencies or constituencies who might benefit from the program. The basic efficiency issues involved in this relatively difficult decision consist of finding the optimal scale for the entire project and then allocating resources among the programs so as to maximize the net benefits of the entire budget. Examples of this allocation issue abound. When a police department decides how many patrol officers to hire and how many to allocate to each neighborhood, or a transportation authority adopts a total annual budget and a set of highway construction projects to fund within the budget, the efficient allocation of funds should be considered. Of course, political factors are also likely to be involved in such decisions.

Determining both the budget scale and allocation among various programs or constituencies involves elements of both the optimal budget concept and the optimal allocation of funds within that budget. Using marginal analysis, one can see some elements of this process more explicitly. The analysis of the total scale of the project and allocation involves

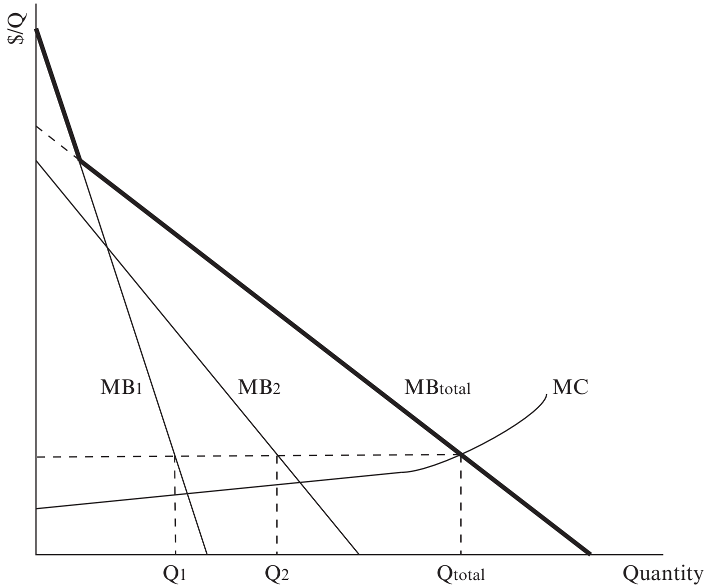

Figure 1.2 Allocating resources between two related programs

several steps (see Figure 1.2). First one needs to calculate the marginal benefits of the given programs. In Figure 1.2 there are two programs with marginal benefit curves MB_1 and MB_2. Then one adds the marginal benefit curves horizontally to find the marginal benefits of the total budget. One then finds the quantity where the sum of the individual marginal benefits meets the marginal cost (Q_{total}), as well as the dollar value of the marginal benefit or marginal cost at this quantity. Cumulatively, these steps involve the aggregation of individual programs into a total budget, and then the determination of the optimal level of total production. This completes the scale portion of the analysis.

The second phase of the analysis is to allocate the total budget among the various programs. To do this one sets the marginal benefits of each program equal to the dollar value of the marginal cost of the last unit produced. The quantities at which the individual marginal benefits equal the optimal marginal cost value dollar value (Q_1 and Q_2 in Figure 1.2) are the optimal levels of production that should be allocated to each group. One might also notice that if $MB_1 = MC_{total}$ and $MB_2 = MC_{total}$, this result also meets the marginal rule for an optimal budget, $\frac{MB_1}{MC_{total}} = \frac{MB_2}{MC_{total}} = 1$. For an example of this problem see Bellinger (2016), p. 181–2.

This section has introduced decision rules for several different situations, including approving or rejecting a single project, the optimal budget concept, choosing projects within a limited budget, and two related decisions involving the scale or size of a project. While the motivation provided by marginal analysis has been discussed, the key to most of these rules is to have sufficient information for estimating the benefits and costs of a reasonable set of alternatives. Most of the rest of the process involves a few concepts and a fair amount of common sense.

CONCLUSION

This chapter suggests that there may be value in relating the marginal and non-marginal decision rules for public policy in one's classes on the subject. The marginal and non-marginal decision rules used to analyze policy alternatives depend to some degree on the problem being addressed and the information available. Choices range from the approval or rejection of a single policy or project to the determination of an optimal budget and optimal allocation of resources across individual programs, constituencies or locations. In each case there is some role for economic rationality concepts in interpreting the decision rules, if instructors choose to draw this connection.

Neither the Kaldor-Hicks principle nor the marginal scale or optimal allocation rules discussed in this chapter actively consider equity, political practicality or other policy goals. Also, benefit-cost calculations are only as good as the information and numerical values that go into them. Since benefits and costs are often difficult to calculate, a substantial degree of humility is helpful when discussing your findings with experts, clients or the general public.

NOTES

1. Equation 1.1 is a variant of multiple optimal allocations rules that appear in undergraduate microeconomics texts. Most basically, the consumer equilibrium model states that a utility maximum exists when MUx/Px = MUy/Py, where MU refers to marginal utility and X and Y are two consumer goods. Similarly, a single person general equilibrium with production (often referred to as autarky) reaches an optimum when the marginal rate of substitution for consumption equals the marginal rate of product transformation. In equation form, the slope equality can be stated as −MUx/MUy = −MCx/MCy which easily transforms to MUx/MCx = MUy/MCy, which is identical to equation 1.1 other than the non-monetary measure of marginal benefits.
2. Dayananda et al. (2002) provide a useful overview of linear programming as a tool for analyzing resource allocation with multiple constraints in Chapter 11.

REFERENCES AND RECOMMENDATIONS FOR FURTHER READING

Bellinger, W. (2016), *The Economic Analysis of Public Policy, 2nd Edition.* London: Routledge.

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APPENDIX: ANSWERS TO STUDENT EXERCISES

Student Exercise 1: If one includes operating costs as part of the cost totals, these are the correct answers:

Project 1: Net Benefits = $4m Benefit/Cost Ratio = 1.36 rate of return 36.3 percent
Project 2: Net Benefits = $2m Benefit/Cost Ratio = 1.25 Rate of return 25 percent

If one included operating costs as negative operating revenues, Project 2 would have different rates of return and B/C ratios. Project 1 will have similar changes.

Project 2: Net Benefits = $2m Benefit/Cost Ratio = 1.33 Rate of Return = 33 percent

A policy analyst would generally recommend building wind farm Project 1, given the higher net benefits.

Student Exercise 2:

Table A1.1 Real estate alternatives

	Housing	Industrial Park	Outlet Mall	Vacant Lot
Benefits	$1,000,000	$1,250,000	$1,600,000	$1,000
Costs	$1,100,000	$900,000	$1,200,000	$1,000
Net Benefits	−$100,000	+$350,000	+$400,000	$0
B/C Ratio	0.909	1.389	1.333	1.000
Rate of Return	−9.09%	39%	33%	0%

Rankings:
Net Benefits: 1. Outlet Mall, 2. Industrial Park, 3. Vacant Lot, 4. Housing
B/C Ratio or Rate of Return: 1. Industrial Park, 2. Outlet Mall, 3. Vacant Lot, 4. Housing
The outlet mall would be recommended due to its higher net benefits.

Student Exercise 3: The optimal budget would be sufficient to fund the industrial park and the outlet mall. The total costs for the two projects equal $2,100,000.

Student Exercise 4:

Table A1.2 Project choices given a budget

	Housing	Industrial Park	Outlet Mall	Golf Course	Power Plant	Vacant Lot
Benefits	$1,000,000	$1,250,000	$1,600,000	$1,500,000	$4,200,000	$1,000
Costs	$1,100,000	$900,000	$1,200,000	$900,000	$3,000,000	$1,000
B/C Ratio	0.909	1.389	1.333	1.667	1.400	1.000
Net Benefits	−$100,000	+$350,000	+$400,000	+$600,000	+$1,200,000	$0

B/C Ratio Rankings:

1. Golf Course, 2. Power Plant, 3. Industrial Park, 4. Outlet Mall, 5. Vacant Lot, 6. Housing
Two alternative strategies could be chosen. First build the golf course, skip the power plant, which you could not afford, and build the industrial park and outlet mall, for a total cost of $3 million and $1,350,000 in net benefits. The second strategy would be to build the power plant, with net benefits of $1,200,000. The first strategy maximizes net benefits, and is the correct choice according to this decision rule.

Student Exercise 5: Strictly on the basis of benefit-cost analysis, it is not clear that any change in the arsenic standard should be made. Only for the 10 ppb and 20 ppb levels do the benefit and cost estimates overlap. The EPA chose the 10 ppb standard, in part based on other factors.

The dollar benefits from lives saved equals $6 million times ½ (the death rate) times the number of cancer cases avoided. Using the high estimates of cancer cases avoided, the dollar values are $414 million for 3 PPB, $300 million for 5 PPB, $168 million for 10 PPB and $60 million for 20 PPB. If accurate, these benefits would account for a substantial majority of the total estimate for health benefits.