An Intuitive and Effective Cost-Benefit Analysis Method to Evaluate Different Options of Public Health Programs in Terms of Economics

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***Abstract* — In public health, cost-benefit analysis is customarily carried out to evaluate all possible options in terms of health economics to determine the government best investment decisions. However, non-determinacy of formulae parameters prevents the scientific and accurate cost-benefit analysis, such as the discount rate. In this paper we established a "four-step" cost-benefit analysis method including: i) confirming the costs and benefits, ii) identifying the discount rate and estimating discount duration, iii) selecting an appropriate formula, and iv) determining the optimal alternative to calculate Net Benefits (NB) and Benefit-Cost Ratios (BCR) in discounted monetary units of all possible program options. The "four-step" cost-benefit analysis method was applied and the results showed: the NB was ￥291.391, 279.0352 and 224.298 million, while the BCR for domestic attenuated live vaccine, domestic inactivated vaccine and imported inactivated vaccine was 6.96, 3.82 and 2.46 respectively. Vaccinating with domestic attenuated live vaccine for children in Guangdong province was recommended as the optimal option for government decision makers which had the maximum NB and BCR. The proposed method is an intuitive and effective approach with good operability in health economics evaluation work of government public health programs. It has the potential for popularization and application in the area of public health.**

Keywords-benefit analysis; Public health; Health economics

I. INTRODUCTION

Cost-benefit analysis (CBA) is one of the main approaches used to assess the efficiency of public health programs. If the economic benefits are greater than the costs and the program is proved to be one of the most cost-effective ways to improve public health in the country, such as the prevention and control of diseases, the program should be seriously considered by the government [1]. For example, Brazil planned to vaccinate the pre-adolescent female population against the human papillomavirus (HPV) to prevent cervical cancer [2]. Since the vaccines were expensive, a detailed cost-benefit analysis conducted before a final decision was made [3].

Generally, the economic estimate will be biased if the CBA is static rather than dynamic because the value of cost and benefit inflates over time. Discount rate [4] and discount duration [5] are two vital parameters in CBA which change future benefits to the present value and solve the problem how to evaluate future earnings today in the investment evaluation. On the one hand, the discount rate is hard to get an accurate value because it is determined by many economic factors, such as market interest rates etc [6]. In light of the importance of discounting to economic evaluations, the exploratory analyses on identifying the discount rate of economic evaluation have developed [7]. On the other hand, discount duration needs to be confirmed by the data from published studies instead of assumption [5, 8]. Meanwhile, some economic evaluation models such as the decision tree model [9, 10] ,the actuarial model [11]and etc, the complexity of calculation process limits its application. Besides primary evaluation indicators such as DALY and QALY are not intuitive for decision-makers to understand, which may limit its utility to public health policy making [12].

This paper aims to establish an intuitive and effective CBA method to identify the best investment selection for government decision-makers on public health by discounted monetizing and comparing costs and benefits of different alternatives. Our method also provides groundbreaking different economic evaluation formulae for different investment and income situations in the public health program.

II. METHODS

In the following section, we established a "four-step" cost-benefit analysis method, namely, confirming the costs and benefits, identifying the discount rate and estimating discount duration, selecting the appropriate formula, and determining the optimal alternative.

A. *Confirming the costs and benefits*

Costs and benefits of health program are the key aspects to decision-making. We should make use of the cross-sectional survey data or literature data to confirm the benefits and costs of intervention. All cost and benefit estimates are monetized and discounted at a discount rate within a certain period of time.

B. Identifying the discount rate and estimating discount duration

From national accounts and statistical point of view in modern economics, we identify the discount rate by a weighted average method and make it more specific and accurate [6]. A weighted average discount rate is obtained by using relevant statistical yearbook data, calculating the proportion of private consumption and investment and the impact of the tax.

Define r as the discount rate, which is an addition of two parts. The first part is the product of k_1 and i_g, where ig is the pre-tax rate of return on investment and k_1 represents the private accumulation rate. To calculate k_1, one can subtract the total amount of final consumption (including total household consumption and total government consumption), net exports and fixed asset saving of state-owned enterprises from the under-year GDP, then using the obtained difference divided by GDP. The second part is another product of k_2 and in, where the consumption ratio, k_2, is equal to the ratio of total household consumption and GDP, while in is after-tax rate of return on saving. In this formula, ig and in can be transformed by the second equation. Define i as market interest rate measured by risk-free securities, which can be replaced by the one-year bank deposit rate. The average tax rate in the private sector, t_1, is determined by the division of two parts. The numerator can be obtained by subtracting the tax created by the state-owned enterprises from the total tax revenue. The denominator can be calculated by deducting the production of the state-owned enterprises from GDP. The rate of interest tax, t_2, which is stipulated by the state is equal to 20%.

$$\begin{aligned} \mathrm{r} &= k_i i_g + k_2 i_n \\ &= {k_1 i}/{(1-t_1)} + k_2(1-t_2)i \\ &= \left[{k_i}/{(1-t_i)} + k_2(1-t_2) \right] i \end{aligned} \tag{1}$$

For public health programs, discount duration is defined as the time in which the health intervention implements and plays an effective role among a specific cohort in a specific area. But CBA is usually carried out before the implementation of public health program, it is unfeasible to obtain the accurate data of intervention effective period. An alternative approach is to review references and estimate a conservative value of discount duration. More details will be described in following Section 3.

C. Selecting the appropriate formula

Considering different ways of investments and returns, we derived three patterns from the classical formula (2), we select one appropriate formula to calculate net benefit(NB) and benefit-cost ratio(BCR) and make the results of CBA in line with the actual situation of public health programs.

Pattern 1: When it need to invest a certain annual cost and achieves a certain annual income, the NB and BCR are calculated as follow classical formula where *r* denotes the discount rate and t represents for discount duration and the cost and benefit in t year are defined as C_t and B_t respectively：

$$NB = \sum_{t=1}^{T} \frac{B_t - C_t}{(1+r)^t}$$

$$BCR = \frac{\sum_{t=1}^{T} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{T} \frac{C_t}{(1+r)^t}} \tag{2}$$

Pattern 2: When it need to invest a certain annual cost and achieves a total income, the NB and BCR are calculated as follow formula where the cost in t year and the total benefit are defined as Ct and B respectively：

$$NB = \frac{B}{(1+r)^t} - \sum_{t=1}^{T} \frac{C_t}{(1+r)^t}$$

$$BCR = \frac{\frac{B}{(1+r)^t}}{\sum_{t=1}^{T} \frac{C_t}{(1+r)^t}} \tag{3}$$

Pattern 3: When it need to invest total one-time cost and achieves a certain annual income, the NB and BCR are calculated as follow formula where the total one-time cost and the benefit in t year are defined as C and Bt respectively：

$$NB = \sum_{t=1}^{T} \frac{B_t}{(1+r)^t} - C$$

$$BCR = \sum_{t=1}^{T} \frac{B_t}{(1+r)^t} / C \tag{4}$$

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Pattern 4: When it need to invest total one-time cost and achieves a total income, the NB and BCR are calculated as follow formula where the total one-time cost and benefit are defined as C and B respectively：

$$NB = \frac{B}{(1+r)^t} - C$$

$$BCR = \frac{B}{(1+r)^t} / C \tag{5}$$

D. Determining the optimal alternative

NB and BCR are calculated according to the selected formulae, alternatives of BCR＞1 are sorted by the value of BCR or NB. Select the alternative with the largest NB and BCR as the optimal one and recommend it to government decision-makers.

III. RESULTS

In this section, we apply the "four-step" cost-benefit analysis method to illustrate how hepatitis A vaccine was brought into the national expanded program on immunization (EPI) in Guangdong Province.

When Hepatitis A vaccine was brought into EPI in 2010, government decision-making faced three alternatives, domestic attenuated live vaccine, domestic inactivated vaccine or imported inactivated vaccine to supply free vaccination for children at 18 months to prevent Hepatitis A. The "four-step" cost-benefit analysis method was applied and the optimal program was determined and recommended to government decision makers according to the comparisons of NB and BCR for all possible alternatives.

A．Confirming the costs and benefits

In 2010, we carried out a cross-sectional survey and estimated vaccination costs by a uniform questionnaire and investigated the economic burden of hepatitis A cases by using stratified sampling method. As Table 1 and Table 2 showed, total cost of domestic attenuated live vaccine, domestic inactivated vaccine and imported inactivated vaccine was ￥48.9112, 98.8685 and 153.6057 million respectively, while total benefit was ￥560.2898, 622.1986, 622.1986 million respectively.

B． Identifying the discount rate and estimating discount duration

According to the data from Guangdong statistical yearbook 2011, the proportion of private consumption and investment and the impact of the tax can be attained. Let $k_1=0.31$, $k_2=0.35$, $t_1=0.33$, $t_2=20\%$, $i=4.55\%$, the weighted average discount rate is 3.38% according to formula (1).

Based on the related references, the antibody positive rate for 1 month after first dose of domestic attenuated live vaccine was 81%~100% and the duration of vaccine protection was 15 years. Both domestic and imported inactivated vaccine, the antibody positive rate for 1 month after twice vaccination was about 100%, however, there has been no report on the duration of domestic inactivated vaccine protection. Mathematical models predict antibody levels will persist beyond 25 years in immunocompetent adults and more than 14 years in children [13]. Therefore, the discount duration, namely, the duration of vaccine protection, can be determined as 15 years. We conducted the following cost-benefit analysis for three vaccination programs in the same discount duration.

C．Determining the evaluated methods

In the expanded program on hepatitis A vaccine immunization into Guangdong Province, purchasing vaccine is one-time investment cost. Considering it is difficult to estimate the annual benefit during the protection of the vaccine, while the total benefit can be estimated, the NB and BCR are calculated by formula (5). According to the parameters, the vaccination cost and benefit for three programs are listed in Table 1 and Table 2. After converting the vaccination benefit to current NB, the NB and BCR can be attained. The NB for domestic attenuated live vaccine, domestic inactivated vaccine and imported inactivated vaccine are ￥291.391, 279.0352 and 224.298 million respectively, the BCR are 6.96, 3.82 and 2.46 respectively, while (see Table 3).

D． Determining the optimal alternative

As results show that vaccinating domestic attenuated live vaccine for children in Guangdong province has the maximum NB and BCR. In a word, this program has the robust economic benefits and higher investment returns. With the minimum cost as well as the maximum benefits, this program realize the effective allocation of government financial resources, therefore we recommend it as the optimal investment plan for the government decision makers.

IV. CONCLUSIONS

With the rapid socio-economic development and increased government investment on public health programs, there was a growing emphasis on the economy and benefits to public health programs. To maximize the benefits to the public health from health services and interventions, we have a responsibility to use resources as efficiently as possible [14]. Both cost-effectiveness and cost-benefit analyses are valid for different types of public health programs [15]. Cost-benefit analysis (CBA) is a tool measured by monetary units that helps the policy-maker to decide whether a specific intervention is worthwhile in which non-health benefits can be added to health benefits, while health effects in cost-effectiveness analysis are measured either in natural units or in composite indices of health, in which non-health benefits cannot be added to the effectiveness side of the analysis. Compared with monetary unit in CBA, primary evaluation indicators (such as DALY and QALY) in CEA are not well articulated the long-term benefits to decision-makers, which may limit its utility to public health policy making. Thus, as an evaluation framework, CBA is more intuitive to demonstrate the long-term benefit of public health programs despite CEA is used more frequently in health economics [12].

In the long-term investment decisions, cost-benefit analysis, mainly by calculating NB and BCR, is considered to be the best and relatively intuitive investment evaluation method [6]. However, for different public health programs, there may be a one-time or an annual government investment in the duration of program. Similarly, there may be a one-time or continuously generated income in the effective period of intervention. According to the initial and classic formula calculating NB and BCR in commercial investment, we derived three formulae which considered different patterns of investment and income of public health programs, and allowed the users to evaluate the costs and benefits of alternatives according to actual condition.

Discount rate often has a large impact on results of cost-benefit evaluation of public health programs. The most common method is to apply a constant discount rate, usually varying from 3% to 7% and lacking a uniform definite value [5, 8, 16-20]. However, how to select a discount rate is still controversial[21-23]. Since they have distinct characteristics not shared by many other health interventions, meanwhile, different countries have its specific economic conditions which makes the discount rate different from one country to another [20, 23]. From the point of national economic accounting and statistic, we proposed a weighted average method to determine the social discount rate by referring to the related statistical yearbook data and social opportunity cost approach of capital, which was proved to be relative specific and accurate[6].

Generally, the government will conduct cost-benefit analysis to all possible alternatives prior to the establishment of public health program. Some economic evaluation models such as the decision tree model [9, 10] and the actuarial model [11] are also powerful and essential techniques, but it seems too complex for decision-makers to grasp and understand. In this paper, we established an intuitive and effective CBA method to determine the optimal alternative for the government decision-makers and make the full use of the resources allocated on public health. As the result displayed in empirical analysis, by conducting “four-step” cost-benefit analysis, the BCR for vaccinating domestic attenuated live vaccine, domestic inactivated vaccine and imported inactivated vaccine for children in Guangdong province was 6.96, 3.82 and 2.46 respectively, while the NB was ￥291.391, 279.0352 and 224.298 million respectively. We selected vaccinating domestic attenuated live vaccine as the optimal alternative which has maximum BCR and NB and recommended it to government decision makers.

In conclusion, the proposed method is based on the reliable and available data resource, having advantages of easily understood calculation process and more intuitive results. Even though the statistical data is not comprehensive and accurate, our proposed method is an intuitive and effective approach with good operability in health economics evaluation work for government public health programs, especially suitable for early implementation of the program. Therefore, the proposed method has the potential for popularization and application in the area of public health.

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