REVIEW
ΑΝΑΣΚΟΠΗΣΗ

Quality of life and QALYs in the measurement of health

Health status measurement has been an important topic of investigation by epidemiologists, demographers, statisticians, psychologists, and economists. Different approaches have been explored to conceptualise health and to analyse health related issues of quality of life. Health is a multidimensional phenomenon including not only medical or clinical aspects but also other important dimensions related to the physical, psychological and social aspects of well-being. This paper reviews the methods explored by various disciplines for measuring quality of life using both generic instruments, based on general population studies and disease specific instruments, designed to assess the evolution of a disease and to evaluate the impact of alternative therapies or medical interventions. The concept of Quality Adjusted Life Years (QALYs) has become a popular topic among doctors and economists during the last two decades. It combines "quantity" i.e., life expectancy with "quality" adjusted life years. The alternative approaches to estimation of QALYs are explored and reference is made to simple rating methods such as the category and the magnitude methods. Sound theoretical approaches, based on utility theory, i.e., the Time Trade Off and the Standard Gamble are discussed. The Standard Gamble method, based on Von Neumann Morgenstern cardinal utility is analysed and the psychological assumption for deriving utility based values are discussed. Since Greece is currently in the process of designing a comprehensive regional health policy, the methodology proposed by this paper could be useful for setting priorities among the regions and devising effective and efficient criteria for resource allocation.

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Η ποιότητα ζωής και τα ποιοτικώς σταθμισμένα έτη επιβίωσης ως παράμετροι μέτρησης της υγείας

Περίληψη στο τέλος του άρθρου

Key words

Health measurement
Health produetion
QALYs
Quality of life
Standard Gamble

1. INTRODUCTION

Quality of life is a term which has been used extensively by philosophers, psychologists, theologists, poets and politicians. It is extremely difficult to formulate a commonly accepted definition of quality of life. Clinicians appear more inclined to consider the physical aspects of the term whereas psychologists emphasise the emotional and cognitive dimensions of health. In the literature of health measurement the concept of quality of life appeared during the early 1980's.[1–3] However, its roots may be identified in the definition of health proposed by the WHO in 1958, in the classic publication "The first ten years of the World Health Organization":[4] "Physical, mental, and the social well-being and not merely the absence of disease and infirmity".[4] At the beginning the WHO definition of health received strong criticism as being an unmeasurable and non-operational concept.[5] After the 1980's, this definition inspired the quality of life researchers to devise techniques and to develop instruments for evaluating and measuring health in terms of the physical, mental and social dimensions of well-being (fig. 1).

In the literature of health status measurement various approaches have been developed by epidemiologists, demographers, sociologists, psychologists, statisticians, and economists to evaluate the different dimensions of health. In an attempt at taxonomy of the alternative approaches four broad disciplines can be distinguished which have been involved in providing both theoretical and empirical methods for measuring and evaluating the level of health of a population, a social class or a group of patients. The first is the epidemiological or biomedical approach, according to which health is defined as a biological phenomenon.[6] This approach focuses on the

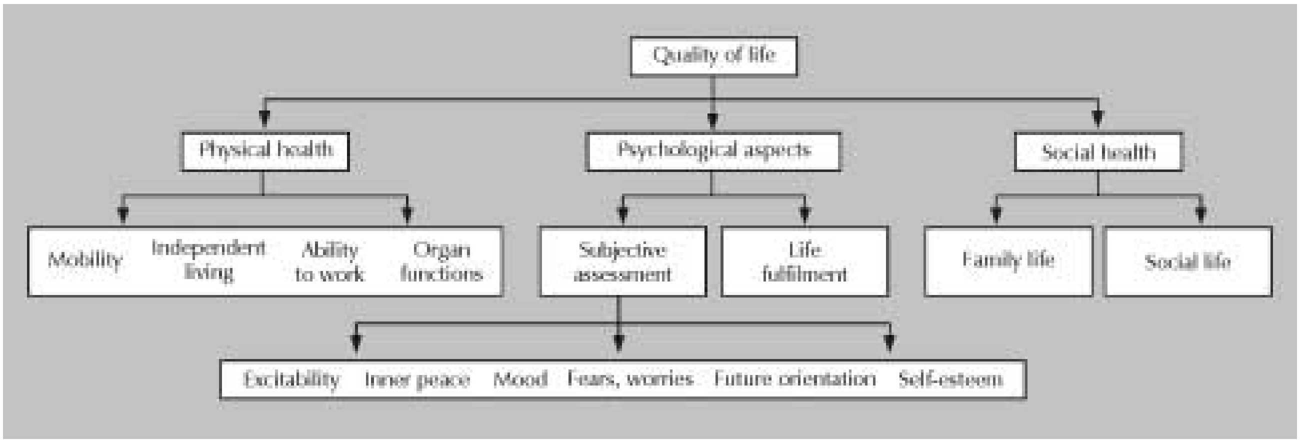

Figure 1. Major components of quality of life.

classification of diseases in categories according to the symptoms of each disease and it considers the different "cases" of treatment, or hospital discharges, as units of output of the medical system.

The second method is the functional/dysfunctional approach which may be considered as an extension of the biomedical approach, since it concentrates on measuring the impact of biomedical conditions or dysfunctional states of health (e.g. inability to walk, dress, etc.) upon capabilities and feelings as regards everyday activities. The statistical methods used for evaluating the different dysfunctional states are based on the Guttman Scale,[7] or on the Tenhouten Scale Gradient analysis.[8] This method has been used by Wright[9] and others. Culyer[10,11] provides an extensive review of this method and its applications.

The third method is the cultural approach which may be viewed as an expansion on the first two methods and concerns the "labelling" or stigmatisation process applied by society in response to "deviant" behaviour. This approach introduces a new interpretation of the definition of ill health accepting the fact that people's perceptions regarding whether someone is clearly ill or not ill, regardless of biomedical and dysfunctional acknowledgment, would vary significantly between age groups, income and social classes, religious groups etc. This approach was used by Gordon[12] and Twaddle.[13]

Finally the fourth method for measuring health is the economic approach.[10,14–17] This approach considers the definition and measurement of health status by considering the concept of utility. Inevitably the concept of utility is based on certain ethical beliefs, norms or value judgments concerning the identification and assessment of medical needs.

The purpose of this paper is to discuss briefly the methods explored in the empirical literature of health economics for assigning values to different health states. The concept of Quality Adjusted Life Years (QALYs) is analyzed and emphasis is given to the Standard Gamble (SG) technique. The mathematical properties of SG are presented and a theoretical framework is proposed for allocation resources among the Greek health regions.

2. QUALITY OF LIFE

The term quality of life has many applications in different disciplines. Scientists in different fields of applied research have attempted its conceptual justification. Fries and Singh[18] favored the need or a more concise approach to quality of life measurement: "Quality of life is a term at once pejorative and vague. The term as often used offers hope and meaning but lacks focus and precision. In the context of clinical studies, we have a restricted concept of quality of life in mind. We do not mean happiness, satisfaction, living standards, climate or environment. Rather, we are speaking topically of health related quality of life–those aspects of life quality that relate to health".

In analysis, the notion of Health Related Quality of Life (HRQL) can be used, which refers to a composite concept combining the individual's perception of health with his or her social, emotional, and physical well-being. Patrick and Erickson[19] draw the link between HRQL and health policy.

"Health related quality of life is the value assigned to duration of life as modified by the impairments, functional states, perceptions, and social opportunities that are influenced by disease, injury, treatment, or policy".

In the literature of health, the first empirical attempts to measure quality of life began around the 1970s.

Since then, there has been an increasing tendency to develop different instruments to measure subjective valuations of people's ability to function in their everyday life.[20–22] The proposed instruments belong to two categories:

a. *Generic instruments* are designed to measure the health status of the general population in different socio-economic groups and various cultural settings. They are widely applicable across various types of diseases, disabilities, impairments and medical treatments. Several instruments have been developed, among which are, indicatively: SF-36, Nottingham Health Profile, Sickness Impact Profile, EQ-15D, EQ-5D. The main characteristics of selected generic instruments are summarised in table 1.

b. *Disease specific instruments* are designed to assess the health status of specific population groups, or people in specific diagnostic categories. Diseases specific instruments are sufficiently sensitive to capture changes in health condition or in the stages of a specific illness such as diabetes, arthritis (Arthritis Impact Measurement Scale), asthma (Asthma Quality of Life Questionnaire), inflammatory bowel disease (IBD Questionnaire) etc. Table 2 presents the disease specific instruments which have been discussed in the literature of quality of life measurement.

The instruments vary considerably in the completion time, and the complexity of their application. Several authors[23–25] have provided interesting reviews on the features of generic and disease specific instruments. It should be emphasized that the choice of the appropriate instrument depends on the objectives of the exercise.

The specification and measurement of all quality of life instruments should fulfil basic choices concerning:

a. The choice of dimension or domains of measuring health.

Table 1. Generic instruments for quality of life measurement.

Questionnaire	Summary of characteristics
EuroQol (EQ-5D)	Consists of 5 domains: Mobility, self-care, usual activity, pain/discomfort and anxiety/depression Three levels in each domain: No problem, some problem, major problem Questions easy to understand and answer Not very sensitive
Nottingham Health Profile (NHP)	Part 1 consists of 36 health statements in 6 dimensions: Energy, pain, emotional reaction, sleep, social isolation and physical mobility Part 2 asks about 7 areas of performance affected by health: Looking after the home, work, social life, home life, sex life, hobbies, and holidays Questions answered by "Yes" or "No" Widely used Good reliabiliy and validity Limited sensitivity
Rosser index	Measures distress and disability through 8 categories of disability (from no disability to unconscious), and 4 levels of distress (no distress, mild, moderate, severe) Scores compared to a valuation matrix obtained from 70 respondents from different backgrounds Quick method
Short Form 36 (SF-36)	36 questions divided into 8 dimensions: Physical functioning, bodily pain, general health, vitality, social functioning, mental health, role functioning-physical, role functioning-emotional Gives 8 profiles, or 2 cumulative profiles Relatively quick (10 minutes) and can be used in postal, telephone and personal interview surveys High internal consistency, validity and sensitivity
Short Form 12 (SF-12)	Abbreviated version of the SF-36 Contains 12 questions, and combines to give 2 dimensions of physical and mental health Very quick to complete (2 minutes)
Sickness Impact Profile (SIP)	Consists of 136 questions in 12 categories: 5 concerned with independence, 3 with physical activity and 4 with psychological behaviors Can be used in telephone and personal interview surveys Takes a long time to complete

Source: Kielhorn A, Graf von der Schulenburg J-M. *The Health Economics Handbook.* Adis, 2000

Table 2. Selected disease-specific measures of health status and quality of life.

Diagnosis/condition	Measure
Alzheimer/dementia	Blessed information-Memory-Concentration Score
	Brief Cognitive Rating Scale
	Clinical Dementia Rating Scale
	Dementia Rating Scale
	Global Deterioration Scale
	Gottfries, Brane and Steen Scale
	Mini-Mental State Examination
	Progressive Deterioration Scale
	Sandoz Clinical Assessment-Geriatric
	Short Portable Mental Status Questionnaire
Arthritis	American Rheumatism Association Classification
	Arthritis Impact Measurement Scales (AIMS)
	Functional Capacity Questionnaire
	Health Assessment Questionnaire (HAQ)
	McMaster-Toronto Arthritis Patient Preference Disability Questionnaire (MACTAR)
	WOMAC (Western Ontario and McMaster Universities)
Asthma	Asthma Symptoms Checklist
	Living with Asthma Questionnaire
	Quality of Life Questionnaire for Asthma
	Simple Asthma Scales
Back pain	Manchester Back Pain
	Oswestry Low Back Pain Disability Questionnaire
	Roland Scale
	Waddell Disability Index
Cancer	Breast Cancer
	Breast Cancer Chemotherapy Questionnaire
	CARES
	EORTC-Quality-of-Life Questionnaire
	Functional Living Index: Cancer
	Karnofsky Performance Status Measure (KPS)
	Quality of Life Index (QL-Index)
	Questionnaire for Patient Self-administration-Lung Cancer
	Rotterdam Symptom Checklist
Diabetes	DCCT Questionnaire (DQOL)
Digestive diseases	Ostomy Adjustment Scale
	Rating Form of IBD Patient Concerns (RFIPC)
	Inflammatory Bowel Disease Questionnaire (IBDQ)
Heart	Cardiac Follow-up Questionnaire
	Chest Pain Questionnaire
	Chronic Heart Failure Questionnaire
	Karolinska-Erasmus Classification
	Minnesota Living with Heart Failure Questionnaire
	New York Heart Association Functional Classification (NYHA)
	QOL and Severe Heart Failure Questionnaire
	Quality of Life Myocardial Infarction
	Specific Activity Scale (SAS)
	Summary Index for Angina
Neurological head injury	Glasgow Outcome Scale
	Modified Sickness Impact Profile
Multiple sclerosis	Expanded Disability Status Scale (EDSS)
	Minimal Record of Disability
Psychological/psychiatric	Beck Anxiety Inventory
	Beck Depression Inventory
	Center for Epidemiological Studies Depression Scale
	General Health Questionnaire
	Geriatric Depression Scale
	Hamilton Rating Scale of Anxiety
	Hamilton Rating Scale of Depression
	Hospital Anxiety and Depression Scale
	Montgomery-Asberg Depression Rating Scale
	Profile of Mood States
	Psychological Adjustment to Illness Scale
	Rosenberg Self-Esteem Scale
	Self-rating Anxiety Scale
	Self-rating Depression Scale
	State Trait Anxiety Inventory
	Symptom Checklist (SCL90)
Rehabilitation	Edinburgh Rehabilitation Status Scale
	Level of Rehabilitation Scale
Respiratory	Bronchitis-Emphysema Symptom Checklist
	Chronic Respiratory Disease Questionnaire
	Dyspnea Index
	MRC Chronic Bronchitis Questionnaire
Urological	Benign Prostatic Hyperplasia: Symptoms, Bothersomeness, and Activities
	American Urological Association Symptom Index

b. The choice of levels or severity by which each dimension is evaluated.

c. The assignment of values to each dimension.

The choice of the dimension of health status, as well as the method of combining different dimensions of health and assigning values to these combinations, requires the identification and evaluation of certain value judgments. Culyer[26,27] provides an extensive review and criticism of the different kinds of value judgments adopted by different researchers.

Quality of life is particularly helpful for measuring the social, physical and cognitive effects of various forms of treatment on people's everyday life.

3. QALYs

Differentiation should be made between quality of life measures and utility measures. Quality of life measurement attempts to investigate the direct impact of a medical intervention or a therapy on people's ability to function well in their daily life. Utility measurement is an economic notion and is based on the calculation of QALYs which depends on concepts both of quantity and quality of life. The quantity of life is measured in terms of life expectancy which is the most widely accepted indicator and is often used to describe survival across nations and socio-economic categories. The concept of quality of life is much more difficult to quantify, because it embraces a large spectrum of health dimensions dealting with physical, emotional, social and cognitive aspects of well-being. The combination of Quality (Q) and Quantity (L) is expressed in terms of an individual's subjective utility, and both concepts are incorporated into a single measure which is called QALYs and its mathematical expression is the following:

$$U\{Q, L\} = a\, L^r\, U(Q)$$

Where:

a=constant,

r=a parameter which measures the individual's attitude to risk (i.e. risk lover, risk neutral, risk averter)

U (Q) describes the quality of health or quality of a given level of health status adjusted over a range of values of 0 to 100.

Where U (Q)=0 usually expresses the worst possible level of health and U (Q)=100 expresses the best imaginable level of health.

A large number of techniques have been described in the literature which generate valuations of different levels of health, which will be discussed below.

The main objective of the QALYs is to calculate an algorithm for assessing the relative benefits of alternative treatments.[28–32] The idea is to provide a theoretical framework for the establishment of priority setting within the health care system.

Rationing health care resources can be achieved:

a. Through the market forces of supply and demand where the consumer's willingness to pay would define what health services should be provided.

b. Using the concept of "need" as been developed by Williams,[33,34] Culyer[27] and Maynard.[35,36]

Williams argued that the concept of need includes both demand and supply issues. Maynard favored the definition that "need is the patient's ability to benefit per unit of cost". Using this criterion health care resources will be allocated to those patients and medical interventions which maximize the health benefit. Health benefit may be defined as the maximum improvement in a population health status given the budget constraint. At an individual level this may be expressed as the maximum QALYs per unit of cost.

In order to obtain a better view of QALYs the following example can be used:

a. Consider a therapy (A) which results in a life expectancy of 5 years, and the quality of life as subjectively estimated by a patient to be 0.8.

b. Another therapy (B) ensures 10 years of life expectancy but the subjective utility is estimated to be 0.3.

Estimating QALYs using the above formula gives:

Therapy A 5×0.8=4 QALYs

Therapy B 10×0.3=3 QALYs

The medical practitioner who used life expectancy as a criterion would suggest therapy B because L(10)>L(5), however decisions based on QALYs would suggest therapy A because QALYs (4)>QALYs (3). Hence the additional number of QALYs generated by therapy A is 1 QALYs. Figure 2 provides a visual impression of QALYs gained from two medical interventions (treatments).

When cost implications are introduced into the above example, further calculations can be made:

Cost of therapy A=5,000,000 drachmas

Cost of therapy B=4,000,000 drachmas

$$\text{Cost utility ratio} = \frac{\text{Cost (A)–Cost (B)}}{\text{QALYs (A)–QALYs (B)}}$$

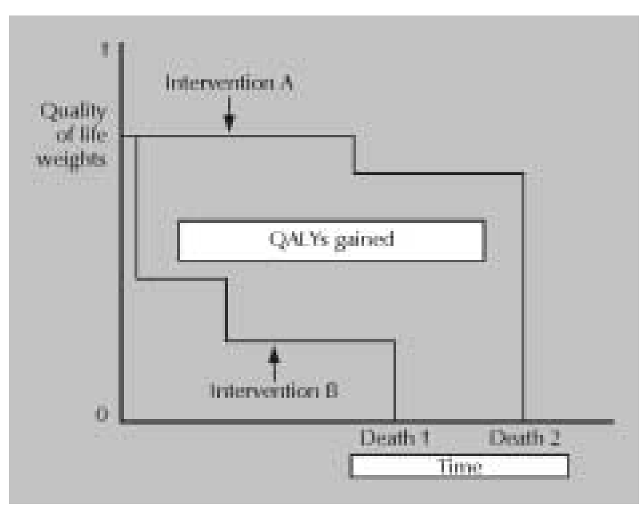

Figure 2. Quality of life weights for two medical interventions.

The result is 1,000,000/1=1,000,000 drachmas per QALYs.

In the empirical literature of health economics cost per QALYs league tables have been produced for several medical interventions (tabl. 3).

The intellectual fathers of QALYs in health economics are Williams from University of York, UK, and Torrance from McMaster University, Canada.

In the empirical and theoretical study of health economics five major methods have been developed for assigning values of health states:

a. *The category method*. This is the simplest and the most comprehensive method of assigning values to a state of health. Subjects are asked to evaluate their own level of health on a scale with values ranging from: dead=0 and perfect health=1. Figure 3 provides a visual impression of a rating scale with values of 0 to 100. This is based on the EuroQol instrument[37–42] which is a Visual Analogue Scale (VAS) presented in the form of a "thermometer" with values of: 100=best imaginable health state and 0=worst imaginable health state.

b. *The magnitude method*. This method promotes the idea of comparisons between two or more levels of health states. Subjects are asked to evaluate a given level of health (Hi), and to compare it with alternative health

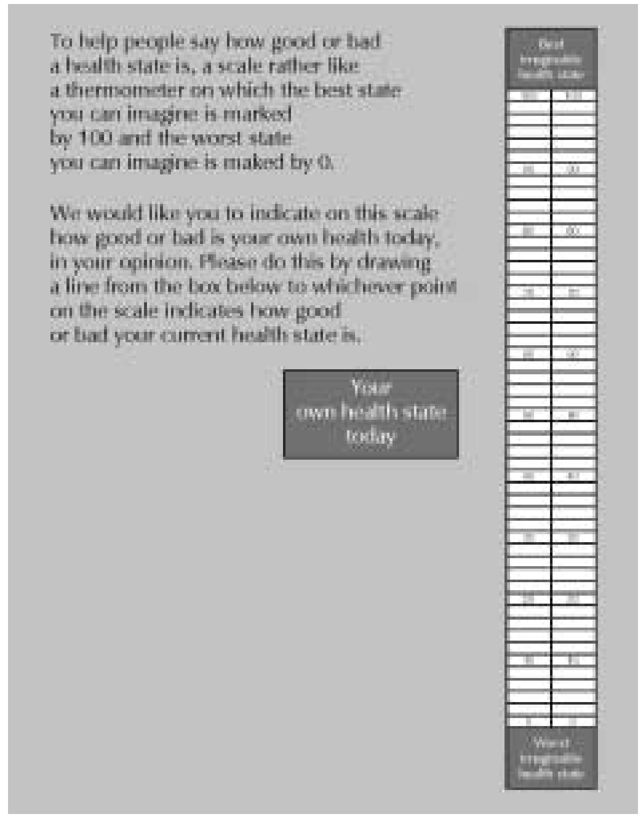

Figure 3. EuroQol thermometer.

Table 3. Cost per QALYs of health interventions. Quality Adjusted Life-Years (QALYs) of competing therapies: some tentative estimates.

	Cost/QALYs (August 1990)
Cholesterol testing and diet therapy only (all adults, aged 40–69)	220
Neurosurgical intervention for head injury	240
GP advice to stop smoking	270
Neurosurgical intervention for subarachnoid hemorrhage	490
Anti-hypertensive therapy to prevent stroke (ages 45–64)	940
Pacemaker implantation	1,100
Hip replacement	1,140
Valve replacement for aortic stenosis	1,180
Cholesterol testing and treatment	1,480
Coronary artery bypass graft (CABG) (left main vessel disease, severe angina)	2,090
Kidney transplant	4,710
Breast cancer screening	5,780
Heart transplantation	7,840
Cholesterol testing and treatment (incrementally of all adults 25–39 years)	14,150
Home hemodialysis	17,260
CABG (1 vessel disease, moderate angina)	18,830
Continuous ambulatory peritoneal dialysis	19,870
Hospital hemodialysis	21,970
Erythropoietin treatment for anemia in dialysis patients (assuming a 10% reduction in mortality)	54,380
Neurosurgical intervention for malignant intracranial tumors	107,780
Erythropoietin treatment for anemia in dialysis (assuming no increase in survival)	126,290

Sources: Hutton J et al, *PharmacoEconomics* 1996, Nord E et al 1997 states. Each subjects is asked to judge by how many times Hi is better, or worse, than other states of health. In the empirical literature Rosser[43] proposed a health matrix composed horizontally of 5 distress ratings ranging from severe, moderate, mild to no distress and eight vertical disability levels starting from no disability,[1] to unconscious[8] (tabl. 4). The values were obtained from a sample of 70 health professionals (doctors and nurses) patients and healthy volunteers (tabl. 5).

Rosser's approach found multiple applications in general population studies as well as in clinical trials. Williams and Kind[44] repeated the initial work of Rosser using 300 individuals from the general public. Three methods were explored, based respectively on category, magnitude (thermometer), and the time trade-off (TTO) method, to allocate values to different health states. Table 6 presents the results of their exercise.

c. *The time trade-off method (TTO)*. This method is based on utility theory and was developed by Torrance.[45–48] It represents a theoretical and empirical expansion of the above approaches. Applications of the TTO method to elucidate utility values were attempted initially by Torrance and later by Dolan et al.[49,50] In the TTO method the subject is asked to consider health states that are better than death. Hence the worst possible level of health is considered to be death.

The subject is asked to express preference between a certain and an uncertain condition. Three stages are considered.

Table 4. Rosser's matrix.

Disability		Distress
I	No disability	A. No distress
II	Slight social disability	B. Mild
III	Severe social disability and/or slight impairment of performance at work	C. Moderate
		D. Severe
	Able to do all housework except very heavy tasks	
IV	Choice of work or performance at work very severely limited	
	Housewives and old people able to do light housework only but able to go out shopping	
V	Unable to undertake any paid employment	
	Unable to continue any education	
	Old people confined to home except for escorted outing and short walks and unable to do shopping	
	Housewives able only to perform a few simple tasks	
VI	Confined to chair or to wheelchair or able to move around in the house only with support from an assistant	
VII	Confined to bed	
VIII	Unconscious	

Table 5. Rosser's valuation matrix: All 70 respondents.

Disability rating		Distress rating			
		A (none)	B (mild)	C (moderate)	D (severe)
I	(None)	1,000	0,995	0,990	0,967
II	(Slight social)	0,990	0,986	0,973	0,932
III	(Severe social or slight work)	0,980	0,972	0,956	0,912
IV	(Work severely limited)	0,964	0,956	0,942	0,870
V	(Unable to work)	0,946	0,935	0,900	0,700
VI	(Confined to chair)	0,875	0,845	0,680	0,000
VII	(Confined to bed)	0,677	0,564	0,000	–1,486
VIII	(Unconscious)	–1,028	Not applicable		

Source: Kind P, Rosser RM, Williams A. Valuation of quality of life: Some psychometric evidence. In: Jones-Lee MW (ed) *The Value of Life and Safety*, North Holland, 1982

Table 6. Synthesised valuation matrix. Synthesised values (derived by personal judgment) from the medians of individually transformed data elicited by ME, TTO, and CR valuation methods.

Disability states	Distress states			
	A	B	C	D
1	(1.00)	0.89 0.90 0.85	0.89 0.90 0.85	0.67 0.45 (0.35)
		0.90	0.85	0.55
2	0.89 0.90 0.85	0.81 0.70 (0.45)	0.78 (0.60) (0.45)	0.56 0.35 (0.50)
	0.90	0.70	0.60	0.45
3	0.70 (0.55) (0.50)	0.63 0.53 0.44	0.57 (0.55) (0.30)	0.44 0.20 (0.30)
	0.60	0.55	0.50	0.35
4	0.63 (0.70) (0.55)	0.56 (0.45) 0.42	0.51 (0.55) (0.40)	0.40 0.33 0.22
	0.60	0.50	0.45	0.30
5	0.44 0.55 (0.25)	(0.43) 0.45 (0.35)	(0.44) (0.43) (0.26)	0.22 0.20 0.17
	0.50	0.40	0.35	0.20
6	0.44 0.43 (0.41)	(0.44) (0.45) (0.39)	(0.34) (0.45) (0.30)	0.22 0.15 0.14
	0.40	0.35	0.30	0.15
7	(0.38) 0.20 0.20	(0.40) 0.10 (0.16)	0.33 0.03 (0.20)	0.20 (neg).0
	0.30	0.25	0.20	0.10
8	0.01	(neg)		0.00
			30	

Source: Williams A, Kind P, 1992[44]

Firstly, the subject is asked to consider a certain disease, which would leave him/her in a state of Hh level of health for a period of T years without any medical intervention or treatment. This is the case of "no treatment" for T years (fig. 4).

Secondly the subject is asked to take a medical intervention (a treatment) which would be provided at zero cost and would cure him/her perfectly but reducing life expectancy to t years. This is the case of treatment with t years (fig. 4).

Thirdly the subject transforms duration of life with and without treatment into a utility scale (QALYs). In figure 4, the vertical axis presents the subjective utility per period of time taking the values:

U (H*)=1 for the state of perfect health and

U (0)=0 for the state of death

Hence the vertical axis shows the values 0=death to 1=perfect health. Finally, considering the rectangular of 0t*DH* and 0TAB the subject is asked to readjust the life span t until there is indifference between the two states of health (i.e. volume of rectangular 0t*DH*=volume of rectangular 0TAB).

The ratio between treatment and no treatment provides the value of the weight which is attached to health status H_h:

$$\text{Weight}=Wa\ (1,\ H_h)=t^*(T,\ H_h)/T$$

Table 7 presents the results of Torrance's empirical work. He estimated utility values for selected health states. The utility values range from 1.00 representing perfect health to zero representing death. In addition he derived utilities for health states which may be considered worse than death such as quadriplegic, blind, confined to bed with severe pain, and unconscious. These states received negative utility values (<0.00) showing the individual's dis-utility to live in a such a state.

The main conclusion of Torrance's[47] experiments is that the TTO method was found more reliable and more valid

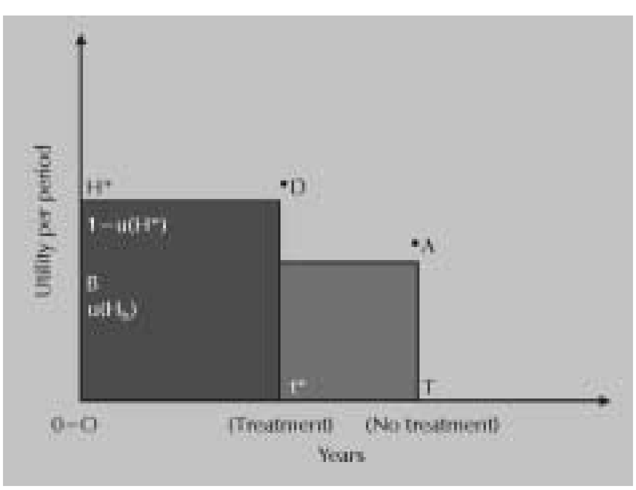

Figure 4. The time trade-off method.

Table 7. Sample utilities for selected health states.

Health state	Utility
Healthy (reference state)	1.00
Life with menopausal symptoms (judgment)	0.99
Side effects of hypertension treatment (judgment)	0.95–0.99
Mild angina (judgment)	0.90
Kidney transplant (TTO, Hamilton, patients with transplants)	0.84
Moderate angina (judgment)	0.70
Some physical and role limitation with occasional pain (TTO)	0.67
Hospital dialysis (TTO, Hamilton, dialysis patients)	0.59
Hospital dialysis (TTO, St. John's, dialysis patients)	0.57
Hospital dialysis (TTO, general public)	0.56
Severe angina (judgment)	0.50
Anxious/depressed and lonely much of the time (TTO)	0.45
Being blind or deaf or dumb (TTO)	0.39
Hospital confinement (TTO)	0.33
Mechanical aids to walk and learning disabled (TTO)	0.31
Dead (reference state)	0.00
Quadriplegic, blind, and depressed (TTO)	<0.00
Confined to bed with severe pain (ratio)	<0.00
Unconscious (ratio)	<0.00

Source: Torrance, 1987:595
TTO=Time Trade-Off

than the category method. It was also found that this method was easier to cope with than the SG technique.

d. *The Standard Gamble (SG) technique*. Finally the SG method was developed by Wolfson[51] and Torrance,[46,47] based on the Von Neumann-Morgenstern classical work on cardinal utility measurement.[52] The SG technique, because of its high theoretical relevance to economic foundation analysis, will be further analysed and discussed in the next section.

4. VON NEUMANN-MORGENSTERN UTILITY

The SG approach is based on the formulation of consumer preferences under uncertainty. According to the concept of the expected utility theory, as developed by Von Neumann and Morgenstern,[52] a utility scale (interval) can be devised which will represent the subjective utility of any individual. In economics, the concept of expected utility was used by several authors[53,54] and in the health economic field it was further developed by Jones-Lee[55,56] and others,[57] who adopted the SG technique for obtaining estimations of individual's attitudes towards the risk. Wolfson[51] and Torrance[46,47] by applying the same technique obtained a utility scale which measures the level of health status of different disease states. The application of the SG technique, to a conventional health planning exercise, implies the following procedures:

a. The respondent (individual, doctor, health administrator) is assumed to maximize the expected utility derived from the choice between alternative levels of health status.

b. The events (e.g. disease states) under consideration are ranked according to the preference ordering of the respondent.

c. The two most extreme events, e.g. event A=death and event Z=perfect health, are clearly distinguished from each other in the list of preference orderings.

d. The events A and Z can be arbitrarily assigned any value by the respondent.

e. The respondent is asked to choose between two alternative outcomes:

1st alternative: This implies choice under risk and the respondent (patient) is asked to take gamble and choose either outcome A (death) or outcome Z (perfect health) with 0.50 probability attached to each outcome (fig. 5).

2nd alternative: This implies the choice, under certainty (sure event) (fig. 5), of any other intermediate event D (sickness, pain etc.) between the two extreme cases.

f. The intermediate events, or the probabilities attached to these events, are rearranged until the individual is indifferent between the first and the second alternatives (fig. 6).

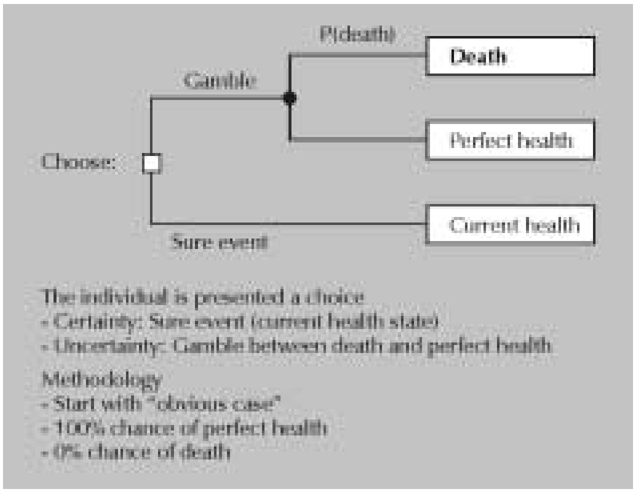

Figure 5. Standard Gamble.

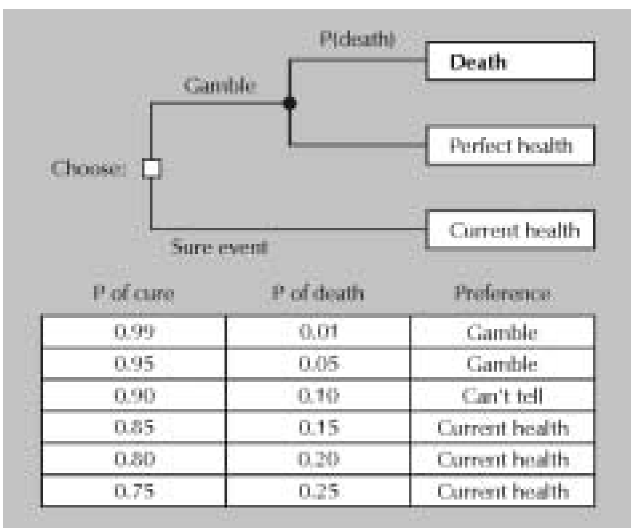

Figure 6. Standard Gamble.

Hence the utility, or the expected utility derived by one intermediate event D (disease state) may be expressed by the following indifference equation:

$$\text{Expected utility } E[U(D)]=P[U(A)]+(1-P)[U(Z)]$$

where U( ) denotes the utility levels of every event.

P represents the probabilities assigned.

g. The events A and Z can be arbitrarily assigned any value, since this is an interval scale, and all the possible utility values of the intermediate events (Di) can be calculated, under the assumption that the respondent is making rational choices and is consistent in his/her preference ordering between the alternative events.

Axioms

Von Neumann and Morgenstern (N-M) established a set of consistent axioms upon which their method is based.[58] They proposed a set of postulates i.e. ordering of basic outcomes, transitivity among choices, continuity of preferences, substitutability, applicability of probability rule, and monotonicity.[59] They suggested five assumptions which suffice to produce valid predictions based on N-M calculations of utility values. The notations *I* are used to express indifference between two states of health or medical interventions and *P* to imply preference of one health state (medical intervention) in comparison to another.

Assumption 1. *Transitivity*: The individual is asked to consider three health states i.e. A, B, and C. Then following the transitivity principle if the individual is indifferent between the state A and B, and indifferent between the states B and C then he/she will be indifferent for the states A and C. This is the usual assumption to construct an indifference-map in the utility space. Mathematically the transitivity assumption is expressed:

If: A*I*B and B*I*C, then A*I*C.

Assumption 2. *Continuity of preferences*: This assumption implies that the individual is rational in establishing a preference ordering in levels of health states as well as in the attached probabilities. Hence for any three health outcomes, E, A and D, if E is preferred to A (E*P*A) and A is preferred to D (A*P*D), there exists a probability P_a which is referring to an intermediate state A that takes values between $0<P_a<1$ and A is indifferent between A*I* [P_a: E, D].

Assumption 3. *Independence*: For any four levels of health A, B, C, and F, if the following conditions hold:

A indifferent to B A*I*B and

C indifferent to F C*I*F

then the individual will be indifferent between the probabilities of

[P: A, C] *I* [P: B, F] for any probability P.

This assumption states that if two medical interventions (in health the gamble may be presented as health lottery tickets) involve equal probabilties of attaining health outcomes which are different but which are valued equally, then the two medical interventions will be equally attractive.

Assumption 4. *Desire for high probability of attaining a successful health outcome:* Given two health lotteries with identical medical outcomes the individual would prefer the lottery with the higher probability. This is expressed below as:

1. For any health outcomes E and D, and
2. Any probability numbers r and r´,
3. If E is preferred to D (E*P*D), then
4. [r: E, D] is preferred to [r´: E, D],
   [r: E, D] *P* [r´: E, D],
5. If and only if r>r´.

This assumption implies that, other things being equal, the individual will always prefer the medical intervention with the greater probability of a favorable health outcome.

Assumption 5. *Compound probabilities*: In order to explain the compound probability assumption a combination of medical interventions is used. Each medical intervention may represent a lottery. If the medical outcome is successful then the patient may undertake the risk to carry out a second more advanced therapy.

For any alternative health states E and D and any probability numbers P, P_a and P_b, then the following condition holds:

$$\{P:[P_a: E, D], [P_b: E, D]\} \; I \; [r: E, D]$$

where r is a probability number given by:

$$r = PP_a + (1-P)P_b$$

The above presentation requires some explanation. In order to investigate the choices of the individual under uncertainty the following cases can be considered:

1. Suppose an individual (patient) who undertakes a health lottery (decision under risk for a medical intervention) wins in the first instance i.e. he/she has a successful first result.
2. Then the individual obtains another health lottery [P_a: E, D].
3. If he/she loses and has an inferior medical outcome, the inferior health lottery is expressed as [P_b: E, D].
4. Overall the individual may maintain the level of his/her health status but with poorer odds about the future.
5. The main question under consideration is what is the probability of eventually coming out of all this with the grand success of a health status E?
6. There is a probability P of winning the better health lottery which offers the level of health E with probability P_a, so the probability of attaining the health status E in this way is PP_a.
7. However, if the individual loses the first medical intervention, a loss which will occur with probability (1–P), there is still the probability P_b of getting e, so that there is a probability $(1-P)P_b$ of obtaining E in this way.
8. The total probability of obtaining E is then $PP_a+(1-P)P_b$, which is named r.

The validity of these postulates is a necessary and sufficient condition for the derivation of the expected utility hypothesis.

Culyer and Wagstaff argued that using the SG method QALYs can be derived based on individuals' perceptions about attitudes to risk. In a selected sample of individuals each respondent may be asked to consider a choice between:

a. A certain level of health status Hi (sure event) and
b. A gamble which may lead to perfect health Hp with probability p or
c. Death Hd with probability (1–p) death with a probability.

The gamble is expressed as:

$$\{[p, H_p];[(1-p), H_d]\}$$

By varying the probability p, a point can be reached where the respondent is indifferent between the two alternative states Hp and Hd (fig. 7).

This relationship can be expressed as:

$$U(H_i) = p^* \cdot U(H_p) + (1-p^*) \cdot U(H_d)$$

Where $U(H_i)$ corresponds to different utilities, $U(H_p)$ expresses the utility of being in perfect health and $U(H_d)$ the utility of being "dead".

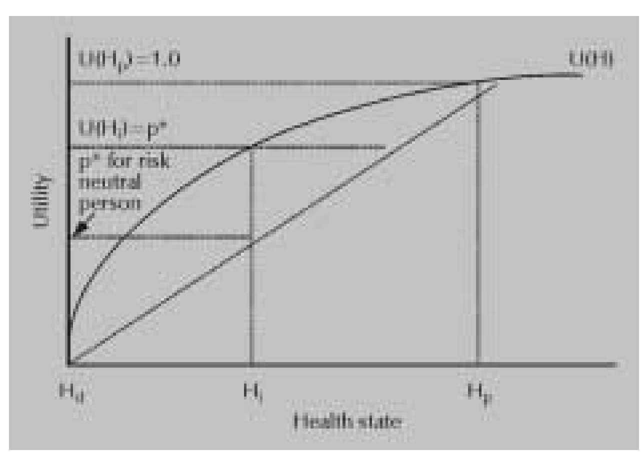

Figure 7. The Standard Gamble approach for risk averter.

By setting the values $U(H_p)=1$ and $U(H_d)=0$ different levels of utility are calculated for all the intermediate levels $U(H_i)$ (fig. 7).

The risk aversion of the individual using the concepts "risk averter", "risk neutral", is presented in figures 7, 8.

The more risk avert the individual, the higher the convexity of the utility function (fig. 7).

If the individual is risk neutral then the utility functions becomes linear with a constant slope (fig. 8).

The strength of the N-M utility functions was proved mathematically and it was shown that once two arbitrary values have been assigned to two health state events, e.g. $U(H_p)=1$ and $U(H_d)=0$, then a whole set of utility values can be derived for any intermediate event. It is required solely that the utility number attached to any event, maintains the same ordering in subsequent experiments.

It has been shown by Alchian,[60] that the utility values of, say U_i^*, must not only be an increasing function of some other utility values, say U_j but also their values should obey a linearly transformed function, i.e.

$$U_i^*=a+bU_j \qquad b>0$$

In such a linear information, the origin a and the scale b, can be chosen arbitrarily provided that $b>0$.

In the empirical health economics literature Wolfson and Torrance, by applying the SG technique, calculated utility values for different disease states. The assigned utility values for different disease states were based on physicians' subjective evaluations. However problems may arise from the doctors evaluates because, although doctors may know their subject best, sometimes they are more risk adverse than their patients (e.g. when advising a patient as to the possible outcomes of a dangerous surgical operation, the physician may be more of a risk averter than the patient).

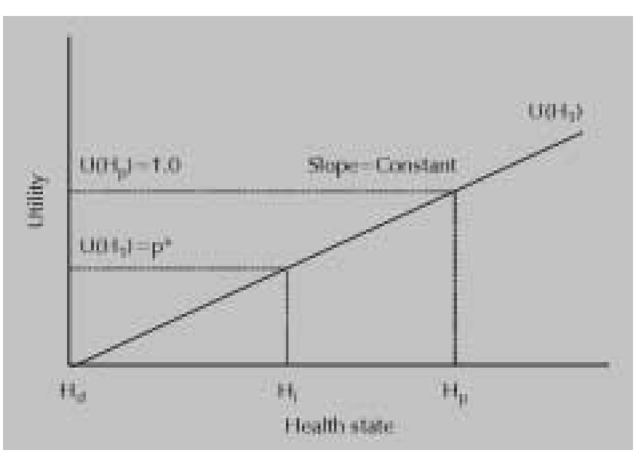

Figure 8. The Standard Gamble for risk neutral.

A further problem with the doctors' evaluation is that they may provide certain answers during the interview different from those they would give if faced with a similar event in their practice, where they would be influenced by other emotional and cultural factors.

Torrance[1] argued in a later paper what the weighting process of a health status index should be based not only on the doctors' opinion, but should also include the evaluation of other members of the community. Torrance used four different samples of people comprising:

a. Highly educated people (43 members)

b. Randomly chosen people from the city of Hamilton (246 members)

c. Patients in a local home dialysis program (29 members)

d. A subset of 39 educated people who had been considered in sample (a).

In order to facilitate the SG technique, Torrance used various devices such as coloured cards and an adjustable probability wheel along with other methods, for helping the respondent to visualise the alternative events in each experiment. The feasibility reliability of the obtained utility values from each sample of people were compared and evaluated by using different statistical techniques, e.g. coefficient of reliability (product-moment correlation coefficient).

By using the SG technique a social preference index for different levels of health status may be devised. Hence certain health indices for different individuals, living in different geographic areas, may devised and compared with each other. These indices can be used for some cost-effect, cost-benefit, or PPBS exercises. Furthermore this analysis can be applied for allocating health resources across regions. Since resource allocation among the 17 health regions is a prime objective of the Greek Government it is worth analysing this concept further.

5. REGIONAL ALLOCATION

The Greek Government enacted in 2001 a legislative act on the establishment of health regions, according to which Greece is divided into 17 health regions. The concept of productive efficiency becomes a core objective for health policy development. This implies the measurement of health status and the investigation of productivity of health resources. Production theory provides a good theoretical framework for investigating productivity and resource allocation issues. The following function may be considered as a health production function.

HS_A=(Doctors, Nurses, Hospital beds, Technology)

Where HS_A=Health status of region

The theoretical foundations of such a relationship and the mathematical form will not be considered here.[61] It is assumed that health status could be measured as a index based on TTO or on a SG technique proposed by the above framework. Inputs are measure in physical units such as doctors per 1,000 population, nurses per 1,000 population and beds per 1,000 population. Technical efficiency can be assessed using the production theory (fig. 9). The health production function portrays the relationship between health status and health resources.[62] The slope of the function, at any level of resource utilisation, is expressed by the partial derivative dHi/dHR which defines the marginal product.

A problem inherent in the SG technique is that it provides an interval, not a ratio scale. It cannot show, for instance, that the level of health status in region A is twice that of the level of health status in region B. However despite this limitation, the SG technique, by providing an interval scale, does enable comparisons based on marginal changes, e.g. the improvements in health status in area A are twice those of area B. By analysing the rate of change (i.e. marginal increases) in health status in area A and determining the impact of region A's health resources (e.g. medical personnel, nurse, beds etc.), upon such a change, these marginal

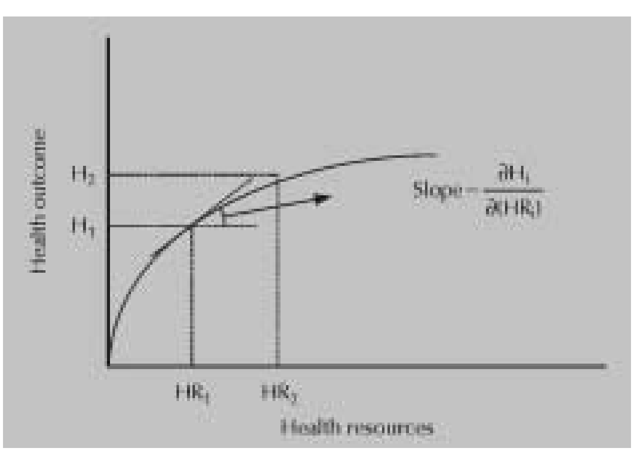

Figure 9. Health production function.

changes in region A can be compared with some other corresponding changes in other regions.

It can be shown mathematically that, by using different scales of health status indices transformed up to a linear functional relationship, some interregional comparisons can be established and extent of changes in the level of health indices, attributable to changes in health resources can be studied. In order to establish these comparisons an invariant indicator is needed, which implies the device of a mathematical formula (algorithm), independent of the values of measurement of inputs and outputs.

In the next subsection it will be shown that only the ratio of marginal productivities for different inputs and the ratio of partial elasticities provide such an invariant measure for interregional comparisons.

5.1. Applications based on invariant measures

The purpose of this sub-section is to show mathematically that the ratio of marginal products between two factors of production, and the ratio of elasticities provide an invariant measure, i.e. the indicators (algorithms) obtained from these ratios are independent of the units of measurement of the outputs and inputs. The mathematical proof is important for analysis because in the subsequent sections the theory of production function will be applied to some specific kinds of production specifications, where the output will be measured on an interval scale and all the inputs will be measured on a ratio scale. Hence, if no attempt is made to devise a meaningful invariant measure for studying regional productivities, then the actual production parameters e.g. average-marginal products, returns to scale, the efficiency parameter, input elasticities and elasticity of substitution, will be meaningless.

In order to devise invariant measures for production theory following methodology will be considered:

Suppose the existence of two health status indicators, G and H. Gi is measured in certain arbitary units and H_i is measured in different levels of abstract units. It is assumed that the vector of Gi health status units can be expressed as a linear transformation function of Hi units.

This implies:

$$(1)\ G_i=g+hH_i \qquad \forall I=1 \dots\dots\dots e$$

where g and h denote certain parameters.

It will now be shown that, by using either/or as a health status indicator, the results obtained from the ratio of marginal products of these indicators are independent of the units of measurement. Moreover, it will be shown that the ratio of output elasticities (which in a Cobb-Douglas function shows the factor intensity) is also invariant, i.e. that the ratio of output elasticities are independent of the units of measurement and of health status indicators.

In order to prove the above proposition two production functions will be considered, for the purpose of simplicity, two Cobb-Douglas functions, since this is the most widely used mathematical form in empirical research:

$$(2)\ H_i = A_i B_i^b N_i^n \qquad \forall i = 1.........e$$

$$(3)\ G_i = A_i B_i^b N_i^n \qquad \forall i = 1.........e$$

By substituting (1) into (3), function (3) can be transformed into (4) as follows:

$$(4) \qquad g + hH_1 = A_i B_i^b N_i^n \Rightarrow Hi = \frac{Ai}{h} B_i^b N_i^n - g$$

where A, b, e denote the parameters to be estimated.

B and N denote two types of inputs used in the i^{th} region.

First proposition. The ratio of marginal products is independent of the values of measurement of Hi and Gi.

Proof

(1) Consider equation (2)

$$\left.\begin{aligned} (5)\ MP_B &= \frac{\partial H}{\partial B} = b * A * B^{b-1} * N^n \\ (6)\ MP_N &= \frac{\partial H}{\partial N} = n * A * B^b * N^{n-1} \end{aligned}\right\} \Rightarrow \left\{\frac{MP_B}{MP_N} = \frac{b * B^{-1}}{n * N^{-1}}\right\} (7)$$

(ii) Consider equation (4)

$$\left.\begin{aligned} (8)\ MP_B &= \frac{H}{B} = b * \frac{A}{g} * B^{b-1} * N^n \\ (9)\ MP_N &= \frac{H}{N} = n * \frac{A}{g} * B^b * N^{n-1} \end{aligned}\right\} \Rightarrow \left\{\frac{MP_B}{MP_N} = \frac{b * B^{-1}}{n * N^{-1}}\right\} (10)$$

By comparing (7) and (10) it can be seen that under both cases exactly the same results are obtained. Hence the ratio of marginal products is a measure independent of the units of output.

Second proposition. The ratio of output elasticities (factor intensity) is an invariant measure (i.e. a measure independent of the values of units Hi and Gi health status).

Proof. Again the two production functions (2) and (4) are considered, first the output elasticities of function (2).

$$\left.\begin{aligned} (11) \quad e_B &= \frac{MP_B}{AP_B} = \frac{(\partial H/\partial B)}{(H/B)} = b \\ (12) \quad e_N &= \frac{MP_N}{AP_N} = \frac{(\partial H/\partial N}{(H/N)} = n \end{aligned}\right\} \Rightarrow \left\{\frac{e_B}{e_N} = \frac{b}{n}\right\}$$

Consider now the elasticities of function (3)

$$\left.\begin{aligned} (13) \quad e_B &= \frac{MP_B}{AP_B} = \frac{(\partial H/\partial B)}{(H/B)} = \frac{b * (A/h) * B^{b-1} * N^n}{(A/h) * B^{b-1} * N^n - (g/B)} \\ (14) \quad e_N &= \frac{MP_N}{AP_N} = \frac{(\partial H/\partial N)}{(H/N)} = \frac{n * (A/h) * B^b * N^{n-1}}{(A/h) * B^{b-1} * N^{n-1} - (g/N)} \end{aligned}\right\} \Rightarrow$$

$$\frac{e_B}{e_N} = \frac{\left[b * (A/h) * B^{b-1} * N^n\right] * \left[(A/h) * B^b * N^{n-1} - (g/N)\right]}{\left[n * (A/h) * B^b * N^{n-1}\right] * \left[(A/h) * B^{b-1} * N^n - (g/B)\right]} \Rightarrow$$

$$(15) \quad \frac{e_B}{e_N} = \frac{bB^{-1} * \left[(A/h) * B^b * N^{n-1} - (g/N)\right]}{nN^{-1} * \left[(A/h) * B^{b-1} * N^n - (g/B)\right]} \Rightarrow$$

In (15) (N^{-1}) is extracted from the nominator and (B^{-1}) for the denominator.

Hence

$$(16) \qquad \frac{e_B}{e_N} = \frac{bB^{-1}N^{-1} * \left[(A/h) * B^b * N^n - g\right]}{nB^{-1}N^{-1} * \left[(A/h) * B^b * N^n - g\right]}$$

After some transformations the desired ratio is obtained from (16).

$$(17) \qquad \left\{\frac{e_B}{e_N} = \frac{b}{n}\right\}$$

By comparing (13) and (17) it can be clearly seen that under both cases the same results are obtained. Hence the ratio of output elasticities is a measure independent of the units of output (invariant).

Concluding this section it can be stated that having proved the validity of propositions (1) and (2), the ratio of marginal products, as well as the ratio of output elasticities can be used quite justifiably for interregional comparisons.

6. QALYs AND RESOURCE ALLOCATION

Following the above analysis on regional productivity we may device a theoretical framework for resource allocation using QALYs into a social welfare function. Suppose we can aggregate QALYs and we can have an estimate of QALYs for each region.

Following Wagstaff[64] we assume the existence of an iso-elastic social welfare function taking the mathematical form:

$$W = \left[\left(aQAR_{a}\right)^{1-t} + \left(bQAR_{b}\right)^{1-t}\right]^{\frac{1}{1-t}}$$

Wher W=The total level of welfare
a=The weight attached to region A
b=The weight attached to region B
QAR=QALYs for region A and B
T=risk aversion parametre

Using figure 10, we obtain the conditions for an optimal resource allocation among the regions using QALYs as criterion.

We start our analysis from point M where the initial endowment in terms of QALYs is defined in point M where:

QALYs region A=QALYs region B

However point M is inefficient because with a better utilisation of resources other points like R, N of Q in the health frontier could be attained. The shape of the health frontier is determined by:

a. The sum of availabe health resources to provide medical treatment

b. The sum of health expenditure

c. The ability of region A and B to maximize health.

The health frontier is concave showing a diminishing marginal productivity of resources. Given the cost constraint, as it is defined by the tangent line with a slope of –1.0, the most cost effective combination of resources could be identified, point R. Perfect equality is achieved at the point Q (diagonal 45 degree line), where the total amount of QALYs of region B are equal to the QALYs of region A. However society may choose between efficiency and equity and finally accept the point N, where the social indifferent curve is tangent to frontier possibility curve.

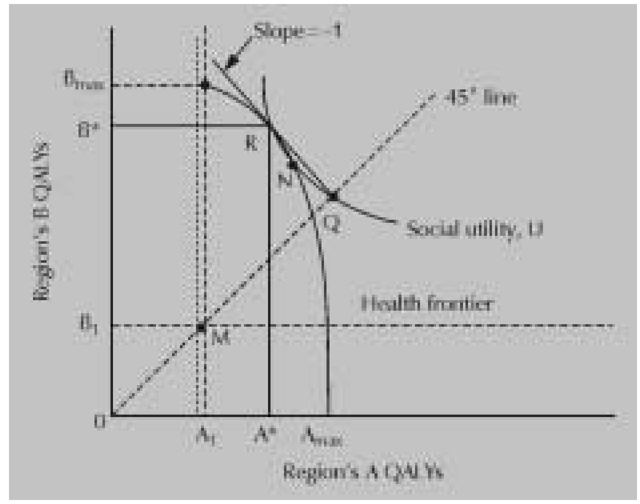

Figure 10. Evaluation of health alternatives using QALYs.

The results derived in this section are particularly useful for the assessment of interregional comparisons of health status as well as for the evaluation of overall technical and economic efficiency in the health sector.

7. CONCLUSIONS

The main aim of this paper has been to provide an overview of health status measurement as discussed in the health economics literature. The various approaches used for constructing health status indices were examined and reference was made to the epidemiological, sociological and economic methods. The concept of quality of life and QALYs was discussed, and the methodology of the SG technique was described. A theoretical framework for establishing interregional comparisons when health is measured in interval and in ratio terms. It was seen that the ratio of marginal products and the ratio of output elasticities can provide invariant measures for establishing interregional comparisons. The construction of health indices are of fundamental importance for establishing priorities in the health sector and for assessing the objectives of efficiency and effectiveness.

ΠΕΡΙΛΗΨΗ

Η ποιότητα ζωής και τα ποιοτικώς σταθμισμένα έτη επιβίωσης ως παράμετροι μέτρησης της υγείας

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Η μέτρηση της κατάστασης υγείας του πληθυσμού αποτέλεσε ένα ενδιαφέρον θέμα έρευνας των επιδημιολόγων, δημογράφων, στατιστικών, ψυχολόγων και οικονομολόγων. Στην επιστημονική έρευνα χρησιμοποιήθηκαν διαφορετικές προσεγγίσεις, που απέβλεπαν στον εννοιολογικό προσδιορισμό της κατάστασης υγείας και στην περαιτέρω ανάλυση της ποιότητας ζωής. Η υγεία είναι ένα πολυδιάστατο φαινόμενο, που συμπεριλαμβάνει όχι μόνο τις ιατρικές και κλινικές διαστάσεις, αλλά κυρίως άλλες πτυχές που συνδέονται με τη φυσική κατάσταση του ατόμου, την ψυχολογική του διάθεση και την κοινωνική του ένταξη και συμμετοχή. Η έρευνα αυτή σχολιάζει τις διαφορετικές προσεγγίσεις που αναπτύχθηκαν στη βιβλιογραφία για τη μέτρηση της ποιότητας ζωής, κάνοντας ειδική αναφορά τόσο στις γενικές μελέτες που βασίζονται σε φυσιολογικό πληθυσμό, όσο και σε ειδικές έρευνες που αποσκοπούν στην αξιολόγηση των σταδίων εξέλιξης μιας νόσου, καθώς και στη διερεύνηση της συμβολής μιας ή άλλων εναλλακτικών θεραπειών ή ιατρικών παρεμβάσεων στη βελτίωση της υγείας ενός ατόμου ή ενός πληθυσμού. Η έννοια των σταθμισμένων ποιοτικά χρόνων επιβίωσης (QALYs) έχει διεγείρει το ενδιαφέρον των ιατρών και των οικονομολόγων κατά τη διάρκεια της τελευταίας εικοσαετίας, γιατί συνδυάζει την «ποσότητα» μακροβιότητα, μετρούμενη με το προσδόκιμο επιβίωσης, με την έννοια της «ποιότητας», σταθμισμένη σε ποιοτικά χρόνια επιβίωσης. Παρουσιάζονται οι διαφορετικές μέθοδοι που έχουν χρησιμοποιηθεί στη βιβλιογραφία, όπως η μέθοδος κατηγοριοποίησης, η μέθοδος αποτίμησης μεγεθών, καθώς και οι περισσότερο θεωρητικά τεκμηριωμένες μέθοδοι, που βασίζονται στη θεωρία της ωφελιμότητας και στη διαχρονική επιλεκτικότητα. Η μέθοδος της ωφελιμότητας αναλύεται περαιτέρω και οι ψυχομετρικές υποθέσεις για την τεκμηρίωση της ωφελιμότητας συζητούνται. Τέλος, επειδή η Ελλάδα βρίσκεται στο στάδιο σχεδιασμού και υλοποίησης μιας περιφερειακής πολιτικής στον τομέα της υγείας, προτείνεται μια μέθοδος βασισμένη στην ωφελιμότητα, για την ιεράρχηση των στόχων πολιτικής και την αποτελεσματική κατανομή των πόρων υγείας.

Λέξεις ευρετηρίου: Μέθοδος παιγνίων, Μέτρηση υγείας, Παραγωγή υγείας, Ποιότητα ζωής, Σταθμισμένα ποιοτικά έτη επιβίωσης

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