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On the estimation of QALD (Quality Adjusted Life Days) based on expenditure data for Childbirth and Maternity services in India using utility theory

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Abstract

Objectives: Quality-Adjusted-Life Years (QALY)helps to measure health outcome for a particular health state. This study redefines QALY by working on the expenditure function incurred in deliveries for private and public hospitals.
Methods/ Statistical Analysis: Data has been taken from the NSS 71st round 'Health in India' (January – June 2014). Utility functions have been estimated by fitting the polynomial of different degrees and then marginal rate is computed. This utility function is estimated using multiplicative and logarithmic form. Also, utility functions are constructed from the method given by Afriat (1964). Further, QALD's are computed for different quintiles based on usual monthly per capita expenditure.
Findings: Through this data we examine the health outcome which is found to be approximately same when obtained from both the methods. Also, QALD's are not significantly affected even if individuals spend out of pocket in case of private hospitals for childbirth and maternity cases. Thus maximum utility is derived in case of treatment for a pregnant woman. The different functional forms of utilities are formed based on assumption of patient's behavior. The duration of stay in both the hospitals gives the value of quality adjusted life days instead of expressing the result in the form of QALY. Under different quintile class lower the economic quintile class higher the proportion of institutional childbirth that took place in public as compared to private hospitals. This study also gives us an overview about how well our facilities for childbirth and maternity services are prevalent in both the type of hospitals and how far is the patient able to access it.
Application/ Improvement: This unit of health outcome will help the health economists in the allocation of health care resources. New methods for estimation of functional forms of utilities can also be applied.
***Keywords*:** QALD, Expenditure, Utility, Estimation, Childbirth, Maternity.

1. Introduction

An economic evaluation of a health care program can be done in different ways. It can be descriptive in nature based on burden of disease or cost of illness. This kind of evaluation is a systematic tool which evaluates the benefits derived from a health care technology against the cost incurred in its usage. In our case, it is a healthcare utilization study which has different perspectives as well as insights. For an individual or groups of individuals, earlier health was measured on the basis of presence or absence of a disease concern. It was done by using the epidemiological indicators supported by biomedical and clinical results. In the present scenario, measurement of health is described in a different way. It has moved to the amount of life lived and how far is the satisfaction level achieved. This has further led to the introduction of psychological social models which emphasis on the concept of "Quality of Life".

Health outcome is defined as changes in health that result from a treatment measure or specific health care interventions. QALY is a metric used by health economists to evaluate new and innovative healthcare treatment for any particular disease. It is an important measurement of health outcome which gives the quality adjusted life years for an individual or groups of individuals. There is now shift in the paradigm of conventional epidemiological models to psycho-social models based on the theories of psychology, sociology, economics and statistics. QALY is also defined as an index which integrates the biomedical as well as psycho-social models.

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The health economists have introduced the quality of life which can be quantified by using the concept of utility [1-2]. Various authors have combined the effects of health care interventions on mortality as well as morbidity. Their definition of QALY goes around a single index termed as common currency enabling comparison across different disease areas. According to them, QALY is a summary measure which incorporates the impact on quantity as well as quality of life. However there lies a big concern on saving lives of patient's under treatment. Few authors have redefined this concern as, "Where should we spend whose money, to undertake what programs, to save whose lives and with what probability?" This question in turn implies on how many lives are saved along with the justification of the resources expanded [3-4]. Their definition defines health as a value weighted over a time period. This value is further measured in terms of preference, which is observed uniformly across all the individuals. Thus this measure is also aggregated over them. There has been lot of discussions on "QALY is a QALY". Some authors define it in terms of maximizing the efficiency of health care interventions on the basis of available resources. The past literature deals with the weightage of QALY by stating equity and efficiency. From efficiency point of view it refers to those individuals whose distribution is higher in terms of production considering the age group where high weights are assigned to young people who are disabled yet they are more productive than the new born or older [5]. Recent research has stated QALY as a leading metric to perform cost effective analysis. It allows for standardized measurement of health outcomes which compare across different disease and population subtypes [6].

To study the effect of a treatment on a particular state, there are different measures of health outcome. The main impact should be observed on the patient's length of life and health related quality of life. Thus, a good health outcome should capture both the impacts carefully. QALY's are defined and computed using different methods such as standard gamble, time trade off, person's trade off, visual method and multi-attributable scale. Apart from these techniques, in this paper we have estimated QALY by fitting the polynomials of different degrees and constructing the utility function from the expenditure data. In all the previous study different approaches have been used to estimate QALY but none of the studies have used polynomial fitting approach for the estimation of QALD. In this paper we have proposed a novel technique for estimating QALY by fitting polynomial of different degrees and constructing the utility function from expenditure data. In the present study QALD has been estimated by multiplying QALY with a factor of 24 hours or 1440 minutes. These QALD's can also be interpreted as QALM (quality adjusted life minutes).

2. Health Utilities

The utilitarian philosophers describe utility as a measure for increasing or decreasing the value for happiness. People desire for things or goods which in turn leads to maximization of positive utility (pleasure) or negative utility (pain). QALY's are defined as the summation of utility adjusted values over various time intervals. There is a controversy in defining the measurability of utility. Some authors define it as a measure of satisfaction which is subjective in nature. On the other hand it is also defined as an indicator of preferences which is objective in nature. There lies an underlying assumption for QALY to be of additive separability. It states that the utility of a given health state is unaffected by the other health state which precedes or follow it.QALY as a cornerstone of economic analysis which combines morbidity gains and mortality impact of a treatment. The usage of utilities in the formulation of QALY helps in decision making for healthcare when resources are scarce or limited. Edge worth proposed that utility of a bundle of goods $x_1, \ldots\ldots, x_n$ is conceptualized as a multidimensional construct: $U = U(x_1, \ldots\ldots, x_n)$ [7].

Here each item represents one dimension and bundle of goods have the same multi-attribute utility value which is linked by an indifference curve. Utilities are also defined as preference weights measured on a cardinal scale. In cardinal utility we apply the law of diminishing marginal utility. This concept was given in such a way which states that as consumption increases so the marginal utility derived from each additional unit decreases. This helps us to indicate a point at which utility is maximized. The concept of utility is derived from consumer choice theory. Few economists describe how consumers decide what to do on the basis of two important factors, namely budget constraints and preference value. If a preference value for a health state is higher than the utility value attached with a particular health state will also be higher. These utility values are defined on a scale from 0 to 1. They also suggested that the expected number of QALYs which a person enjoys over a lifetime is to be taken into consideration. He argues that each individual who is entitled to an amount of QALY which can be regarded as an ethical entitlement [8-9].

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According to them, utility have been categorized as experienced utility and decision utility. They have also stated different implications of utility values for evaluation of health states [10]. In [11] QALY has been derived based on generalizations of expected utility theory which is rank dependent. According to them, aggregation is done on the number of QALY's gained corresponding to the QALY maximization rule. In [12-13] proposal of equity weighted QALYs where relative changes in QALY receive the same weight for all individuals controlling for age and sex. Some authors place a concern for severity and weightage of age in an analytical framework. They distinguish between the gains in QALY as a result of past healthcare gain and otherwise gain [14].

QALY maximization model provides large benefits to few individuals and small benefits to many individuals. He has stated the preferences of individuals of one over other [15]. According to him, these preferences will be affected by positive time preference, threshold values, risk aversion and equity preference. He holds the opinion that time preference and equity preference guides the respondents in the direction of achieving more benefits. On the other hand if a gain in health is below a threshold value then an individual is risk averse. The plausibility of QALY has been stated as a choice for an individual to prefer a shorter healthier life than to survive a longer period of time in a state of discomfort and disability. He also defines QALY as agent wherein younger people have more life expectancy to gain from a treatment than the older people [16].

3. Methodology

New forms of analysis are done in the healthcare segment with an aim to improve the efficiency for allocation of resources. Data has been taken from the "Key indicators of Social Consumption in India: Health". The survey is conducted by National Sample Survey (NSS) organization, Ministry of Statistics and Program Implementation, Government of India, New Delhi. In NSS 71st round detailed information was collected on childbirth with emphasis on institutional birth of a child. The survey period was from January 2014 till June 2014. The objective of the survey was to generate basic quantitative information about health sector all over the nation. Data on expenditure incurred for hospitalizations of maternity and childbirth was collected. It includes 65932 households divided into 36480 rural households and 29452 urban households spread all over India. The result was based on pregnant women of age group 15-49 with a number of 8157 women in urban. On an average there was a stay of 4 days in public hospital and 5 days stay in private hospital. The expenditure is based on the childbirth and maternity services before and after childbirth. On an average of Rs 11685 was spent on institutional childbirth in urban areas. Thus an average amount of expenditure done on an in-patient as private hospital was higher than that of public hospitals. However it is observed that this average expenditure increased as one moves from lower to higher quintile class.

During their stay in hospital, 93% of the pregnant women availed the pre natal services and 84% of the pregnant women availed the post natal services during the reference period. The total expenditure during the last 365 days for medical treatment was categorized under different parameters:

Package Component: This component comprise of packages of treatment involving specific surgical or non-surgical medical procedures such as Operation theatres (OT) charges, OT consumables, medicines, doctor's fees, bed charges etc. When treatment cost is available in the form of package with predetermined total cost then information for different constituents of the treatment is not separately available.

Doctor/Surgeon Fee: This is the total amount paid for doctor's or surgeon's fee. This fee is chargeable for the treatment imparted to the patient within the reference period for stay in the hospital.

Medicine: It accounts for the charge of medicine used during the treatment (including drips)

Diagnostic Test: This charges the fees of diagnostic test done for the patients within the reference period.

Bed Charges: It refers to the amount paid for bed charges during the stay in the hospital

Other medical expenses include attendant charges, physiotherapy, personal medical applicants (eg: nebulizer, pace maker, hearing aid etc.)

Out of all the pregnancies during the reference period, 94% ended with a live birth while other cases were reported as either abortion or still birth in urban areas. Thus the estimate of total expenditure for hospitalized treatment was taken as the sum of medical expenditure and other expenditures. Substantial increment is noticed in the expenditure when one starts from the fourth quintile to fifth quintile for childbirth taking place in private hospitals. The quintiles have been defined on the basis of usual monthly capita consumption expenditure (UMPCE). Table 1 & 2 presents average medical expenditure for childbirth in public and private hospitals.

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Table 1. Average medical expenditure for childbirth in public hospitals

Quintile	Package component	Doctor/surgeon fee		Diagnostic Tests
1	158	96		203
2	176	103		312
3	276	253		342
4	980	193		381
5	1271	202		477
Bed Charge	Medicines	Other	Total	Pregnant women (%)
28	758	242	1485	54
76	1063	232	1962	48
82	1080	356	2389	42
110	1187	354	3205	32
119	1108	266	3443	19

Source: NSS 71stround, India

Table 2. Average medical expenditure for childbirth in private hospitals

Quintile	Package component	Doctor/surgeon fee		Diagnostic Tests
1	68	160		25
2	45	222		10
3	123	243		40
4	163	286		35
5	138	312		71
Bed Charge	Medicine	Other	Total	Pregnant women (%)
156	696	848	1953	32
161	687	1010	2135	41
191	816	1030	2443	47
265	929	1236	2914	60
282	768	1335	2906	77

Source: NSS 71stround, India

1. Method I

Firstly QALD has been estimated by fitting the polynomial of degree 2, 3, 4 using R software. R^2Valuesfor polynomials of degree 2, 3 and 4 for public and private hospitals are presented in Table 3.

Table 3. R^2Values at different degrees of polynomials for public and private hospitals

Degree	R^2_{public}	$R^2_{private}$
2	0.9794	0.9973
3	0.9896	1
4	1	1

From Table 3 and 4 we can infer that the polynomial of degree 2 gives 97.94% of the total variation in expenditure for public hospitals and 99.73% of the total variation in expenditure for private hospitals is explained by the number of pregnant women who lie in respective quintiles based on UMPCE. Similarly polynomial of degree 3 gives 98.96% of the total variation in expenditure for public hospitals and 100% of the total variation in expenditure for private hospitals is explained by the number of pregnant women who lie in respective quintiles based on UMPCE. Thus we can conclude that a polynomial of degree 4 gives the best fitted value for R^2 in the case of expenditure done from a public hospital and polynomial of degree 3 gives the best fitted value for R^2 in the case of expenditure done from private hospitals for childbirth and maternity services. After applying the code for fitting the polynomial in R we define f(x) as the expenditure function for public hospitals and f(y) denotes the expenditure function for private hospitals.

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Table 4. Functional form of utility derived from the expenditure data

Hospital	Function
PUBLIC	$-887 + 4286x - 2514.42x^2 + 659x^3 - 58.58x^4$
PRIVATE	$10929.4 + 2571.8y - 720.85y^2 + 207.33y^3$

Then the utility function for expenditure is estimated by using the following functional forms:
When the joint expenditure is of multiplicative form:

$$f(x, y) = f(x) * f(y)$$

For computing the marginal utilities we differentiate the above equation:

$$\acute{f}(x, y) = \acute{f}(x)f(y) + f(x)\acute{f}(y)$$

On substituting the average values of expenditure for public and private hospital as x=302, y=2616 we get very high utility value of the order 10^{21} so we considered the next functional form i.e.
When the joint expenditure function is of logarithmic form:

$$f(x, y) = \log(f(x)f(y))$$

For computing the marginal utilities we differentiate the above equation:

$$\acute{f(x, y)} = \frac{f\acute{(x)}}{f(x)} + \frac{f\acute{(y)}}{f(y)}$$

So the marginal utility =*0.002484196*

Note: If we consider the functional form to be of inverse or exponential type then we get very absurd values for utilities. So we consider the logarithmic value of utility for the computation of QALY's. Both the expenditure functions are independent of each other, so the joint distribution of expenditure can be defined in different forms. On using health utility index we are forming an indirect utility function. It is the arithmetic product of life expectancy with quality of remaining life years.Then the estimated values of QALY's for different quintiles based on duration of stay in hospitals are presented in Tables 5 and 6.

Table 5. QALY's for public hospitals

Quintiles	Stay	QALY
01	3.9	0.009688
02	4.3	0.010682
03	4.1	0.010185
04	5	0.012421
05	4.4	0.010930

Average $QALY_{Public} = \sum_{i=1}^{5} Q_i/5$
$= 0.01078$per days
Average $QALY_{Public}$ = 0.25875 per hour
Average $QALY_{Public}$ = 15.524 per minute

Table 6. QALY's for private hospitals

Quintiles	Stay	QALY
01	4.5	0.011178
02	4.7	0.011675
03	4.5	0.011178
04	4.6	0.011427
05	5.3	0.013166

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Average $QALY_{Private} = \sum_{i=1}^{5} Q_i/5$
$= 0.01172$per days
Average $QALY_{Private}$ = 0.2813 per hour
Average $QALY_{Private}$ = 16.883 per minute

2. Method II

Afriat proposed a method for the construction of utility functions from the expenditure data. In this method utilities of a composition of goods (say(x)) is a sum of utilities for separate goods [17].

$$\phi(x) = \phi(x_1) + \phi(x_2) + \cdots + \phi(x_n)$$

If p is the vector of prices, x is the vector of quantities so expenditure function e can be defined as: $e = p'x$
The classical assumption of economic theory states that, a consumer whose purchase is done in a manner which gives maximum utility on the amount of money spent after purchasing goods.

$$\varphi(x) = \max\{\varphi(y)/p'y \leq e\}$$
$$\varphi(x) = \max\{\varphi(y)/u'y \leq 1\}$$

where$u = \frac{p}{e}$, for any composition x there exists a vector u which satisfies the condition of maximum utility , $u'x \leq 1$. In our study $\vec{p}$ denotes the total average expenditure, $\vec{x}$ denotes the percentage distribution of number of delivery in hospitals. The data has been classified into intervals based on usual monthly per capita expenditure (UMPCE). The expenditure data has been grouped into:
PART A: Public Hospital Expenditure

$$\vec{p} = \begin{pmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \end{pmatrix} = \begin{pmatrix} 1485 \\ 1962 \\ 2389 \\ 3205 \\ 3443 \end{pmatrix}$$

Here $\vec{p}$ denotes the total average medical expenditure in public hospitals, $\vec{x}$denotes the percentage distribution of number of deliveries in public hospitals, $\vec{e}$ denotes the total medical expenditure in public hospitals

$$\vec{x} = \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{pmatrix} = \begin{pmatrix} 54 \\ 48 \\ 42 \\ 32 \\ 19 \end{pmatrix}$$

$$u = \frac{p}{e}$$

$$\vec{e} = \begin{pmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \\ e_5 \end{pmatrix} = \begin{pmatrix} 1609518 \\ 1603095 \\ 1483991 \\ 1130083 \\ 504906 \end{pmatrix}$$

$$\vec{u} = \frac{\vec{p}}{\vec{e}} = \begin{pmatrix} 0.00092 \\ 0.00122 \\ 0.00161 \\ 0.00283 \\ 0.00682 \end{pmatrix}$$

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$$\acute{u}x = (u_1 \quad u_2 \quad . \quad . \quad u_5)\begin{pmatrix} x_1 \\ x_2 \\ . \\ . \\ x_5 \end{pmatrix} = \sum_{i=1}^{5} u_i x_i$$

$$\acute{u}x = 0.396 \approx 0.4$$

Thus the above equation satisfies the condition of maximum utility such that $\acute{u}x \leq 1$. Then the estimated values of QALY's for different quintiles based on duration of stay in hospitals are presented in Table 7 and 8 [18].

Table 7. Average QALY for public hospitals

Quintiles	Stay	QALY
01	3.9	0.003588
02	4.3	0.005246
03	4.1	0.0066
04	5	0.01415
05	4.4	0.03

Average $QALY_{Public} = \sum_{i=1}^{5} Q_i/5$
$= 0.0119$per days
Average $QALY_{Public}$ = 0.2856 per hour
Average $QALY_{Public}$ = 17.136 per minute

3. Private hospital expenditure

Here $\vec{q}$ denotes the total average medical expenditure in private hospitals, $\vec{y}$denotes the percentage distribution of number of deliveries in private hospitals, $\overrightarrow{eq}$and denotes the total medical expenditure in private hospitals. For any composition x there exists a vector v defined as $= \frac{q}{eq}$, such that it satisfies the condition of maximum utility , $v'y \leq 1$

Table 8. QALY for private hospitals

Quintiles	$\vec{q}$	$\vec{y}$	$\overrightarrow{eq}$
1	12985	32	4627846
2	14859	41	7871057
3	17739	47	8747985
4	22963	60	11991810
5	31681	77	14655894
$\vec{v}$	Stay		QALY
0.0028058	4.5		0.01262
0.0018878	4.7		0.00887
0.0020278	4.5		0.009125
0.0019149	4.6		0.008808
0.0021616	5.3		0.0114567

$$\acute{v}y = 0.5438335 \approx 0.5$$

Thus the above equation satisfies the condition of maximum utility such that $\acute{v}y \leq 1$
Average $QALY_{Private} = \sum_{i=1}^{5} Q_i/5$
$= 0.010175$per days
Average $QALY_{Private}$ = 0.2442 per hour
Average $QALY_{Private}$ = 14.6533 per minute

4. Conclusion

When a pregnant woman is admitted in a hospital then number of purchases done for her treatment during delivery should give the maximum utility for the amount of money spent. Though it was earlier difficult to measure this qualitative concept of utility but now economist can easily quantify the satisfaction level of a consumer.

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We have also discussed a functional form for the utilities based on assumption of observed patient's behavior for getting a treatment done from either a private hospital or public hospital. Also the information about the duration of stay in both the hospitals gives the detailed insights. It gives the value of quality adjusted life days instead of expressing the result in the form of QALY's.Harris stated in his paper, "Qualifying the value of life", by defining reasonable quality as well as extended quality of life. He describes QALY as a year of healthy life expectancy which is worth 1 year of perfect health. While a worth of less than one is a year of unhealthy life expectancy. Nord proposed that the usage of utilities based on QALY by means of societal values. These values reflect the changes in health at different states. However in this paper we define QALD's in a completely different fashion. We form a functional form of utility and tried to compute the marginal utilities by differentiation which is performed in method 1. In method 2 we apply the consumer theory of utility given by Afriat. From the respective QALD obtained we can infer how a standard treatment can give better quality of life for pregnant mothers as well as for neo natal. This quality of life is observed for both private as well as public hospitals. The expenditure data gives a true picture of the amount of money spent in private as well as public hospitals. It includes a range of parameters starting from doctor's fee, medicine, bed charges etc. Lower the economic quintile class higher the proportion of institutional childbirth that took place in public hospitals as compared to private hospitals. The Utilizations of private hospitals increases with improvement in economic status. More than half of the childbirths occurred in public hospitals for lowest quintile class (as seen also from expenditure point of view). This proportion gradually decreases and is in the highest quintile class, one-fifth of the childbirth took place in public hospitals.

The focus of this study was to show how well our facilities for childbirth and maternity services are in both the type of hospitals and how far is the patient able to access it. On analyzing the different functional form, the utility value has been obtained from additive, multiplicative, logarithmic form. The utility value comes out to be a decent value from a logarithmic function. We can conclude that expenditure is more in private hospitals than in public hospitals but QALD's obtained from public is slightly higher than QALD's obtained from private hospitals from both the proposed methods. Thus when an out of pocket expenditure is done in the case of private hospitals for different classes of quintiles, serves an equal likely purpose for gain in quality of life when done from public hospitals.

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