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Health Sector Planning: Modeling and Implications

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Abstract
A social cost benefit analysis (SCBA) is a common methodology used in economic evaluation of health programs. However, SCBA is not yet fully developed in health economics and some technical issues such as benefit and cost measurement, incorporating ethics in economic evaluation, social discount rate, shadow pricing, intergenerational equity etc. require further research. Operational mathematical models for SCBA, especially for sectoral analysis, are not well developed either. It is argued that a SCBA of health programs should be based on the recent advances in the principles of welfare economics, and operations research techniques such as dynamic optimisation to operationalise SCBA. To demonstrate the application of this approach, an operational model of cost-benefit analysis and health sectoral planning (Pharmaceutical Benefit Scheme (PBS)) is developed. The GAMS system is used to solve the dynamic optimisation model. This research demonstrates that an application of operations research techniques such as dynamic optimisation provides a proper health sector project planning.

1 Introduction

In spite of the persuasiveness of the use of cost benefit analysis, there are several limitations in the existing literature in applying cost benefit analysis to health economics and other areas in economics and social sciences. Present applications of cost benefit analysis in health economics focus predominantly on financial and economic analysis rather than *real* social and welfare economic analysis based on principles of ethics, social and extra-welfaristic considerations. Rigorous specifications of health sector modeling and planning based on cost benefit analysis of programs and policies are not yet well developed. Furthermore, certain useful mathematical methods of capital budgeting and project appraisal have not yet been applied in health sector planning and project evaluation (Brent 2003; Pearce and Nash 1981).

In order to overcome these limitations, the objective of this paper is to develop a new cost benefit analysis approach with an appropriate basis of normative economics in a dynamic optimization framework for planning in the health secotor (PBS). In some previous papers of the authors (Islam and Mak 2002a, 2002b, Islam, Mak and McCallum 2005), a cost benefit analysis of six medications was performed. That exercise was useful in providing information in decision-making about listing individual medication on the Pharmaceutical Benefit Scheme (PBS) in Australia. These costs and benefits estimates are given in Islam and Mak (forthcoming). However, a realistic exercise of health programs evaluation should be in the form of proactive health sector planning. In health sector planning, a set of health programs is chosen from alternatives to be financed by the available budget. In this chapter, we develop a PBS sub-sector planning. We apply the new[3] cost benefit analysis developed for sub-sector planning of the PBS referred here as PBS planning, and discuss the implications of PBS sub-sector planning in selecting a set of medications for PBS listing that can maximise the health and social welfare of a society.

This paper is structured is as follows. Section 2 discusses sector planning in general and Section 3 is about the issues and model of PBS sub-sector planning, and discussion of implications of results of PBS sub-sector planning. Section 4 discusses the implications for decision making in the PBS setting. Section 5 discusses welfare economics implications. Section 6 discusses the plausibility of the approach and the results. Section 7 presents the conclusion.

2 Sector Planning via Project Planning

The PBS is a prominent example of a health project or program. It is an Australian Commonwealth-funded health program through which pharmaceuticals are provided with government subsidy for the Australian public.

The objective of this research is to apply social cost benefit analysis in a holistic manner to the PBS setting to go beyond a single program consideration and towards health sector planning. So far we have considered the economic evaluation of individual medications for PBS listing, but the real challenge is the decision-making on a set of medications to be included in a systematic manner. In this situation, economic evaluation needs to be applied to each medication. In order decide on a set of medications among other alternatives to be included in the PBS, i.e. to prepare a PBS sub-sector planning, we need to apply the principles and methodologies of project planning which are discussed below.

Project planning in the health sector involves identification of a set of health programs to be approved and implemented by the Government. Health sector planning is a sectoral exercise: a sum of money (the sectoral budget) is allocated to the health sector, and certain programs are selected and financed by such a budget on the basis of the principles and methodologies of project planning. In selecting programs to be undertaken in a sector, the relative cost benefit ratios or net present values are used. Formulation of a total sectoral plan for the health sector on the basis of cost benefit analysis by applying some health sector-wide mathematical models is not yet a popular practice. Such an exercise will be undertaken in Section 3.

3 PBS Sub-sector Planning – Issues and Models

3.1 Issues in PBS Planning

In the area of healthcare, project planning is a decision making process of selecting a suitable health program. In the context of the PBS in Australia, project planning is about the selection of a set of medication from their alternatives for government subsidy which can be funded by an available budget in a particular year or time period. With the aid of economic analysis, a set of medications should be selected on the basis that it achieves the desired health outcomes at the minimum possible cost of resources. When conducting the economic analysis, one should consider the macroeconomic and sector implications, economic efficiency, equity and distributional justice, ethics and moral philosophy, as well as sustainability and issues of intergenerational equity of the project (Hurley 2000; Carter 2001).

Through provision of medications to the public, the PBS aims to preserve or maintain, to restore and hopefully improve the health status of the Australian population. Fiscal responsibility was identified as one of important measures in the Intergenerational Report 2002 (Costello 2002) for preserving intergenerational equity over a 35-year time span. With the ageing population in Australia, investment in health is important to maintain optimal health status of the population, to preserve and/prolong the productivity of the labour market, and hence the tax revenue of the government.

Early intervention is crucial in the area of health. Without early intervention, most conditions such as cardiovascular diseases and type 2 diabetes will progress to critical stages, resulting in hospitalisation, or even impaired functional status or disability of patients. In the latter case, institutional care such as hostels or nursing homes may become the only viable, and perhaps most expensive alternative.

At the initial planning stage of the project, one should assess the demands or needs of the project. In the context of the PBS, the demand of a medication can be estimated by epidemiological studies, statistical data on the prevalence of the diseases, and the burden of the diseases to Australia. These data help to establish the economic rationale for public sector involvement. However, a more efficient system, regardless of public or private sector involvement, should be established. The PBS in Australia is implemented under a public system, and is administered by the Health Insurance Commission of the Commonwealth Government of Australia. Therefore, economic efficiency of individual medications in the PBS system as well as their social considerations stated above need to be considered in the PBS decision making.

Another issue in the Australian health sector is the sustainability of the health of the population. Sustainability is a concept from environmental economics. Sustainable development refers to the notion that economic development should proceed at a pace and in a manner which conserves the environment and depletable natural resources (see Bannock et al. 1998). In the context of health, sustainability should be considered in implementing health programs aiming at preserving the optimal health status of the Australian population.

New[3] cost benefit analysis (discussed in Section 3.4), based on new[3] welfare economics (also defined in Section 3.4), provides an appropriate framework for addressing the above issues of PBS sub-sector planning. By applying the new[3] cost benefit analysis in PBS planning, the economic and social costs and benefits of medications are valued in monetary terms and compared. A set of medications is selected among other alternatives by using the criteria of new[3] cost benefit analysis, an exercise which addresses the PBS issues discussed above. Health policy on pharmaceutical subsidy formulated under such criteria offers a much broader perspective and caters for the needs of the whole population.

3.2 Capital Budgeting and Operations Research Techniques

A social cost benefit analysis is developed on the basis of the capital budgeting technique and can be considered as capital rationing. Capital budgeting is an operations research technique designed to select a portfolio of projects from a set of alternative proposals in order to achieve maximisation of social welfare or health outcome.

Operations research methods have been applied to the healthcare sector since the 1960s. With cost containment being the common theme in public healthcare systems around the world, interest in operations research methods in healthcare delivery is growing. When applying an economic evaluation of a health program such as the PBS, studies of operations research methods in the area of allocation, forecasting demand, as well as quality and efficiency are most relevant (Gass and Harris 2001).

With scarcity of resources, allocation is an important measure to ensure optimal health outcomes. Forecasting helps to establish future demand in healthcare services and resources in order to allow a meaningful proactive project planning exercise. Mathematical programming such as goal programming and integer programming are commonly used in this area of operations research. Mathematical programming is a study of optimising the use and allocation of scarce resources. Linear programming solves the problem by finding the maximum (or minimum) of an objective function $f(x)$ subject to a set of constraints of the form $g_i(x) \leq b_i$. Stochastic programming deals with optimisation models when available data are subject to significant uncertainty. Stochastic programming is closely related to other paradigms for decision making under uncertainty. Decision analysis is usually restricted to problems in which discrete choices are evaluated in the view of sequential observations of discrete random variables. The analytic approach allows decision makers to use general preference functions in comparing alternative courses of actions. Theoretically, both single and multiple objectives can be incorporated in the decision-making framework. However, it is not practical to enumerate all choices (decisions) as well as outcomes (of random variables) in the context of decision-making. This approach is normally used when a few strategic alternatives are considered (Gass and Harris 2001)

Optimisation models developed under mathematical programming can then be interpreted under the normative social choice and the new^3 welfare economics framework. By incorporating social welfare criteria and the static and dynamic constraints of the economy based on new^3 welfare economics, a set of optimal decisions for resource allocation that specifies optimal social welfare and health outcome in the health sector can be formulated (Islam 2001). This optimisation can also be specified by embedding cost benefit analysis concepts (in the present study new^3 cost benefit analysis), issues and decision making problems (Craven and Islam 2005a; Clarke and Islam 2004).

3.3 Public Policy Objectives

A social cost benefit analysis should incorporate the underlying government social and economic policies including extra-welfaristic outcomes such as equity, justice, ethics and moral philosophy. When considering the sector planning of the PBS, one should take into account macroeconomic and sector implications in addition to benefits and costs of the health program alone. The main objective of a health program is health maximisation, and improving the quantity and quality of life of the individuals in a society. Other macroeconomic issues such as employment in the healthcare sector, sustainability of the pharmaceutical industries, viability of a timely and efficient distribution network of PBS medications should also be considered.

3.4 Sector Planning Models and New^3 Cost Benefit Analysis

In new^3 welfare economics, making social choices and decisions is feasible since quantifiability, measurability, and comparability of social benefits or welfare are assumed in this paradigm on the basis of the possibility perspective (Sen 1999) in social choice theory. This paradigm also provides a framework for incorporating ethics and non-economic elements in economic analysis (therefore also in cost benefit analysis) relatively conveniently and appropriately. This approach has not yet been applied to economic evaluation of projects for making decisions or social choices in general and in the health sector. It is possible to develop a type of cost benefit analysis (which we can name new^3 cost benefit analysis) on the basis of the principles of new^3 welfare economics. In new^3

cost benefit analysis, social choice can be operationsalised for practical application and social value judgments, expert opinion, and scientific information need to be applied to the making of social decisions. This paradigm can enable the development of a full social cost benefit analysis (i.e., the new^3 cost benefit analysis) with plausible estimates of social costs and benefits of health programs.

The elements of the new^3 cost benefit analysis (Islam 2001; Islam and Mak forthcoming) are the following:

a. it considers *economics* and *ethics* in estimating costs and benefits in economic evaluation;
b. it assumes *measurability* of social welfare, non-economic costs and benefits on the basis of *social value judgment*, *preferences* and public policy objectives; and
c. it aims to estimate costs and benefits of the health program by using scientific information, expert opinion and social preferences.

The inclusion of the elements of the new approach in a health sector planning model developed in this paper is done by the following methods:

a. including social costs and benefits in estimating the parameters of the values;
b. applying a combination of scientific information, expert opinions and social value judgment in identifying and estimating parameters and coefficient, equations and objective functions of this model; and
c. including social value judgment and ethical issues in the model through the objective function and constraints and discount rates of the models.

By incorporating social objectives, the objective function represents social value judgment. By adjusting the discount factor, intergenerational equity is considered and emphasis is put on future generations.

In the context of PBS sector planning, new^3 cost benefit analysis is used as an evaluation tool for PBS decision-making by incorporating the elements of new^3 cost benefit analysis discussed above. Firstly, the Therapeutic Goods Administration assesses a medication for its safety and efficacy by using scientific information, in order to determine whether the medication should be approved for the Australian market. Secondly, medical treatment guidelines of the medication are established to determine the clinical indications that are subsidised or funded by the PBS budget. Under the new^3 cost benefit analysis, both social costs and benefits are included in the evaluation. Details of calculation of the costs and benefits estimates are discussed in Islam and Mak (forthcoming). In defining the costs and benefits of medications, social value judgments and ethical considerations are incorporated in the analysis, in addition to the narrow definition of benefits under the Pharmaceutical Benefits Advisory Committee criteria where social costs and benefits are excluded.

Thirdly, the percentage of government subsidy on PBS medications depends on the entitlement status of patients. The population is divided into general patients and concessional patients according to their entitlement. The entitlement status of patients is linked to income and is determined by the Treasury. In addition to the distributional weights incorporated when calculating costs and benefits, it is important that the government address the distributional issues through taxation system rather than to rely on the process of project selection and design to redistribute income. It is usually outside the terms of references of project analysts to influence government tax and transfer policies (Jack 1999, p. 227).

The cost benefit ratios and net present values of the six medications, namely Atorvastatin, Clopidogrel, Pioglitazone, Letrozole, Fluticasone/Salmeterol and Tiotropium are calculated in Islam and Mak (forthcoming). Medications should be selected for listing on the PBS if their cost benefit ratios are greater than 1, and/or their net present values are positive. Under the PBAC criteria, the net present value of Clopidogrel is $4971.42 and its cost benefit ratio is 2.05. The net present value of Pioglitazone 30mg is $3160.45 and its cost benefit ratio is 1.57. The net present value of Tiotropoium is $579.55 and its cost benefit ratio is 1.13. All three medications should be accepted on the PBS under the PBAC criteria. For the other three, Atorvastatin, Letrozole and Fluticasone/Salmeterol, their net present values are negative and cost benefit ratios are less than 1. The net present value and cost benefit ratio of Atorvastatin is -$190.22 and 0.96. The net present value and cost benefit ratio of Letrozole is -$1054.07 and 0.91. The net present value and cost benefit ratio of Fluticasone/Salmeterol is -$2822.41 and 0.37. Using the decision rules of cost benefit analysis, all three medications should be rejected under the PBAC criteria (see Islam and Mak forthcoming).

Under the financial cost benefit analysis approach, the net present values of Atorvastatin, Clopidogrel, Pioglitazone, Letrozole, and Tiotropium are $2790.92, $8733.55, $7111.09, $3410.63, and $4022.69 respectively. The cost benefit ratios of Atorvastatin, Clopidogrel, Pioglitazone, Letrozole, and Tiotropium are 1.60, 2.85, 2.29, 1.28 and 1.92 respectively. The cost benefit ratio of Fluticasone/Salmeterol is 0.98 and its net present value is -$104.27. Based on net present values and cost benefit ratios, all medications should be selected with the exception of Fluticasone/Salmeterol.

Under the new[3] cost benefit analysis approach, the net present values of Atorvastatin, Clopidogrel, Pioglitazone, Letrozole, Fluticasone/Salmeterol and Tiotropium are \$30645.29, \$31906.50, \$24639.47, \$35046.27, \$31921.88 and \$36501.23 respectively. Their cost benefit ratios are 6.34, 4.52, 3.22, 2.47, 5.68 and 6.98 respectively. Based on net present values and cost benefit ratios, all medications should be selected (see Islam and Mak forthcoming).

The cost data are obtained from the Schedule of Pharmaceutical Benefits (published by the Medicare Australia) and computer dispensing programs used by community pharmacies. The benefits are calculated from statistical data of health services consumption from the Australian Bureau of Statistics and the Australian Institute of Health and Welfare, the Medicare Benefit Scheme, published data of the statistical values of life, and professional opinions of researchers.

3.5 Health Sub-sector Planning: PBS Planning Model

As an exercise for health sub-sector planning, let us assume that selection of medications for listing on the PBS is subject to the constraints of an allocated budget. In addition to the positive net present values and cost benefit ratios being greater than 1, the net cash flow of that year must be within the allocated budget so that the chosen program is socially and financially viable within that year. The net cash flow of the program is calculated as the net benefits (benefits less costs) of these medications considered for PBS selection.

A PBS planning model

$$\text{Max} \quad \sum_i \sum_j A_{tj} X_j (1-\xi_j)^t \tag{1}$$

subject to: $\sum_i \sum_j R_{tj} X_j \leq R_t$

$X_j = \{0,1\} \qquad j = 1 \,..\, N \text{ (drugs)} \qquad t=1 \,..\, T \text{ (time)}$

where:

A_{tj} = net benefit stream of drug j at time t = $(B_{tj} - C_{tj})$;

X_j = 1 if drug j is active, 0 otherwise;

R_{tj} = allocation of resource to drug j at time t;

R_t = total resource to allocate at time t;

ξ_j = the social discount rate of drug j;

B_{tj} = benefit for a drug j at time t; and

C_{tj} = cost for a drug j at time t.

This is a dynamic integer-programming problem for choosing a set of medications in the PBS for a planning period. The objective function represents economic efficiency (net benefits) and public policy objectives. The constraints represent the economic and social costs of the medications, and the RHS figures show available PBS budgets. The model results can provide information regarding which medications should be chosen for the PBS in the given period. Public policy objectives derived from extra-welfaristic considerations can be represented by the discount rate, the cost and benefit estimates and the availability of funds. *This objective function explicitly can incorporate both equity and efficiency and other extra-welfaristic elements of social welfare objectives simultaneously*, allowing the choice on the amount of government subsidy and its distribution to be made concurrently, not sequentially (Jack 1999, p. 221).

An Australian PBS Planning Model (PBSPLAN)

Let the decision variables of the Australian PBS model be:

X_1 = Atorvastatin 40mg

X_2 = Clopidogrel 75mg

X_3 = Pioglitazone 30mg

X_4 = Letrozole 2.5mg

X_5 = Fluticasone/Salmeterol 500/50

X_6 = Tiotropium 18mcg

The Objective Functions

The objective function is derived by maximising the net present values/benefits of the six medications under budget constraints (the details of the estimates of costs and benefits may be seen in Islam and Mak (forthcoming)). The government cost of the PBS prescription for the year ending 30 June 2004 is $5 billion. Cardiovascular diseases, type 2 diabetes, breast cancer, asthma and chronic obstructive pulmonary diseases together account for about 30% of the disease burden in Australian society. The budget constraint for the six medications is assumed to be $1.5 billion (30% of $5 billion). The government cost of PBS prescriptions increased at 8.5%

annually for the last five years (1999-2004). Assuming budget constraints increase by 8.5% annually for the 5-year period, objective functions and constraints are derived as follow.

Model 1 PBAC criteria

Objective Function

$$-190.22X_1 + 4971.42X_2 + 3160.45X_3 - 1054.07X_4 - 2822.41X_5 + 579.55X_6 \quad (2)$$

Subject to Budget Constraints

Year 0: $3464.82X_1+8652.41X_2+7468.65X_3+2959.01X_4+633.7X_5+3981.41X_6 \le 1500000000$

Year 1: $-1030.77X_1-1038.09X_2-1214.97X_3+2959.01X_4-983.13X_5-959.37X_6 \le 1627500000$

Year 2: $-1030.77X_1-1038.09X_2-1214.97X_3-2633.91X_4-983.13X_5-959.37X_6 \le 1773975000$

Year 3: $-1030.77X_1-1038.09X_2-1214.97X_3-2633.91X_4-983.13X_5-959.37X_6 \le 1933632750$

Year 4: $-1030.77X_1-1038.09X_2-1214.97X_3-2633.91X_4-983.13X_5-959.37X_6 \le 2107659698$

$X_j = \{0,1\} \qquad j=1,2,3,4,5,6$

Model 2 Financial Cost Benefit Analysis

Objective function

$$2790.92X_1 + 8733.55X_2 + 7111.09X_3 + 3410.63X_4 - 104.27X_5 + 4022.69X_6 \quad (3)$$

Subject to Budget Constraints

Year 0: $4815.32X_1+10783.91X_2+9788.65X_3+4764.26X_4+1751.20X_5+5793.91X_6 \le 1500000000$

Year 1: $-305.77X_1-313.09X_2-489.97X_3+4764.26X_4-258.13X_5-234.37X_6 \le 1627500000$

Year 2: $-668.27X_1-675.59X_2-852.47X_3-2271.41X_4-620.63X_5-596.87X_6 \le 1773975000$

Year 3: $-668.27X_1-675.59X_2-852.47X_3-2271.41X_4-620.63X_5-596.87X_6 \le 1933632750$

Year 4: $-668.27X_1-675.59X_2-852.47X_3C2271.41X_4-620.63X_5-596.87X_6 \le 2107659698$

$X_j = \{0,1\} \qquad j=1,2,3,4,5,6$

Model 3 New[3] Cost Benefit Analysis

Objective Function

$$30645.29X_1 + 31906.50X_2 + 24639.47X_3 + 35046.27X_4 + 31921.88X_5 + 36501.23X_6 \quad (4)$$

Subject to Budget Constraints

Year 0: $25946.95X_1+29847.28X_2+23491.77X_3+31661.16X_4+28243.42X_5+32374.45X_6 \le 1500000000$

Year 1: $1712.56X_1+1052.78X_2+824.90X_3+6389.13X_4+1839.07X_5+1457.59X_6 \le 1627500000$

Year 2: $995.26X_1+335.48X_2+107.60X_3-1001.34X_4+1121.77X_5+740.29X_6 \le 1773975000$

Year 3: $995.26X_1+335.48X_2+107.60X_3-1001.34X_4+1121.77X_5+740.29X_6 \le 1933632750$

Year 4: $995.26X_1+335.48X_2+107.60X_3-1001.34X_4+1121.77X_5+740.29X_6 \le 2107659698$

$X_j = \{0,1\} \qquad j=1,2,3,4,5,6$

Results

A dynamic optimisation integer-programming model is used to solve the problem. Under budget constraints of the data above and the parameters, the PBSPLAN model was solved with the GAMS program (Brooke et al. 1992; Levary et al. 1990). The GAMS program and output for PBSPLAN is given in Islam and Mak (forthcoming).

For Model 1, the objective value of the social welfare function is 8711.3522 and the integer solution is $X_2=X_3=X_6=1$. Within the limitations of the allocated budget constraints, only three medications are selected with ranking in the order of Clopidogrel, Pioglitazone and Tiotropoium. Atorvastatin, Letrozole and Fluticasone/Salmeterol are rejected from PBS listing.

For Model 2, the objective value of the social welfare function is 26068.7841 and the integer solution is $X_1=X_2=X_3=X_4=X_6=1$. Within the limitations of the allocated budget constraints, only five medications are selected with ranking in the order of Clopidogrel, Pioglitazone, Tiotropoium, Letrozole, and Atorvastatin. Fluticasone/Salmeterol is rejected from PBS listing

Table 1 Results of PBSPLAN under different criteria

Cost benefit analysis model	Discount rate	Budget Constraints	Objective function value	Ranking of medications	Medications rejected
1. PBAC criteria	5%	As in Section 3.5	8711.3522	X_2, X_3, X_6	X_5, X_4, X_1
2. Financial CBA	5%	As in Section 3.5	26068.7841	X_2, X_3, X_6, X_4, X_1	X_5
3. New[3] CBA	0%	As in Section 3.5	190660.6400	X_6, X_4, X_5, X_2, X_1, X_3	None
4. New[3] CBA	0%	Half of the budget as calculated in Section 3.5	190660.6400	X_6, X_4, X_5, X_2, X_1, X_3	None
5. New[3] CBA (less benefits of QALY)	0%	As in Section 3.5	66636.5600	X_2, X_3, X_6, X_1, X_4, X_5	None
6. New[3] CBA	5%	As in Section 3.5	189216.3610	X_6, X_4, X_2, X_5, X_1, X_3	None
7. New[3] CBA	5%	Increase in the first year budget	189216.3610	X_6, X_4, X_2, X_5, X_1, X_3	None
8. New[3] CBA	5%	Increase in the fifth year budget	189216.3610	X_6, X_4, X_2, X_5, X_1, X_3	None
9. New[3] CBA	10%	As in Section 3.5	187977.8427	X_6, X_4, X_2, X_5, X_1, X_3	None
10. New[3] CBA	-5%	As in Section 3.5	0	None	All

Notes:
CBA = cost benefit analysis
X_1 = listing Atorvastatin 40mg on PBS.
X_2 = listing Clopidogrel 75mg on PBS.
X_3 = listing Pioglitazone 30mg on PBS.
X_4 = listing Letrozole 2.5mg on PBS.
X_5 = listing Fluticasone/Salmeterol 500/50 on PBS.
X_6 = listing Tiotropium 18mcg on PBS.

For Model 3, the objective value of the social welfare function is 190660.6400 and the integer solution is $X_1=X_2=X_3=X_4=X_5=X_6=1$. Within the limitations of the allocated budget constraints, all six medications are selected with ranking in the order of Tiotropoium, Letrozole, Fluticasone/Salmeterol, Clopidogrel, Atorvastatin and Pioglitazone.

The results from the GAMS modelling support the decision-making from using the net present values and cost benefit ratios criteria. Under the PBAC criteria, only Clopidogrel, Pioglitazone and Tiotropium are selected. Under the financial cost benefit analysis, Clopidogrel, Pioglitazone, Tiotropoium, Letrozole, and Atorvastatin are selected. Under the new[3] cost benefit analysis, all six medications are selected.

Apart from the criteria under the three models, different parameters are put into the PBSPLAN model in order to test the validity of the model and the effects of the discount rate, budget constraints and net benefit estimates on the results and the ranking of the medications selected. Model 1 is the cost benefit analysis under PBAC criteria with a discount rate of 5%. Model 2 is the financial cost benefit analysis with a discount rate of 5%. Model 3 is the new[3] cost benefit analysis with a discount rate of 0%. Model 4 is the new[3] cost benefit analysis with a discount rate of 0% and half of the allocated budget. Model 5 is the new[3] cost benefit analysis with a discount rate of 0% and the exclusion of QALYs as benefit measures. Model 6 is the new[3] cost benefit analysis with a discount rate of 5%. Model 7 is the new[3] cost benefit analysis with a discount rate of 5% and an increase in the first year budget. Model 8 is the new[3] cost benefit analysis with a discount rate of 5% and an increase in the last year budget. Model 9 is the new[3] cost benefit analysis with a discount rate of 10%. Model 10 is the new[3] cost benefit analysis with a discount rate of -5%. The value of the objective function, the ranking of the medications selected and the medication rejected changes with different criteria of the model specified. The results are listed in the Table 1.

4. Implications of Results

After undertaking a cost benefit analysis under the three different approaches, a set of net benefits, net present values and cost benefit ratios are calculated and included in the PBSPLAN model. Under the new[3] cost benefit analysis, social value judgment and ethical issues as well as scientific information are incorporated in these definition and estimates of costs and benefits of the medications for the PBSPLAN model.

As discussed in Section 3.5, the annual PBS budget is used as a constraint of the PBSPLAN model to address the issues of project viability and sustainability. Issues such as burden of disease and prevalence of the medical condition are factored into the budget constraints in order to address the ethical issues of equity and allocation according to need. Distributional equity is addressed by the entitlement status of patients that determined percentage of government subsidy, as well as the prevalence of diseases in the Australian population. The discount rate is set at 0% in order to address intergenerational equity. Under these criteria, a set of medications is selected under Model 3 new^3 cost benefit analysis leading to an optimal, social, and health outcome for the Australian public.

From Table 1, the value of the objective function is influenced by the discount rate. Comparing models 3, 6 and 9, the criteria of calculating net benefit estimates and the budget constraints are the same for the three models, the objective function increases in value with a decrease in the discount rate. The ranking of medications selected also differs. In Model 3, Fluticasone/Salmeterol is selected ahead of Clopidogrel. The selection order is reversed in models 6 and 9.

The value of the objective function is also sensitive to the criteria of calculating net benefit estimates of the medications. Comparing models 3 and 5, the value of the objective function decreases substantially with the exclusion of QALY as benefits. The ranking of medications selected also changes: Tiotropium drops from first and third position, and Clopidogrel moves from fourth to first position.

When comparing models 3 and 4, as well as 5, 6 and 7, changes in budget constraints does not affect the value of the objective function and the ranking of the medication selected. All medications seem to be selected under the new^3 cost benefit analysis model regardless of changes in the discount rate, budget constraints and criteria of calculating net benefit estimates. Only six medications are tested for PBS listing using PBSPLAN in this study. In a real life setting, there are many more than six medications considered for PBS listing.

However, the new^3 cost benefit analysis approach aids decision-making in the PBS, making it sustainable and ethically justified, leading to better budget management and more efficient resource allocation. The new^3 cost benefit analysis also provides a policy plan that gives a high level of social welfare for the Australian community. Therefore the model produced in this chapter can maximise social welfare in Australia

5. Welfare Economics Implication

By incorporating the social cost into the cost stream calculation, we have also considered the opportunity cost of the forgone capital or fund, in addition to the financial cost of the medications and the program. By incorporating the social benefit into the benefit calculation, we attempt to capture the benefit beyond the cost savings measure of the government. By estimating the improvement in quality of life (health status) and the quantity of life (life expectancy) in addition to saving in health costs and increase in economic productivity, we endeavour to measure improvement in social welfare/utility rather than just the financial benefit to society.

6. Plausibility of the Approach and Results

6.1 Validation of Model and Results

Model validation is a process of substantiating that the model behaves with a satisfactory level of accuracy and consistency within its domain of applicability. During the validation process, the model is run under the same input conditions that drive the system. The model behaviour is then compared with the system behaviour to check whether the ‘right’ model has been built (Gass and Harris 2001).

There are three levels of validation tests, namely descriptive, analytical and experimental. There are also three types of validation criteria applied to the three levels of validation tests. For the descriptive level, the validation criteria include the attainment of the objectives of the model, the appropriateness of the model structure and the plausibility of the results. The objective of the PBSPLAN is to select medications among other alternatives to be listed on the PBS in order to maximise the health and social welfare of the Australian community subject to the budget constraints of that time period. For the analytical level, the validation criteria include the characteristics of model solutions and the robustness of the results. The results of the PBSPLAN model supports the decision deriving from other criteria such as net present values, cost benefit ratios, etc. For the experimental level, the validation criteria include the methodological tests related to model documentation, costs and efficiency in model transfer and extension, tests related to model execution such as accuracy and efficiency of the execution, and cost and efficiency in the software transfer and extension.

The model PBSPLAN is solved by a GAMS program used for capital budgeting. The objective of this model is health sector planning with budget constraints. From the experience of this study such as model convergence, results, the plausibility of the results (to be discussed in the next section) and other model validation criteria, it is found to be an appropriate model for health sector (PBS) planning.

6.2 Plausibility of Results

The accuracy of the results can be verified by checking the relevance of the optimal solution provided by the model to the expected results, the reported actual values or the historical data set. Several methods are used to check the plausibility of the results, namely intuitive judgment, comparison of results, statistical tests and self-auditing or third party auditing.

Intuitive judgment is used to check whether the results are consistent with the theory in this area and acceptable to the profession. In the PBSPLAN, the results are consistent with the theory, where all the six medications return positive net present values and a cost benefit ratio greater than 1. They are selected in PBSPLAN with the ranking of the six medications being consistent with the order of their net present values and the burden of diseases in the Australian society. The capital budgeting approach to health sector planning is new to the profession.

Results can also be compared with historical data, results from similar studies, and the ability to predict the future performance of the system. It is difficult to compare the results of PBSPLAN with historical data and results from similar studies as the model has not been used previously in health sector planning.

Justification of Theoretical Foundation

By including the social costs and benefits component, we capture the change in social welfare better than the PBAC and the financial approach of cost benefit analysis. The social welfare function of the PBSPLAN incorporates both equity and efficiency issues simultaneously, allowing the decision of the amount of resource allocated and its distribution to be made concurrently rather than sequentially (Jack 1999, p. 221).

7 Conclusions

In this paper, we have undertaken a cost benefit analysis for these six medications along with a sector planning exercise. Our exercise implied that the new[3] cost benefit analysis is a suitable methodology in selecting health programs that maximise the social welfare or benefit of society. Under this approach, social value judgment, ethical issues and scientific information are incorporated in the definition and estimation of costs and benefits of the health program. In addition, sustainability and intergenerational equity are built-in criteria of the model. As a result, the model under the new[3] cost benefit analysis leads to selection of health programs that maximise the social welfare and health outcome of the general community.

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