Cost-Effectiveness Analyses of Chemical Risk Control Policies in Japan

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Abstract

Results of cost-effectiveness analyses (CEA) for chemical risk control policies are presented. Advantages and disadvantages of CEA and cost-benefit analysis (CBA) are discussed. It is made clear that CEA is not an incomplete form of instrument for policy appraisal compared with CBA, but has its own value for chemical risk control policies. Firstly, cost-effectiveness ratios are actually too high to make CBA relevant as an instrument of policy appraisal. Secondly, deep-rooted uncertainties in policy appraisal make relative comparisons more attractive than an absolute value approach such as CBA. Thirdly, the index of effectiveness is not restricted to individuals' preferences, and CEA is not restricted to the criterion of efficiency.

Key Words

cost-effectiveness analysis, cost-benefit analysis, risk-benefit analysis, value-of-life, chemical risk control

1 Introduction

Cost-benefit Analysis (CBA) is a standard approach for incorporating economic aspects into public policy programmes. We have, however, been resorting to Cost-effectiveness Analysis (CEA), rather than CBA, in our economic analyses of toxic chemical control policies[1, 2, 3]. CEA is, generally, regarded as an incomplete tool for the economic analysis of public policy programmes as compared with CBA[4, 5]. CEA is regarded as at most a second-best approach when monetary evaluation is difficult for part of the effects of the policy programme in question. Certainly, one reason why we have used CEA is its ease of application, but our experience with the CEA of chemical risk management has led us to believe that our CEA using loss of life expectancy (LLE) as an index of effectiveness has its own value.

In this paper, I will (1) characterize CBA and CEA, (2) present our results on the CEA of chemical risk control policies, and (3) make clear in what respects CEA using LLE as an index of effectiveness has its own value.

2 Characterization of CBA and CEA

CBA is a tool for assessing the economic efficiency of public policies or economic changes in general[6]. In CBA, all the effects of a policy programme on people's economic welfare have to be quantified in monetary terms. Monetary valuation is based on individuals' preferences, i.e., the benefit from a good change—such as supply of food, construction of a hospital, elimination of health risks, etc.— for an individual is measured as his/her willingness to pay (WTP) for the change, and the cost from a bad change—such as reduction of food supplies, destruction of a hospital, generation of health risks, etc. — for an individual is measured as his/her willingness to accept (WTA) compensation for the change. The total social benefit/cost is the sum of the individuals' benefits/costs. When the total benefit exceeds the total cost, i.e. when the net benefit is greater than zero, the change is said to be ‘efficient’.

This concept of efficiency is based on the ‘hypothetical compensation’ principle, which insists that a change that could bring about Pareto improvement, i.e. that could make everyone better-off without making anyone worse-off, on condition that the gainers compensate the losers, can be regarded as efficient even if actual compensation does not take place. A change that causes Pareto improvement under appropriate compensation is referred to as causing ‘potential Pareto improvement’. When net benefit is greater than zero, potential Pareto improvement is brought about.

In CBA for chemical risk control policies, the effects on human health risks, i.e. reductions of risks, are evaluated in monetary terms, and these values are weighed against the monetary costs for risk-reduction. Risk-reduction is measured in terms of the reduction in mortality or the number of deaths, and the reduction in morbidity or the number of diseases. Benefits from risk-reductions are measured on the basis of people’s WTP for reducing mortality and morbidity. WTP for reducing mortality per death is called ‘value-of-life’ or ‘value of a statistical life (VSL)’[4, 7, 8]. VSL times the number of deaths reduced by a programme is the benefit of the programme with regard to mortality risk-reduction.

CEA is a tool for assessing ‘partial’ efficiency. In CEA, only the costs of a programme are evaluated in monetary terms. The positive effects of the programme are not usually monetized, but they should be quatified in physical terms. The ratio of the monetary costs to the quantity of the nonmonetized effects (cost-effectiveness ratio) is the index of partial efficiency: the lower the ratio, the more efficient is the policy in question. In order to obtain the cost-effectiveness ratio, the nonmonetized effects have to be measured on a single scale. To develop a single measure of effectiveness is an essential task in CEA.

Many kinds of measures of effectiveness are possible even when confined to chemical risk control policies. The reduction in the emission of the chemical substance in question, for example, is a candidate for the index of cost-effectiveness. However, such an index can only be applied to the chemical in question. An index with broader applicability would be the number of cases of a particular disease that is thought to be caused by several chemicals under investigation. The number of deaths avoided would be an index with even broader applicability in so far as death is a common event to several kinds of diseases. Gain in life-expectancy is an alternative index to the number of deaths, and has an advantage in that it can incorporate the difference in time when deaths occur. As shown later, we have been using gain in life-expectancy as an index of effectiveness in our CEA.

CEA can be used for assessing priorities among alternative risk control policies. The priority-setting is based on the idea that the total cost for reducing a given amount of risks can be minimized or the total quantity of risk-reductions with a given cost can be maximized by prioritizing the policy according to the cost-effectiveness ratio.

When the total cost that can be incurred is given, CEA can determine the amount of risk reduced, which can be achieved at the minimum cost. When the total cost is flexible, CEA cannot determine the amount of risk reduced. However, one can use CEA in order to determine how much the amount of risk should be reduced, if one can set a limit value for the cost-effectiveness ratio. The limit value is, however, more or less arbitrary, although it is probably based on the cost-effectiveness ratios of past policy programmes.

This is the most prominent disadvantage of CEA. In contrast, CBA can determine how much the amount of risk should be reduced without arbitrariness.

3 Results of the CEA of Chemical Risk Control Policies

Table 1 shows the ratios for several chemical risk control policies based on our research. The results of our CEA are expressed in terms of cost per life-year saved (CPLYS). This means that we measured the risk by loss of life-expectancy (LLE) or measured the effectiveness of risk-reducing policies by gain in life-expectancy.

Table 1: Cost per life-year saved in chemical risk control policies

Policy programme	CPLYS (¥ million)	Source
Prohibition of chlordane	45	[1]
Mercury regulation in caustic soda production	570	[2]
Mercury removal from dry batteries	22	[9]
Regulation of benzene in gasoline	230	[10]
Dioxin control (emergency countermeasures)	9.5	[3]
Dioxin control (long-term countermeasures)	125	[3]
Regulation of NOx for automobiles	86	[11]

LLE as an index of risk has been developed in order to respond to the demand for expressing cancer risk and noncancer risk on the same scale[12, 13]. By using LLE, one can take into account the difference in the time when deaths occur. LLE covers not only fatal diseases but also nonfatal diseases in so far as it takes into account the effects of imperfect health states on mortality[2, 12].

4 In What Respects Does CEA Have its Own Value?

As stated above, the results of CEA can be used for priority-setting among risk control policies. For example, if the control of particulate matters from diesel-engined vehicles costs not more than ¥ 44 million per life-year saved [14], there is no reason not to introduce this control when dioxin emissions are to be reduced by 'long-term countermeasures'.

Alternatively, one may set a limit value of, for example, ¥ 100 million per life-year saved, to declare that programmes with a cost-effectiveness ratio lower than this limit value should be implemented. Such setting of a limit value is more or less arbitrary. In contrast, if one is willing to apply CBA, one can appeal to WTP to elicit a limit value.

In spite of this advantage, are there any justifications for not applying CBA?

4.1 Too High CPLYS to Justify by Using CBA

WTP for reducing a unit of risk has been estimated as VSL mainly in the US and the UK. According to Fisher et al.[15], estimates on VSL range from US$1.6 million to US$8.5 million (in 1986 dollars). VSL used in the CBA of the Clean Air Act in the US was US$4.8 million[16]. In the UK, the VSL of £0.9 million is used in evaluations of road safety[17].

From these instances, it would be safe to say that VSL in Japan is also not larger than ¥ 1 billion. Even taking into account that there is an estimate of Japanese VSL of ¥ 1.7 to 3.5 billion, which was observed in a contingent valuation study[18], it is very unlikely that VSL exceeds ¥ 4 billion. The value of a life-year would therefore never exceed ¥ 100 million, provided that a statistical life is equivalent to about 40 life-years[19]. It is fair to say that the value of a life-year would be in the order of ¥ 10 million.

Since CPLYS often exceeds ¥ 100 million as shown in Table 1, most of the chemical control policies would be judged to be inefficient according to CBA. This fact means that to use CBA would probably be regarded by decision-makers as irrelevant to actual chemical risk control policies.

CPLYS for chemical risk controls exceeds not only the value of a life-year, but also CPLYS in other policy areas such as safety control and health care[20]. This means that CBA may justify many health-related programmes in the areas of safety control and health care. This fact may incline one to think that the value of a life-year for chemical risks must be greater than that for the risks in safety control policies and in health care programmes.

The risks from toxic chemicals are often classified into so called ‘societal risks’. The most distinguishable feature of societal risks is their ‘involuntariness’. Chemical risks are, especially when they appear through environmental pollution, involuntary risks. In contrast, most of the risks related to health care programmes are voluntary ones. Risks related to safety control include both voluntary and involuntary risks. In road safety and workplace safety controls, risks are partly voluntary and partly involuntary, while in railway safety, most of the risks are involuntary.

It is often considered that people's WTP for reducing risks is, generally, greater for involuntary risks than for voluntary risks[21]. In fact, Jones-Lee and Loomes[22] have observed that people are willing to pay a greater amount for reducing involuntary risks than for reducing voluntary risks. If this is the case, high CPLYS for chemical risk controls may be justified by CBA using a higher value of a life-year.

However, WTP is only observed for a change that individuals can choose voluntarily, and cost-benefit analysis is, from the outset, a tool for determining economic efficiency for public programmes concerning the supply of public goods or the reduction of public bad, by using data on people's willingness to pay for such changes when they can choose them voluntarily. A public good is consumed collectively and its private supply is not imaginable, but the benefit of a public good has been evaluated on the basis of how much individuals are willing to pay for purchasing the good or services of the good voluntarily. This should also be the case for a public bads such as health risks. In many cases, individuals cannot avoid suffering a public bad or cannot be excluded from the removal or reduction of the public bad, but its evaluation must be based on their voluntary willingness to pay for removing or reducing the bad as if they could choose whether or not to remove it or to what extent to reduce it. This discrepancy between the involuntariness in the supply of goods or bads to be evaluated and the voluntariness intrinsic to the WTP concept is inevitable in the CBA of public policies.

It is impossible to resolve such a discrepancy based on the fallacious notion of WTP for reducing involuntary risks. Jones-Lee and Loomes[22] argued that they observed 1.5 times greater WTP for involuntary risks than for voluntary risks, but, in actual fact, what they observed is that people think, on the average, that the reduction of a certain amount of involuntary risk is equally desirable as the reduction of about 1.5 times greater amount of voluntary risks, when those risks are reduced by public sectors. Such people's judgements on the relative importance of the reduction of voluntary risks to the reduction of involuntary risks through public policies are not inconsistent with the fact that people are willing to pay an equal amount to the reduction of both voluntary and involuntary risks when those risks can be reduced by their payment.

Consequently, the allegation that people's WTP for reducing involuntary risks should be greater than that for reducing voluntary risks is equivalent to negating the WTP concept itself, and the attempt to make CBA relevant to chemical risk management by adjusting the value of a life-year by taking into account the involuntariness of the chemical risks is not legitimate.

4.2 Significance of Comparative Approaches

We have a substantial degree of uncertainty with risk assessement, cost estimation and WTP estimation.

When there is uncertainty with the estimation of the quantity of risks, then persisting in the absolute magnitude of risks will tend to lead to a false decision. However, the comparative assessment of risks will be more reliable when biases in risk assessment are common to all the objects of assessment. Hence, the order of policy programmes with respect to the magnitude of risks will be more robust than the absolute magnitude of the risks.

Similarly, the order of policy programmes with respect to the cost-effectiveness ratio will be more robust than the absolute magnitude of the cost-effectiveness ratios. However, in CBA, the absolute magnitude of cost-effectiveness ratio matters, and the absolute value of WTP for reducing a certain amount of risk also matters. CBA is, therefore, the most vulnerable analytical tool in condition of uncertainty. CEA is less vulnerable.

In actual policy appraisals, even when CBA is employed, CBA is often utilized as if it were CEA. For example, CBA is widely accepted as a tool for policy appraisal in road construction projects in Japan. In the CBA for road construction, the benefit-cost ratio

(B/C ratio) must not be below 1.5 for a project to be adopted as a subsidized project by the central government. Actually, adopted projects must have been selected from among the plans whose B/C ratios are not less than 1.5. Therefore, the average B/C ratio of the adopted projects will considerably exceed 1.5. From the theory on which CBA is established, however, there is no reason to set a criterion for the B/C ratio above 1.0. The current criterion has led to the abandoning of many projects that would have improved the efficiency in resource allocation of society, according to the theory of welfare economics.

Nevertheless, the criterion for the B/C ratio of 1.5 may be justified owing to the great uncertainty concerning the estimates of the benefits from road construction. Time saving for automobiles is usually the largest component of the benefits from road construction, but such estimates depend on the forecast for transport demands. It is this forecast that includes the greatest uncertainty. Due to this uncertainty, absolute values of benefits are not considered to be significant, and the question of whether or not the total benefit exceeds the total cost is not also thought to be significant. Actually, priorities are attached to the plans with B/C ratio not less than 1.5.

Taking these things into account, in reality, CBA may have little advantage over CEA.

4.3 Flexibility of Effectiveness Index

CBA is based on a solid structure of welfare economic theory, which is a source of the advantages of CBA, but at the same time is a source of some restrictions under which CBA is conducted. CEA is, to some extent, free from these restrictions.

Firstly, benefit estimation in CBA should be based on individuals' WTP. WTP is dependent on individuals' preferences and abilities to pay, namely incomes. The benefit from risk-reduction is smaller for individuals who do not regard it as serious and for individuals who cannot afford to pay much money to it. In CEA, the index of effectiveness does not have to be based on individuals' valuations. Gain in life-year, for example, is adopted *a priori* as an index of effectiveness, irrespective of individuals' preferences or incomes. One can base CEA on an objective index of effectiveness.

Secondly, CBA is a tool with a criterion of 'efficiency'. It cannot deal with 'equity'. For programmes where equity aspects are more important than efficiency, CBA becomes irrelevant. For instance, when extremely high risk is borne by a particular group of people, while the benefits in exchange for the risk are enjoyed by the public, then such a risk should be eliminated from the criterion of equity irrespective of the costs or the benefits that would be forgone by the public. In such a case, simple 'risk assessment', rather than CBA, would be a relevant analytical tool.

CEA is an analytical tool for assessing 'partial efficiency', but the fact that CEA does not view all the effects in the light of efficiency makes it possible to incorporate equity aspects. One can make the index of effectiveness reflect some equity considerations. For example, to treat a life-year as equal for all individuals includes an egalitarian view. In CEA, analysts can avoid, for example, such controversial treatment as regarding the value-of-life of people in underdeveloped countries as 15 times smaller than in industrial countries[23].

The index of effectiveness does not need to be based on economic theory concerning consumer choice nor on any utility theory. This fact gives flexibility to CEA.

For example, it is often argued that 'discounted life-year', rather than 'life-year' should be used as an index of effectiveness, in order to take people's time preference into account[24]. Our index of LLE does not include the discounting of life-years, although our CEA includes the discounting of both risk-reductions and costs with an ordinal time discount rate. The discounting of risk-reductions is essential in order not to justify postponing the implementation of risk-reduction programmes to the indefinite future, but the discounting of life-years is not necessary for CEA itself.

Nonetheless, if the index should be based on individuals' preferences, and if individuals' utilities are dependent on the stream of life in time and not on the life expectancy itself, then time preference should not be ignored. So far as time preference originates from people's awareness that their lives are limited, it may be regarded as being included in the index of life-expectancy which reflects the probabilities of people's lives being cut in the foreseeable future, and the discounting of life-years may be regarded as double-discounting. However, the discount rates that are calculated from the probabilities of death are very low for younger people (Table 2). Therefore, discounting life-years does not necessarily mean double discounting.

Table 2: Discount rates calculated from the probabilities of death in the life table 1990. The discount rate for age y for the period t years is calculated to be $[\prod_{i=y}^{y+t}\{1-d(i)\}]^{-1/t}-1$, where $d(i)$ is the death rate at the age of i.

Period				Age			
(year)	10	20	30	40	50	60	70
10	0.04%	0.08%	0.11%	0.27%	0.74%	1.78%	5.13%
20	0.06%	0.09%	0.18%	0.47%	1.19%	3.22%	9.77%
30	0.07%	0.14%	0.35%	0.88%	2.37%	7.01%	19.17%
40	0.12%	0.28%	0.68%	1.84%	5.39%	14.54%	36.88%
50	0.23%	0.56%	1.49%	4.35%	11.62%	28.98%	-
60	0.47%	1.25%	3.63%	9.64%	23.77%	-	-
70	1.08%	3.11%	8.23%	20.10%	-	-	-

In spite of these considerations, the discounting of life-years is not inevitable if the index of effectiveness does not need to be based on individuals' preferences. The fact that life-expectancy itself has been used as an index for public health policies with consensus is sufficient to justify its use as an index of effectiveness, irrespective of individuals' preferences.

5 Conclusion

As discussed above, CEA is not an incomplete form of tool for policy appraisal compared with CBA, but has its own value for chemical risk control policies. Firstly, cost-effectiveness ratios are actually too high to make CBA relevant as a tool of policy appraisal. Secondly, deep-rooted uncertainties in policy appraisal make relative comparisons more attractive than an absolute value approach such as CBA. Thirdly, the index of effectiveness is not restricted to individuals' preferences, and CEA is not restricted to the criterion of efficiency.

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Vitae

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