Chapter 3

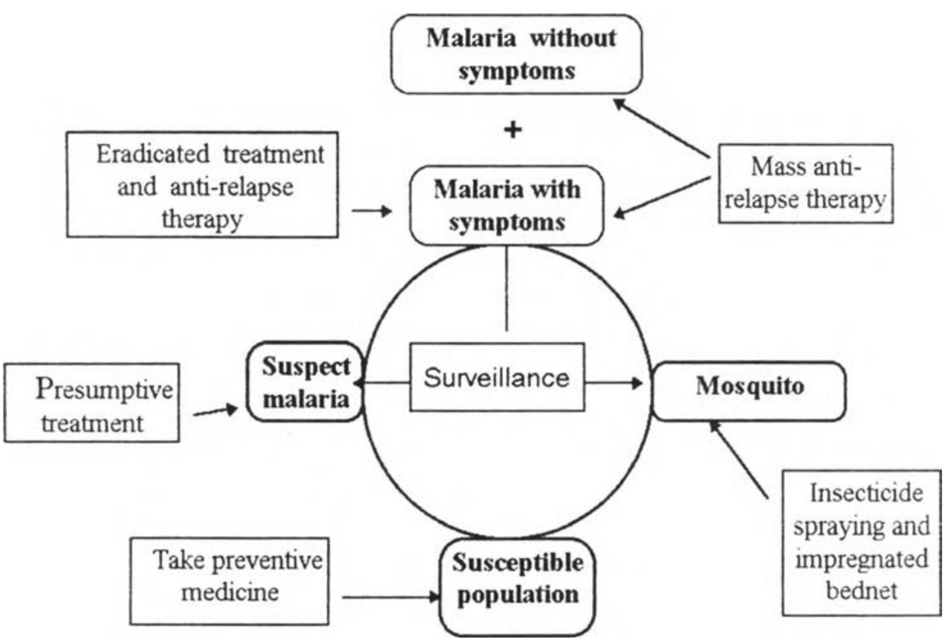
Research methodology

This is an observational time series analysis study. A multivariate model will be built and the marginal concept will be used to analyze allocate efficiency and equity of malaria control activities implemented in different regions.

3.1 Malaria spreading cycle and control activities in Yunnan province

Malaria spreads from infected man -- mosquito -- susceptible man, the cycle is shown in Figure 3.1.

Figure 3.1 Malaria spreading cycle and control activities in Yunnan province



Its spread in Yunnan province varies with the months, the transmission goes down to the lowest level in Winter during November to February and then moves upward to the peak during July to August (Figure 3.2).

Figure 3.2. Malaria incidence rate from Jan 1995 to Dec 1996

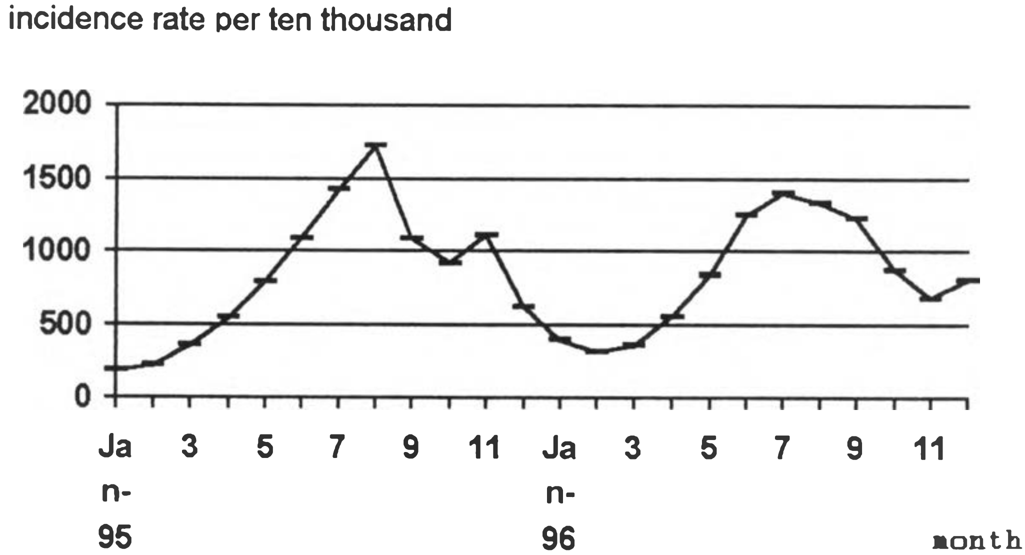


Table 3.1 The profile of malaria in Yunnan province from 1980-1994

Year	Case	Incidence rate (per ten thousand)	proportion of malaria to whole communicable diseases(%)
1980	32244	102.21	2.54
1981	30143	94.25	3.28
1982	27693	85.13	3.24
1983	21403	64.84	2.51
1984	18598	55.31	2.61
1985	19077	56.73	3.57
1986	15802	45.73	3.84
1987	16394	46.26	4.64
1988	15894	45.26	8.04
1989	19108	53.34	10.98
1990	14920	40.35	15.16
1991	17861	48.35	15.05
1992	17602	47.13	19.30
1993	15107	40.14	20.48
1994	16465	43.29	19.25

Until 1994, there was a trend towards decrease of the incidence rate, but the proportion of malaria to whole communicable disease was increasing(Table 3.1); compared with other communicable diseases, malaria is more difficult to control. It is very easy to cause outbreaks and spread to other places.

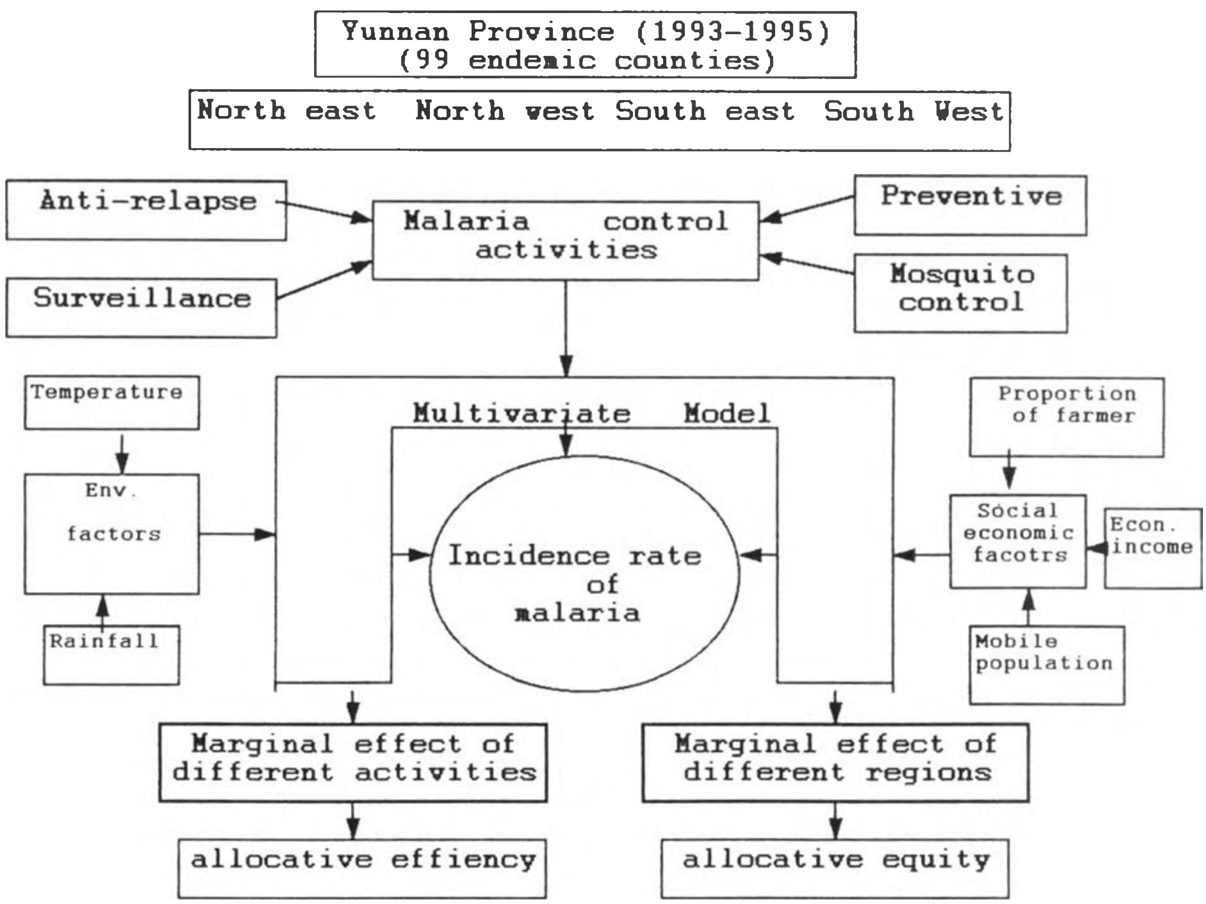
Malaria control activities in Yunnan province can be directed to interfere with links of the chain of transmission: infected man→ mosquito, infected mosquito vector→ susceptible man. Integrated antimalarial activities have been implemented in Yunnan province and deal with both prevention and treatment, as shown in Figure 3.1. The control activities are conducted where the patients appear or ever appeared. These integrated control activities consist of: A. Giving preventive medicine to susceptible population in focal sites; B. Surveillance, including case detection through various mechanisms, and monitoring vector density and resistance to insecticide; C. Treatment of malaria patients with definitive therapy and anti-relapse therapy to people with a P.vivax history in the immediate past one year; D. Mosquito control by insecticide spraying and impregnated bednets.

Malaria endemicity is complex in Yunnan province. It has a vast territory encompassing varied geographical features, economic status and living conditions, which have an impact on malaria prevalence. There are various vectors in the province. *An. minimus*, *An.sinensis*, *An.anthrophagus*, *An. kunmingensis* and *An.jeyporiensis candidiensis* are major vectors. They distribute in different areas. The integrated activities may emphasize some parts according to Victoria species and endemicity in the focal sites. For example, in endemic areas where *An.sinemsis* is the vector, integrated measures with emphasis on elimination of infection source and prevention of mosquito breeding are recommended, in which reduction of mosquito breeding sites in villages is involved; in endemic areas where the major vectors are *An.minimus* and *An.anthrophagus*, the principal measures are focused on the reduction of infection source and protecting susceptible population. The financial resources to support the control activities are from province, prefecture and county governments, each level can adjust their allocation of financial resources. The resources from provincial government lessened year by year.

3.2 Study framework

Epidemiological studies have shown that malaria endemicity is affected by the factors: environment, human behavior and social-economic status. The study will build a multivariate model to show the relationship between malaria incidence rate and these factors in different administrative territories utilizing data from the malaria case reporting system and the statistical yearbook, calculating the marginal effect of malaria control activities in 4 diverse regions based on the model, then analysing of the allocative efficiency and equity. The locations of these regions are shown in Appendix A.

Figure 3.3 Study framework



3.3 Malaria transmission and its determinants

3.3.1 The indicators of malaria transmission

Malaria incidence rate is used in the malaria case reporting system in China to express malaria magnitude. It is defined as:

$$\text{Malaria incidence rate} = \frac{\text{Number of new malaria cases in a year}}{\text{Total population in an endemic area in the year}}$$

The number of new malaria cases are those diagnosed as malaria according to clinical symptoms and reported to the malaria control units. There are several avenues for malaria patients seeking treatment: public health units, private clinics/private doctors and self-treatment, all these cases should be reported, but unfortunately most of cases in the last two categories are not reported, and there is an increasing trend towards missing reports, even though incentive measures, such as subsidy for sending blood slides, have been carried out. So this incidence rate only reflects part of the malaria magnitude in Yunnan province.

3.3.2 Malaria control activities

The integrated malaria control activities are conducted in Yunnan province in accordance with the time and the place, using measures suited to the local conditions. Its aim is to cut spread links, reduce the transmission rate, and eventually eradicate the disease.

<u>Preventive prophylaxis</u>

The aim of giving preventive medicine to a susceptible population is to protect them, reduce the risk of suffering from malaria and transmission. This activity is performed in high transmission areas or endemic focal sites during transmission seasons on a selective basis.

Surveillance

This includes case detection through various mechanisms, monitoring vector density and resistance to insecticide, provision of early diagnosis, early detection for the prevention or containment of epidemics. A large number of malaria cases has been discovered by surveillance operations and treated appropriately, including some of them without any symptoms who are diagnosed by active case detection. It also supplies information for other preventive measures. The annual blood examination rate take as a proxy of surveillance.

Mosquito control measures

In association with the case reporting system residual insecticide of homes spraying and insecticide impregnated bednets are employed in houses. The former is used to control mosquitoes in rooms, kill them and prevent them from transmitting malaria to other people. The later can impede mosquito -- man contact efficaciously.

Treatment

The control activity is focused on malaria patients with symptoms: case detection and treatment. In Yunnan province, most of patients suffer from *P. vivax*, rare *P. falciparum* and other species of malaria. Drug resistance only appears in *P. falciparum* patients. Patients can be cured through standard treatment. On the other hand, it is directed to the transmission source from a prevention point of view, the control program can reduce transmission if treatment is given to patients immediately before malaria spreads to the mosquito. It depends not only on the control activity, but also on patients' behavior of seeking treatment. Treatment can not eradicate malaria in the whole population in a community easily if malaria patients without symptoms exist, and in high endemic areas such carriers do exist. Treatment is the final step in malaria control activities. If the treatment supply is not enough or there is no treatment at all, the patient numbers will increase. The value of treatment depends on the number of patients and whether every patient can seek for treatment automatically. It is assumed that patients can get enough treatment services, this means that we can not reduce the number of patients simply by supplying more treatment. The appearance of new patients means the failure, the unsatisfactory nature of prevention, or that treatment not given in time. In this case, we can not analyse how many cases have been prevented by treatment.

<u>Anti-relapse therapy</u>

Malaria patients are usually treated as outpatients and very often they do not go back to the hospital or clinics for follow-up after they think they are recovered. When the symptoms disappear some of them stop taking medicine, the parasite may still remain in the person In the case of *P. vivax* patients after standardized treatment symptoms or parasite may recur (relapse), the later is not easy to be found but they can also cause transmission. Anti-relapse therapy is used to eradicate these parasites, prevent relapse and also reduce the transmission source. It focuses on people with a *P. vivax* infection history only within one year. The strategy includes individual anti-relapse therapy and mass anti-relapse therapy.

3.3.3 Environmental factors

Malaria transmission varies with the season. The vectors' breeding, development and blood taking activities are affected by environmental factors. Mosquitoes need appropriate temperature, humidity and breeding places. Suitable temperature for growth of mosquito larvae ranges from 11 -- 35^0 C. In this range, when the temperature is lower, a longer time is needed for larval growth. The best temperature for anopheline mosquitoes is about 27^{0}C, Whereas if the temperature is <16^{0}C, the mosquito will not take a blood meal. Appropriate relative humidity for mosquito is >60%, mosquito can survive for a longer time in higher humidity atmosphere but when it is <52%, they stop taking blood meals. Temperature also affects development of parasites in the mosquito, the best temperature for parasites is 20 -- 30^{0}C. Rainfall supplies breeding places and good humidity. But too much rainfall is not good for larval growth. Too low a temperature, and dry air is not good for the vector. In the Winter season malaria transmission ceases or is very low. We use the value of rainfall and average temperature to measure the effect of environmental factors

3.3.4 Economic income

It has been shown that expenditure on malaria prevention varies with household income level(Ettling, 1994). Higher economic status combined with better knowledge of the vector and DDT spraying decreases the risks of infection. Malaria is linked to poverty in a vicious cycle, poorer people tend to suffer more from the diseases, due to poorer sanitation conditions, unhealthy behavior and less prevention, they spend more on malaria treatment in endemic areas. while an increasing economic income will help reduce risk of suffering from malaria. The gross county production per capita is used as a proxy of economic income.

3.3.5 The proportion of farmers

Malaria endemicity is in related to vector distribution. Paddy fields and forests are good places for mosquito vector breeding, and rural areas are closer to mosquito breeding areas. Living in rural areas it is easier to catch malaria compared with urban areas. Agricultural populations therefore represent a high risk group.

3.3.6 Mobile population

In theory, when malaria is eradicated in a community, and no new cases come into the community, the disease has been eradicated in the community. But actually, in practice, some people are mobile from endemic regions to non endemic ones, or from high endemic areas to low and vice versa, because of production, living and other reasons. Mobile populations make malaria more difficult to control, and even give rise to malaria outbreaks in some areas. Mobility is a negative factor for the malaria control program. Mobile populations have with epidemiological significance when they contact with vectors, so here the mobile population means people who stay in neighboring countries for more than one night. The duration of staying are also effect the opportunity to suffer from malaria, staying for a longer time in endemic areas, people will be more easier to catch malaria. But it is difficulty to collect the data like that. Here we just use the number of trips per population (number of trips of domestic mobile population staying outside the country more than one night divided by total population) to measure the effect on malaria transmission.

3.4 Multivariate model

Based on the statement mentioned above, a multivariate model will be built to show the relationship between malaria incidence rate and malaria control activities, social economic factors and environmental factors. The multivariate model can be used to study how several independent variables act together to determine the value of a dependent variable. The coefficient of these independent variables reflects the effect of these independent variables.

The model that will be built is modified from Porchaiwiseskul (1993). He developed a model to estimate the morbidity rates of communicable disease. The model has been showed in chapter 2. The model presents the morbidity rates and annual blood examination rate which will have a lagged effect on the morbidity rate in the future.

In Yunnan province, malaria transmission is not in a perfect steady state. The incidence rate is very low, in most of counties that is below 10 per 10,000 in a year. There are only a few patients in some counties, they may scatter in various villages during different seasons. The ability of transmission is very low, because of less transmission sources. After carrying out control activities, the transmission stops in the community. It may shift to other villages or communities in the next year due to other reasons, such as mobile populations. For whole county, there could be no long term effect of current malaria incidence rate, even if there are any, they will be very low. On the other hand, the control activities are only conducted in a few focal sites, it is only a small part of the whole county. In this case, the assumption is that the control activities and current malaria incidence could have no long term effect on the whole county.

Yunnan province is a large one, there are 46 minority nationalities, highly variable geographic conditions, health resources allocation is diverse. There are 99 counties grouped into 17 prefectures which are separated into 4 regions: south east, south west, north east and north west in the study, based on the administrative territories and their location. on this basis 5 multivariate models will be built using data from 4 regions and from the province as a whole, according to the basic formula:

$$LogINC_{kt} = a0+a1*PREM_{kt}+a2*MOSC_{kt} +a3* ANT_{kt} +a4*SUR_{kt} +a5*FARM_{kt}+a6*MOB_{kt}+a7*GCP_{kt}+a8*RAIN_{kt} +a9*TEMP_{kt} \quad (3.4.1)$$

k= subscript index for cross county
t= subscript index for year

The variable above are discribed in table 3.2.

Model assumption: The relationships between all the independent variables (Table 3.2)and malaria incidence rate changes are log-linear. Log-linear specification yields a diminishing effect of disease control and risk factors. It is useful for deriving marginal effect; this will be shown later.

Table 3.2 The list of variables, units and definitions

Variables	Unit	Definition
INC	case/ population	incidence rate of malaria in a year
PREM	Yuan/population	total cost of preventive medicine /total population
ANT	Yuan/ population	total cost of anti-relapse therapy/total population
MOSC	Yuan/ population	total cost of insecticide spraying and impregnated bednet/total population
SUR	Yuan/ population	total cost of surveillance for ACD and PCD / total population
FARM	%	proportion of farmer
MOB	trip/population	number of trips of mobile population staying outside the country at least one night/total population
GCP	Yuan/person	GCP per capita
RAIN	ml	rainfall in the year
TEMP	^0C	average temperature in the year

3.5 Data collection and calculation

Data used in this study are mainly from two systems. The first is from the case reporting system of malaria control. The data cover 128 endemic counties under 17 prefectures/cities, but malaria has been eradicated in some counties, so data are only from 99 counties in Yunnan province, from 1993 to 1995 The second source is from the provincial statistical yearbook 1994-1996.

3.5.1 Data available in malaria case reporting system.

There is a malaria case reporting system in China. It includes malaria cases reporting and implementation of malaria control activities. It consists of a series of table. We can obtain some of data from the system. They are stated as below:

We can get number of cases and total population in a county and then calculate the incidence rate.

$$\text{INC (malaria incidence rate)} = \frac{\text{Number of malaria new cases in a year}}{\text{Total population in an endemic county in the year}}$$

We can also get number of people detected in prefecture level.

$$\text{SUR} = \frac{\text{(Number of patients detected+number of people detected)* price for one person}}{\text{total population in the county in the year}} *10000$$

Number of patients and people detected* price for one person equal to total cost, the price used only deal with the cost of material.

We can also get implementation data of malaria control activities.

$$\text{PREM} = \frac{\text{number of people received preventive medicine* price of medicine for one person}}{\text{Total population in the county in the year}} *10000$$

$$\text{ANT} = \frac{\text{number of people received anti-relapse therapy * price of medicine for one person}}{\text{total population in the county in the year}} *10000$$

$$\text{MOSC} = \frac{\text{insecticide spraying and impregnated bednet*average price of insecticides for benifiting one person}}{\text{total population in the county in the year}} *10000$$

The average price used in measuring mosquito control can be gotten from total value used divided by number of peopele benifited from them. All price mentioned above are fixed and they are assumed to be equal to 1 Yuan(1 US dollar = 8.3 Yuan in 1993).

The implementation data are at the prefecture level, but are derived from counties, it needs time to collect them. Unfortunately it was not possible to get the data in county level in so short time. So I just asked an expert of malaria control activities who works in provincial institute of parasitic diseases to separate them into county level for me based on her experience. The principle of separating amount of the implementation from prefecture level to county level, are mainly based on malaria incidence rate of the county in last year and current year. In the same year in a prefecture, the amount of imlementation of malaria control activities in a county is related to the percentage of patients of the county in the prefecture, if the percentage is higher in a county, the amount is also greater. In different year in a prefecture, if the number of patients reduced dramatically in a county, it means more control activities are conducted in the county in the year than last year and vice versa.

$$MOB = \frac{\text{number of trips of mobile population staying outside the country more than one night}}{\text{total population in the county in the year}} * 100$$

Number of trips of mobile population is based on assumption that people living along the boundary line go to neighboring countries easily and there are more mobile population, where people live closer to the line. We then gave weight to each county according to their distances to the boundary line: the weight times the total number trips of domestic mobile population and divided by the total population, we get the MOB.

$\sum W_{kt} = 1$

$n = W_{kt} * N_t$

k: index of a county

t: time (year)

n: number of trips of domestic population in a county

N: Total trips in the province. In 1993, N =2,500,000;

In 1994, N= 2,575,000; In 1995, N=3,000,000.

3.5.2 Data available in the statistical year book.

FARM is the proportion of farmer to total people, both of them can be gotten from the provincial statistic year book.

$$FARM = \frac{\text{number of agricultural population}}{\text{total population in the county in the year}} * 10000$$

$$GCP = \frac{\text{Net present value of gross county product in a year (discount to 1993)}}{\text{total population in the county in the year}}$$

RAIN annual rainfall value

TEMP annual average temperature in the year

3.6 Analysis of allocative efficiency and equity:

In malaria control, with a limited budget, the decision maker should optimally allocate the resources, to maximize utility of malaria control activities and obtain allocative efficiency. This can be shown in Figure 3.4.

Figure 3.4 The optimal utitlity status

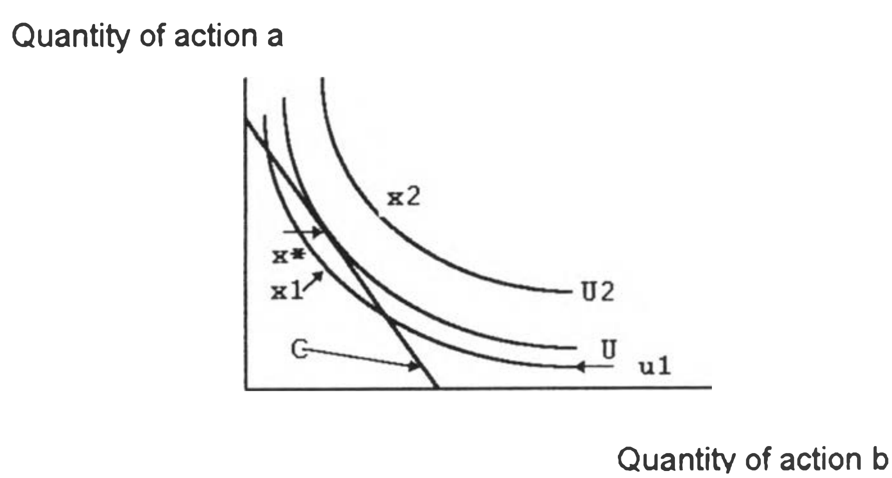


Figure 3.4 illustrates utility maximization for a given level of budget C. point X* represents the greatest utility level that can be obtained for C, X1 is under utility, and X2 can not be reached with constraint budget. Only when all ratios of marginal utility of activities divided by their prices are equal , can the allocative efficiency be achieved. In a perfect competitive market the quantity of action a and action b are based on their prices.

Condition of allocative efficiency:

$$\frac{Mu_{activity1}}{P_{activity1}} = \frac{Mu_{activity2}}{P_{activity2}} = \ldots\ldots = \frac{Mu_{activityn}}{P_{activityn}} \qquad (3.6.1)$$

It was Assumed that the relationship between utility of malaria control activities and malaria incidence rate is linear.

$$u = \alpha + \beta * INC \qquad (3.6.2)$$

β: the coefficient of incidence rate. $\beta < 0$.

From eqaution 3.6.2, we can get:

$$Mu = \frac{du}{dx} = \frac{\beta dINC}{dx} \qquad (3.6.3)$$

x is the quantity of malaria control activities.

Based on equation 3.6.1 and 3.6.3, we can get:

$$\frac{dINC}{P1*dx1} = \frac{dINC}{P2*dx2} = \ldots\ldots = \frac{dINC}{Pn*dxn} \qquad (3.6.4)$$

P is the price of malaria control activity.

In the study, we use expenditure level of malaria control activities per population to measure the effect on the incidence rate. So X's are the expenditure level of the control activities. Because X's are the expenditure level of control activities, they are already in monetary unit, it does not need to divide the price. In other words, prices of all control activities are equal to 1. So ME are the marginal effect of X on incidence rate.

$$\frac{dINC}{P*dx} = \frac{dINC}{dX} = ME \qquad (3.6.5)$$

According to basic economic theory, marginal effects will be employed to analyze the allocative efficiency and equity. Marginal effect is the additional outcome when one more unit of malaria control performance is invested. The algorithm of marginal effect was presented as below:

From model 3.4.1:

$$\frac{dLogINC_{kt}}{dx_{tkj}} = \frac{d(a1*PREM_{kt}+a2*ANT_{kt}+a3*MOSC_{kt}+a4*SUR_{kt})}{dx_{tkj}} \qquad (3.6.6)$$

$$\frac{dLogINC_{tk}}{dx_{tkj}} = a_j$$

$$\frac{dINC_{tk}}{INC_{tk}*dx_{tkj}} = a_j$$

$$\frac{dINC_{tk}}{dx_{tkj}} = INC_{tk} *a_j \qquad (3.6.7)$$

where:

INC = dependent variable, incidence rate of malaria

t = time (year)

k = index of county

j = index of malaria control activity

X = expenditure level of malaria control activity/population

a_j = coefficient of X_j

Under the marginal effect, the assumption is that the malaria control network in Yunnan province with spare capacity during 1993-1995, staffing and other costs is unlikely to be affected by the activities of one more unit. It is also assumed that there is no long term effect.

$$\text{Current } ME_{tkj} \text{ (marginal effect)} = \frac{dINC_{tk}}{dx_{tkj}} = INC_{tk} * a_j \qquad (3.6.8)$$

$$ME_{tkj} = INC_{tk} * a_j$$

3.6.1 Analysis of allocative efficiency

Efficiency means using available resources in a way that will yield the maximum possible benefits. Efficiency can be broken into subcategorizes: technical efficiency and allocative efficiency.

Technical efficiency means getting the largest possible output out of a given combination of inputs. Technical inefficiency corresponds closely to waste or mismanagement.

Allocative efficiency means using inputs and producing outputs in the optimal combinations to satisfy society's wants. Allocative inefficiency can arise if the control program does not select the optimal mix of inputs.

Allocative efficiency emphasizes that resources should be allocated in an optimal way

Assuming no long term effect, the optimal condition is that when ME of all activities are equal. The difference in the value of their ME will indicate the extent of economic inefficiency, which can lead to reallocation of resources.

The optimal condition is:

$$ME_{activity1} = ME_{activity2} = \ldots\ldots = ME_{activityn}$$

From equation 3.6.6 we know that in the same areas the MEs of control activities only vary with their coefficients, so after we compare their coefficients, we can know if there are difference between their MEs.

T test will be used to analysis if the MEs are in optimal condition in different activities during the observation period.

Between different activities the hypothesis are:

H_0: a1 = a2
H_0: a1 = a3
H_0: a1 = a4
H_0: a2 = a3
H_0: a2 = a4
H_0: a3 = a4

Each pair of coefficients will be tested, and the coefficient of control activities in 4 regional model will be tested.

If the coefficients are different between any pair, these mean that the MEs are different, because the incidence rate are same.

$$t = \frac{a1 - a2}{\sqrt{Var(a1 - a2)}} \qquad (3.6.9)$$

$$Var(a_1 - a_2) = Var(a_1) + Var(a_2) - 2\,Cov(a_1 a_2) \qquad (3.6.10)$$

From the result of coefficient covariance matrix we can get var(a1), var(a2) and cov(a1a2).

Because the MEs may vary not only with different activities but also with different regions, a two way ANOVA analysis will be used to test if the MEs of different activities are equal during the observation period in whole province.

$$F_{activity} = \frac{MSE_{activity}}{MSE} \quad (3.6.11)$$

$$ss_{total} = \sum ME^2 - \frac{(\sum ME)^2}{N} \quad (3.6.12)$$

$$SS_{activity} = \frac{\sum_j(\sum_i ME_{ij})^2}{k} - \frac{(\sum ME)^2}{N} \quad (3.6.13)$$

$$SS_{region} = \frac{\sum_i(\sum_j ME_{ij})^2}{k} - \frac{(\sum ME)^2}{N} \quad (3.6.14)$$

$$SS = ss_{total} - SS_{relgon} - SS_{activities} \quad (3.6.15)$$

$$MSE_{activity} = \frac{SS_{region}}{k-1} \quad (3.6.16)$$

$$MSE = \frac{SS}{N - k - b + 1} \qquad (3.6.17)$$

b: number of activities
N: total number of observations
k: number of regions

H_0 $ME_{activity1} = ME_{activity2} = \ldots\ldots = ME_{activity\ n}$

3.6.2 **Analysis of allocative equity**

Another factor associated with resources allocation is equity. Equity refers to the fairness with which those benefits are distributed. There are several concepts of equity, they are stated below:

Equal expenditure/resources for equal needs, means allocation of resources to a particular group or geographical area in proportion to its health needs/demands.

Equal access for equal needs/demand, ensures that for all individuals with the same need they will have the same opportunity to use health services.

Equal utilization for equal need would involve a system whereby use of health services would be allocated pro rata with need or demand.

Equality in health requires allocation to be adjusted in certain ways and standardized at least for age and sex.

Here the equal social welfare weight to different regions will be used, as developed by Pongshaiwiseskul (1993). It is assumed that each of the consumers in the same health district is equally treated from the social welfare point of view or, in other words, each of them is given the same welfare weights. If equal social welfare weights are also given to all health districts, the marginal effect of the disease control resources put into each health district has to be equal in order that the resource allocation among health districts is equitable or optimal. The difference in the value of their marginal effects will indicate the economic inequity between health districts.

$$ME_{kt} \propto \frac{1}{W_{kt}}$$

W_{kt} : social welfare weight.

When we put more social welfare weight into a areas, the ME will reduce; while we put less social welfare weight the ME will increase.

The condition of allocative equity is:

$$ME_{region1} = ME_{region2} = \ldots\ldots = ME_{region\ n}$$

Because the MEs may vary not only with different regions but also with different activities, so a two way ANOVA test(Yang Shuqing, 1990) will be used to assess if equal MEs are given to different areas during the observation period.

$$F_{regions} = \frac{MSE_{regions}}{MSE} \qquad (3.6.18)$$

$$MSE_{reigon} = \frac{SS_{region}}{k-1}$$

SS_{region} can be gotten from equation 3.6.14.

b: number of activities
N: total number of observations
k: number of regions

H_0 $ME_{region1} = ME_{region2} = \ldots\ldots = ME_{region\ n}$

After F-test, if there are difference among them, a Q-test (Yang Shuqing, 1990) will be used to analyse if there are any differences between regions. Q test is also called Newman-keuls test.

$$Q = \frac{|\overline{ME_a} - \overline{ME_b}|}{S_{\overline{ME_{aa}} - \overline{ME_{bb}}}} \qquad (3.6.19)$$

$$S_{\overline{ME_{aa}} - \overline{ME_b}} = \sqrt{(MSE)/n}$$

MSE can be gotten from eqauition 3.6.17
n: number of observations used in the test in a region.

Then Checking Q table directly, we can get P-value, or adjusting α (Watson et al, 1990) then checking t table, we can also get P.

Hypothesis:

Between north east and north west regions.
H_0: $ME_{regionNE} = ME_{regionNW}$

Between north east and south east regions.
H_0: $ME_{regionNE} = ME_{regionSE}$

Between north east and south west regions
H_0: $ME_{regionNE} = ME_{regionSW}$

Between north west and south east regions
H_0: $ME_{regionNW} = ME_{regionSE}$

Between north west and south west regions.

$H_0: \quad ME_{regionNW} = ME_{regionSW}$

Between south east and south west regions.

$H_0: \quad ME_{regionSE} = ME_{regionSW}$