CHAPTER 5

Research Methodology

This chapter discusses the theoretical framework. It consists of two parts which will be the basis of empirical model development: (1) the interrelationship between malaria morbidity, socio-economic status and environmental conditions. (2) modelling and measurement of efficiency and equity in health resource distribution.

Understanding the interrelation between disease, socioeconomic and environmental conditions is useful for a number of reasons. With socioeconomic development affecting health, economic development is focused on the impact of income, and higher income is generally associated with improved sanitation, public hygiene, nutrition level, and awareness of disease. Consequently, it tends to reduce the prevalence of disease and lead to better health. On the other hand, with health affecting the behavior of the population (e.g. via its effect on productivity and mobility) and behavioral characteristics affecting health (via the quality of environment, sanitation conditions, nutrition level and so on), better health of a population will lead to higher productivity and higher economic growth.

Thus, an interrelation clearly exists between a country's health condition and its economic development. If the consequences of a particular disease were better understood, it might be discovered, for example, that the economic and social success of a disease control program requires a complementary set of other programs designed first to win cooperation for implementation of the control measures. Better understanding of risk factors of disease, such as urban or rural settings, socioeconomic class, illiteracy, population mobility, age and sex, as well as the environment will be beneficial to economic development planning. It can guide decision makers to make rational decisions which can reduce the actual or potential risk of disease. With limitation of resources, disease prevention and control programs emphasizing target populations will be more effective than programs thinly spread over the total population.

All nations are facing the problem of health resource limitations, so health authorities need to allocate resources as well as possible in order to gain the most benefits and to solve the most important health problems. This requires setting priorities and making choices. Overall allocative efficiency and equity are always the stated goals of health policy planning. Based on economic theory, allocation of resources is efficient only if the resources are distributed so that all market prices and profits are consistent with the real resource cost of supplying products and the marginal effects of each product on the level of social welfare are equal. Social welfare is the sum of all the consumers' utility in the society. Illness will reduce the utility of consumers, death will cause total loss the consumers' utility. Health resources, such as disease control programs, can protect consumers from illness and death, and reduce the threat of disease so as to increase the consumers' utility.

If we treat every individuals equally from the social welfare point of view and give the same weight to all the provinces, the health resources should be distributed among provinces in such a way that the marginal effects are equal, so as to achieve the maximal social welfare. By comparing the marginal effect among provinces, the inefficiency of resources allocation can be measured and the direction for improving efficiency can be provided.

Efficient allocations are not necessarily equitable. In most cases there is a trade-off between equity and efficiency. Based on the idea of equal opportunity, the most favorable definition of equity in health care should be equal access for equal needs. Regarding health resources distribution, the most equitable allocation should involve an equal allocation of resources among all the members of society. Thus differences in the share of health resource among people will indicate the degree of inequality of resource distribution. The measurement of the pattern of inequality of resources distribution among provinces will give an overview of the degree of equity and point out the way for policy change to improve equity.

5.1 Theoretical framework of malaria morbidity and its determinants:

The epidemiological, biological and curative aspects of malaria have been well analysized from the theoretical and methodological points of view. However, the social and economic aspects of the health problems have received rather less attention and therefore, theoretical and methodological approaches are still largely awaiting development and testing. Some efforts have been made to identify the economic effects of malaria control measures, but few studies have been done to analyze the role played by social and economic factors as determinants of the disease.

The model presented here is based on the work of Pornchaiwiseskul(1992) and attempts to provide an empirical test of theories about social and economic determinants of malaria morbidity.

Malaria morbidity rate, as an indicator, is widely used to identify the magnitude of the problem of malaria disease in specific areas. The morbidity rate is defined thus:

$$\text{Malaria Morbidity Rate} = \frac{\text{Number of malaria patients}}{\text{Total population in the area}} \times 1{,}000$$

The number of malaria patients are those with clinical disease reported by health care units, such as hospitals, malaria clinics or health centers. Malaria is one of the diseases requiring compulsory reporting by the health regulations in Thailand. In the public health care sector, through many years of improvement of case reporting, the underreported rate of disease is quite low. But more and more private clinics and hospitals have been established, consumers' income has increased along with economic development, and health insurance schemes have come to cover the expenses for some people in the private sector. Thus a substantial proportion of malaria patients are now going to private practitioners. These cases are usually not reported to the Ministry of Public Health, so adjustment needs to be made in order to get more accurate morbidity rate data. If we could assume that the proportion of cases treated in the private sector is the same across the country in a short time period, the reported malaria morbidity rate will still be an appropriate indicator for comparing different health districts and different time period, even though the real rates are higher than those reported.

Annual parasite incidence rate (API) is commonly used for assessing the real malaria situation and its risk. It is measured as:

$$\text{API} = \frac{\text{Number of positive cases (new cases)}}{\text{Total population in the area}} \times 1{,}000$$

This indicator is traditionally used to express malaria morbidity. Actually they are different since the number of positive cases include those who don't have clinical symptoms, but are found by the malaria surveillance system and get radical treatment. This latter group can still transmit the disease to others. The greater the number of positive cases, the higher the risk of malaria transmission. So the API is a better indicator for spread of disease than for morbidity rate. According to the data in annual epidemiological surveillance reports, the API reported by the Thai Malaria Division is around two to three times greater than the official morbidity rate.

This thesis attempts to explore the relationship between malaria transmission and socioeconomic factors by using the data of different provinces in a single time period. API is used as an indicator to express malaria morbidity in this thesis.

The annual increase or decrease in morbidity rate is dependent on the transmission rate and patient recovery rate in the past year. If the disease transmission rate is greater than the patient recovery rate, the morbidity rate will increase, otherwise the morbidity rate will be reduced or remain at the same level. As Pornchaiwiseskul(1992) presented, the morbidity rate of a communicable disease can be estimated as:

$$\log C_T - \log C_{T-1} = \eta_T - \rho_T \quad \text{..................... (1)}$$

Where

C_T = the morbidity rate at year T

η_T = the transmission rate

ρ_T = the patient recovery rate

Based on the equation (1), we notice that, except for the nature disease transmission trend, in order to control or reduce the morbidity of malaria it is necessary to interrupt the disease transmission path and to increase the recovery rate. Many factors directly or indirectly influence the rate of transmission and the patient recovery rate. These factors combine to shape the epidemiological pattern within a community. Disease control measures are the most direct way of controlling the disease. For malaria, its transmission is not from man to man directly, it transmitted from one person by mosquito to another person. This transmission cycle can be broken through malaria control measures directed towards reduction of the positive cases, vector density or increasing awareness of people leading to personal control measures. The influence of other environmental factors can’t be ignored. Actually, many socio-economic factors can affect the disease transmission, such as an increase in income, living condition improvement, higher education level, changing natural environment, and so on. Generally, these factors are outside the control of the health authority.

Based on current knowledge, some important determinants of malaria transmission are discussed in the following paragraphs, in order to define terms that must be incorporated in the model.

5.1.1 Malaria control measures:

The objective of implementing malaria control measures is to control or eradicate malaria. Eradication implies the interruption of transmission and elimination of parasite reservoir by intensive, meticulously conducted operations that are limited in time; it is usually very costly, but the benefits will last for a long time. Control, on the other hand, implies measures which will reduce transmission to low levels, but which will require to be maintained indefinitely.

Several types of field malaria control activities have been implemented, such as residual insecticide house-spraying, blood smear examination for high risk populations, biological control, environmental control and health education. The aim of these activities is to reduce vector density, vector longevity, man-vector contact, and to increase the proportion of early positive case finding so appropriate treatment can be given. These activities can reduce malaria whether transmission rate or the duration of sickness of patients. As a result, the malaria morbidity rate can be reduced.

5.1.2 Environmental factors:

Wherever anopheline mosquitoes coexist with a reservoir of infection, transmission will be influenced by atmospheric temperature, rainfall and humidity. High temperatures are detrimental to parasite development in the mosquito, the most suitable temperature is probably in the region of 27°C. Temperature also influences mosquito activity. In the cold season, a fall in air temperature may cause mosquitoes to hibernate until the return of warmer weather. It is observed that during a long, hot and dry season the vectors seem to disappear and yet reappear suddenly when the rains return.

Where distinct wet and dry seasons occur the duration of rain may largely determine the extent of the malaria season. Heavy rainfall may damage or flush out larvae with a subsequent diminution in transmission. Forest is the favorite environment for the Anopheles mosquitoes, affecting the mosquito density and longevity at a level at which substantial transmission can occur. All these natural environmental factors would influence the transmission rate. Some man-made alternations to the environment can cause climatic changes which may indirectly alter epidemiological patterns.

5.1.3 National health care services:

In Thailand the malaria control program is a vertical system, to some extent, largely separate from the general national health care delivery system. Most financial support of this program comes from the national health budget, with some from foreign aid and NGOs. The reason for the separate program is that malaria is still one of the most serious diseases and needs special efforts to solve. General health care services affect the morbidity rate of all diseases, and also make a significant contribution to malaria control. As long as malaria transmission is controlled at a certain low level, malaria control operations can be integrated into the general public health system in which the resources can be used more cost effectively. Some provinces with low malaria incidence rates have already joined the general public health services in Thailand. The public health resources, in terms of manpower, materials, and money, are those concerned with health personnel, hospitals, health centers, drugs and health expenditures. The amount of resources invested in a province will influence the level of morbidity of disease, since these resources will be used to interrupt disease transmission and patient recovery through treatment. Generally speaking, the greater the public health expenditure, the fewer malaria cases that should occur.

5.1.4 Factors of accessibility of health services:

The morbidity rate depends on the people's accessibility to health services and whether control measures can reach the target population. The availability of health facilities is the major factor determining people's accessibility. But whether those health facilities are actually accessible to the people when they are supposed to serve also depends on other factors. These factors include both economic and physical accessibility. Even though government provides free treatment for malaria cases, it does not mean that there is no cost to patients. There is considerable expense for people seeking care, such as transportation cost, food during visit and opportunity cost (travel time, waiting time, absence from work, etc). The costs for poor people are likely to be greater than for the rich. Traveling time spend for the poor will be greater because they are more reliant on public transport. Also the poor are likely to have further to travel to obtain comparable medical care for the areas in which they live are poorly endowed with medical facilities (Nayce et al, 1974). Public transportation and communication infrastructures indicate the physical accessibility of people to health facilities. In poor and remote areas, there is usually a lack of good roads and telephones; this situation makes it difficult to make appointments and arrive when one wishes. Also, it is difficult for control measures to reach them. So these factors can influence people's accessibility to health services, and thus the morbidity rate of disease.

5.1.5 Income:

Low income and high prevalence of disease are strongly and positively correlated both within developed and developing countries. Past experience has shown that a certain minimum level of economic development is necessary for carrying out successful malaria control. An increase in income leads to a reduction in the risk of disease and better health. The reason is that good health, like most 'goods', costs money. Those who can afford to spend more on their health will benefit the most. The spending on averting the risk of disease not only includes medicines and medical attention, but also includes expenditures on housing and maintaining a healthy environment, with safe streets and roads, controlled pollution, good sanitation and safe water. As people's income increases, their nutritional status improves and their resistance to disease will also increase. Prosperity allows communities to improve their physical environment and hygiene, which can reduce the disease transmission rate. Poverty and ill-health are mutually reinforcing, they are in a 'vicious cycle' in which poor health results in poor productivity, which in turn means low income. However, there are also some exceptions to the correlation between income and morbidity rate. Some economic activities, which lead to increased income, also have negative effects on specific diseases, e.g. water irrigation projects result in an increase in agricultural output which increases farmers' income. But at the same time, the environmental changes may cause an increase in malaria transmission.

5.1.6 Geographic population distribution and social factors:

The world population has been growing rapidly in the last several decades. In China and Thailand, the population has almost doubled in the last four decades. The geographic distribution of population is different across each country. Population density and population movement are related to disease transmission. Much evidence has shown that infectious diseases are predominant in highly populated areas, e.g. we find that polio and hepatitis A morbidity are related to the population density. Population movement accelerates the disease transmission rate, as has been observed for malaria transmission in Southeast Asia. On the one hand, people who migrate from malaria free areas to endemic areas lack immunity against malaria. On the other hand, malaria cases in endemic areas who move to malaria free areas may transmit malaria there. It is important to note that in Southeast Asian countries, population movement plays a major role in malaria transmission and spreading of drug resistant strains.

Malaria predominantly occurs in rural areas. Rural populations are more likely to be affected by the disease, because their activities make them more exposed to the disease. People who earn their living by agriculture, forestry and mining have more chance of exposure to the vector and more chance to be infected with malaria. These groups of people have, on average, lower levels of educational attainment, so they may lack knowledge about the cause of disease and effective methods of averting the risk. Furthermore they are more likely to be ignorant of proper health practices and innovations in medicine.

In conclusion, overall socio-economic, health care and environmental factors can influence transmission rate and recovery rate, and thus morbidity rate. They are considered as the basis of the empirical morbidity model to predict the morbidity rate and to quantify the effects from determinant factors.

5.2 Empirical model of malaria morbidity rate

Based on the theoretical framework discussed above and the data obtained, the empirical morbidity model is specified as follows. Data to be used in the model is provincially based, which includes 73 provinces in Thailand. It is annual data in the years 1991 and 1992. The reason we don't select the most updated data is that although the most recent malaria epidemiological data and health care services data can be obtained, the most recent socio-economic and environmental available are only those from 'National Household Socio-economic Survey, 1992' and National Statistic Year Book. In order to make these data consistent and compatible, we select these two years data for our analysis.

Model : Malaria Morbidity Rate

$$\Delta \log MORB_{k,T} = b_0 + b_1 \bullet MORB_{k,T-1} + b_2 \bullet ABER_{k,T} + b_3 \bullet ABER_{k,T-1}$$
$$+ b_4 \bullet NEXP_{k,T} + b_5 \bullet DOCT_{k,T} + b_6 \bullet NURS_{k,T} + b_7 \bullet HBED_{k,T}$$
$$+ b_8 \bullet AVIN_{k,T} + b_9 \bullet GPP_{k,T} + b_{10} \bullet EDUC_{k,T} + b_{11} \bullet FARM_{k,T}$$

$$+ b_{12} \bullet PDEN_{k,T} + b_{13} \bullet SIZE_{k,T} + b_{14} \bullet FRST_{k,T} + b_{15} \bullet RAIN_{k,T}$$
$$+ b_{16} \bullet TEMP_{k,T} + b_{17} \bullet TELE_{k,T} + b_{18} \bullet CAR_{k,T} + \varepsilon_{k,T} \quad \text{.................. (2)}$$

Notation for empirical model:

k	= subscript index for province
T	= subscript index for year
$MORB_{k,T}$	= annual malaria morbidity rate
$ABER_{k,T}$	= annual blood examination rate or the number of blood slides examined per population per year
$NEXP_{k,T}$	= annual national health expenditure
$DOCT_{k,T}$	= number of population to a doctor
$NURS_{k,T}$	= number of population to a nurse
$HBED_{k,T}$	= number of population to a hospital bed
$AVIN_{k,T}$	= annual average income
$GPP_{k,T}$	= annual gross provincial production
$EDUC_{k,T}$	= average schooling years of head of household
$FARM_{k,T}$	= proportion of population working in agricultural sector (farmer, work in forest sector, mining)
$PDEN_{k,T}$	= population density
$SIZE_{k,T}$	= average family size
$FRST_{k,T}$	= annual forest coverage as percentage of total area
$RAIN_{k,T}$	= annual rainfall (millimeter)
$TEMP_{k,T}$	= annual average temperature (degree Celsius)
$TELE_{k,T}$	= number of population to a telephone
$CAR_{k,T}$	= number of population to a passenger car
$\varepsilon_{k,T}$	= error term

log denotes the natural logarithm and Δ denotes the differencing operator.

This empirical model is derived basically by following equation (1)(p27). The assumption is that the relationship between all these independent variables and malaria morbidity rate changes are log-linear. The log-linear specification of dependent variables has two advantages compared with a simple linear model. First it obeys the law of diminishing effect of disease control and risk factors. We can simply understand that increasing malaria control measures in an endemic area will reduce the transmission rate and improve the recovery rate. Along with the morbidity rate decrease, the effect will decline with the same level of control measures. As long as the morbidity rate goes down to zero, the effect of malaria control measures in terms of reducing morbidity rate will be zero. Second the log-linear form restricts the dependent variables greater or equal to zero without introducing any additional constraints. Since a negative morbidity rate has no meaning, this range limitation seems very useful and simplifies the analysis.

The independent variables are selected as proxies of possible determinants discussed in the theoretical framework, to give possible explanations of variation in cause, transmission rate and recovery rate of malaria. As they are expressed in a linear form in the right side of equation, the coefficient of each variable is the marginal effect of that variable. The absolute figure will indicate how the magnitude of the marginal effect changes or how much variation of malaria morbidity rate can be explained by that variable. The signs of the coefficients will indicate whether the factors have positive or negative effects on the malaria morbidity rate.

Annual blood examination rate per population in the past and recent years is used as a proxy for malaria control measures. The sign of the coefficient should be negative, which means increasing the level of malaria control measures will cause a reduction of morbidity rate.

Several indicators are selected to represent general health care services in the provinces. The national health expenditure represents the amount of investment of public health care among provinces. The national health expenditure should be negatively and strongly correlated with morbidity rate, which means less health care provision in provinces that have higher morbidity rates. The number of population to a doctor and a nurse is used as a proxy of health man-power distribution. Doctors can be thought of as the level of treatment measures provided and nurses may represent preventive measures. The number of hospital beds is an indicator of health facilities located in the provinces. All these three indicators are expected to be positively correlated with morbidity rate. That is, the less the provision of health personnel and facilities in the province, the higher the morbidity rate would be.

Average per capita income and gross provincial production are used as proxies of the economic situation of the provinces. It should have a negative effect on morbidity rate; as we discussed in the theoretical framework poor areas suffer more from diseases.

Education level (EDUC), proportion of population working in agricultural sector (FARM), family size (SIZE) and population density (PDEN) serve as the proxies of social and demographic conditions in the provinces. Positive signs are expected for the variables of 'FARM', 'SIZE' and 'PDEN', while a negative sign is expected for education level.

Forest coverage, temperature and rainfall are proxies of the natural environment situation. Forest coverage should be highly positively correlated with morbidity rate, and the temperature and rainfall are also expected to have positive signs. Since all Thailand has a tropical climate, the differences in climate among provinces are small, so there may not be a very strong correlation between temperature, rainfall and morbidity rate.

The number of population to a telephone and to a passenger car reflect the situation of transportation and communication status, respectively. They are used as proxies of people's accessibility to the health facilities. Positive signs are expected, indicating that better infrastructures will increase people's ability to have access to health care services which in turn will lower the morbidity rate.

Through this analysis, we can find out the determinants or correlation between malaria morbidity rate and these socioeconomic factors. The quantitative results are useful for exploring how close the relationship is between malaria transmission and each of the socioeconomic factors, and how the socioeconomic changes will affect the malaria transmission. This analysis will provide useful information for health policy options, to improve efficiency and equity of resources allocation and to make appropriate intervention strategies for malaria control. Such information will enable managers to identify and predict the potential impact of demographic, socio-economic and environmental factors on malaria and strengthen the capacity for negotiation with other sectors. The national plan for malaria control should be part of the national health plan which in turn, should be an integral part of the national social and economic development plan.

This empirical model is specified based on the theoretical framework. If we assume this is a correct model, all these estimation based on the available data can explain the correlation between disease and its determinants. In the case of absence of an information network, this model cannot implemented because some of the necessary data are not available. Omitting some of variables in the analysis will create bias, this bias is likely to give misleading conclusions about statistical significance of the estimated parameters and cannot be fixed using statistical methods.

With the information network, the relevant data on disease, health, socio-econoimic and environmental pattern will be available all the time, which will make it possible to do the analysis correctly.

5.3 Allocative efficiency of health care resources

In any country, health resources are limited, so the choices about pattern of allocating resources must be made, ideally with attention to the principle of minimizing opportunity costs. Health care can be viewed as one of the many inputs into the production of health, so such choices will affect the health of the population. Economic appraisal clearly requires measures of benefits of health care in order to plan the best use of available resources. It must be built on the results of epidemiology and the evaluation of health improvement. One of the direct results can be measured as the reduction of morbidity and mortality rate or the cases prevented and deaths averted through provision of health care services. The results of these measurements will reflect the efficiency of using scarce health resources among alternative options for resources allocation.

5.3.1 Definition of allocative efficiency

There are several aspects concerning the efficiency of resources allocation for health care. In order to analyze the efficiency of health resources allocation, it is necessary to distinguish between technical efficiency, allocative efficiency and social efficiency. Technical efficiency is where the costs of producing a given output are minimized, or where output is maximized for a given cost. It is studied in the search for optimal combination of inputs which give the greatest output. The notion of allocative efficiency is derived from the nineteenth century work of Pareto (Alistair,1988), whose 'principle of optimality' holds that there is a point at which the pattern of consumption of goods or services in a society cannot be rearranged to make any individual better off without making anyone worse off. The existence of perfect markets can be shown to lead to both technical and allocative efficiency, given any initial endowment of resources. But in the health care sector, there exists market failure because of the existence of externalities and asymmetric information between providers and consumers. Health care can be thought as a public goods, it cannot achieve Pareto efficiency by market mechanism without government intervention.

5.3.2 Measurement of allocative efficiency

Allocative efficiency is important because the desirability of moving from an allocatively inefficient to an efficient state would command universal agreement. That is, if it is possible to undertake some change so that at least one person is better off without making anyone worse off, then this must be a good outcome and should be undertaken. This changes are 'Pareto improvement'. Public projects in which no one is made worse off are relatively rare. In order to identify a large range of projects that ought to be undertaken, the criterion of approval has been changed to that of potential Pareto improvement, which could be defined as if the amount by which the beneficiary's gain exceeds the amount of the loser's loss, it ought to be undertaken. The aim is to maximize the total value of output produced, the achievement of which is social efficiency.

Regarding efficiency of health resource allocation, using malaria morbidity as the output measurement, if we treat everybody as the same from a social welfare point of view, then the resource should be distributed so that the number of malaria cases can be prevented are maximized, thus social efficiency could be achieved. In the present health resource allocation situation, there exists an unbalance of resource distribution, e.g. the health care provisions are much greater than the demand in some regions, while others lack provision compared with their health needs. This irrational health resource distribution leads to partial resource wastage, and the desirable level of outcomes cannot be achieved. At this situation, interventions seem to be necessary to modify and redeploy health resources through national health policies setting or modifying, which will allocate the limited health resource to the most needed area. This could significantly increase the utilization rate of resources and improve the efficiency.

The amount of inputs of health resources invested directly effect the level of malaria morbidity and mortality rates. In a region of health resource shortage compared with the number of malaria cases, to mobilize more health personnel will increase the capacity of case diagnosis and treatment, as well as reducing the reservoirs of malaria parasites. So, the prevalence of malaria could be reduced. On the other hand, as more resources are spent to strengthen malaria prevention and control, e.g. to reduce vector density through DDT house-spraying, to reduce man-vector contact through health education to increase the people's awareness of malaria and using mosquito nets or insect repellents, these could reduce the risk of exposure to malaria disease. Consequently the prevalence of malaria will be decreased. Generally it is expected to be true that the more the malaria control expenditure in a region, the more the malaria cases will be prevented.

The efficiency of resource allocation is very much related to the recent level of malaria prevalence. The same amount of resources invested in an epidemic area and in a lower transmission area could result in a similar reduction in malaria morbidity rate, but the number of cases prevented would be much higher in the epidemic region than in the lower malaria prevalence region. This indicates that from a social welfare point of view, since there is the constraint of resources limitation, the most efficient resource allocation should put the limited resources to the most needed area, so as to achieve the maximum number of malaria cases prevented within a given level of resource in the country.

5.3.3 Method of redistribution of health resources

The method of redistribution of health resources is according to the recent morbidity rate in the provinces, the provinces which have high morbidity rate will increase their budget for disease control. As an effect of increasing the level of disease control measures, the morbidity rate should hopefully decline to a certain level. Since the total annual budget is fixed, the extra budget for epidemic provinces must come by sacrificing some from other provinces in which the malaria morbidity rate is relatively low compared with the national average level. This means that it would reduce the level of malaria control measures in these provinces, thus could cause a little increase in morbidity rate, but the total increased number of cases in these provinces would not be as great as the cases being prevented in the epidemic provinces. So the total number of malaria cases in the whole country will be less if we redistribute resources in such way rather than as the original budget does. According to the allocative efficiency concept, if the beneficiaries' gain exceeds the loser's loss, it is potential Pareto improvement. As we mentioned before, if we give the same weight to all the population from the social point of view, the more cases prevented indicates that it is potential Pareto improvement, it ought to be considered as an good alternative to improve the efficiency. In other words, the efficiency can be improved by redistributing health resources based on the level of morbidity rate in each province.

Based on the idea above, equation (2) will be used to assess the health expenditure and cases prevented in the different malaria prevalence areas. Since we want to see how redistribute resources under control of the health sector can influence the morbidity rate in the country, we assume that other factors are constant. From the morbidity model we have:

$$\Delta \log MORB_{k,T} = b_0 + b_1 \bullet NEXP_{k,T-1} + c_i \bullet Z_{i,k,T} \quad \text{.......} (5.3.1)$$

Where

- T = subscript index for time period
- k = subscript index for provinces
- i = subscript index for the socio-economic factors
- $NEXP_{k,T-1}$ = annual health budget
- $Z_{i,k,T}$ = lagged morbidity rate and other socio-economic factors the meaning of these variables explained in morbidity model.

By transforming this equation,

$$\Delta \log MORB_{k,T} = \log MORB_{k,T} - \log MORB_{k,T-1}$$

$$= \log (MORB_{k,T} / MORB_{k,T-1})$$

$$= b_0 + b_1 \bullet NEXP_{k,T-1} + c_i \bullet Z_{i,k,T} \quad \text{...... (5.3.2)}$$

so: $MORB_{k,T} = MORB_{k,T-1} \bullet \exp(b_0 + b_1 \bullet NEXP_{k,T-1} + c_i \bullet Z_{i,k,T})$

number of cases $= Population_{k,T} \bullet MORB_{k,T}$

$$= Population_{k,T-1} \bullet MORB_{k,T-1} \bullet \exp(b_0 + b_1 \bullet NEXP_{k,T-1} + c_i \bullet Z_{i,k,T})$$

$$CASE_{k,T} = (1 + g_k) \bullet CASE_{k,T-1} \bullet \exp(b_0 + b_1 \bullet NEXP_{k,T-1} + c_i \bullet Z_{i,k,T})$$

The optimal health resource distribution will be:

Minimize $\Sigma\, CASE_{k,T} = \Sigma\ (1+g_k) \bullet CASE_{k,T-1} \bullet \exp(b_0 + b_1 \bullet NEXP_{k,T-1} + c_i \bullet Z_{i,k,T})$ .. (5.3.3)

subject to

$$\Sigma_k\, NEXP_{k,T} = NEXP_{TOT} \quad \text{...... (5.3.4)}$$

where

- exp(X) = exponencial function of X
- g = population growth rate
- case = number of malaria cases in the year
- $NEXP_{TOT}$ = actual national health expenditure in a year

According to equation 5.3.3, we can get the result of the number of cases prevented when one more unit of expenditure is imposed on malaria control in different areas. Comparing the marginal effect of the additional unit of input with the effect in terms of additional number of cases prevented gives a measure of effectiveness of redistribution principle. The same processes will continue to distribute the resource to all the regions (input unit 2, 3, 4, 5, ...) until all the resources are exhausted. Ideally, if health expenditure can be distributed according to this rule, the total outcome (number of malaria case prevented) will be maximized. This means it is the most efficient way of distributing resources.

The most desirable resource allocation can be enhanced by improving provision of information; without these data about disease and health care resources in different provinces and different years, decisions about resource distribution could only be made by equal distribution to all the provinces. This distribution method would result inefficient resources utilization, thus the desirable output cannot be obtained. Based on the calculation of a given amount of resource distribution by two different allocation methods(most efficient way and equal distribution way), the difference in number of malaria cases prevented can be obtained. This difference would give the number of cases prevented due to better information. It can be viewed as a benefits of establishing a good information system.

The benefit can be calculated using the unit cost of a malaria patient, multiplied by the number of cases prevented since we have better information. Then comparing this benefit with the investment of establishing this information system, the benefit/cost ratio would be generated. As long as the ratio is greater than 1, it means the benefits are greater than the costs, and we can conclude that it is worthwhile to establish this information system. Considering this information system is not only to facilitate malaria control programs, but also will be used to provide information for other disease control programs would have to be calculated in a similar fashion. Moreover, many intangible benefits are not counted in this analysis. Thus, a full accounting of costs and benefits requires more extensive data than are currently available.

5.4 Equity of health resource distribution

Consideration of equity in health care still leaves open the question of precisely what form it should or does take. Many suggestions have been made, such as equal expenditure for equal need, equal access for equal needs, equal utilization, equal health indices, etc. The evidence would seem to suggest that equal access for equal need is most favoured, essentially the principle of equal opportunity.

Two areas in which there has been great concern for equity in health care are across socio-economic classes and geographically. Vertical equity and horizontal equity are the two basic types of equity. Vertical equity refers to the unequal treatment of unequals, this means if people have different health conditions they should be treated differently. Horizontal equity is concerned with the equal treatment of equals. It is perhaps the simpler to handle largely because recognition of both of conditions and treatment is easier.

In health care, there are many examples of the presence of considerations of equity. Equity is always cited as a goal of public health care systems. Some policies have been made to consider how resources for health care can be deployed more equitably across different regions, and efforts have been made to attract more doctors to undersupplied areas, as well as to promote geographical equity by controlling capital development to alter the locational distribution of medical services.

5.4.1 Inequality measurement of health resources distribution

In order to set policies to promote equity in health care, measures have to be developed to identify the level of inequality of distribution of health resources. In recent times, many different measures of equality have been developed and employed. Through assessing the advantages and limitations of each measure, the *GINI coefficient* is thought to be the most appropriate measures for assessing the inequality of health resources distribution.

The *Gini coefficient* is generally used to measure the inequality of income distribution among populations. It can be applied to measure the variation of health resource distribution between different population groups. The method is that the percentage of the population group arranged from least resources to most resources shared are represented on the horizontal axis and the percentage of resources shared by x% of the population is shown on the vertical axis. If the same proportion of population has same percentage of resources, e.g. 10% of population has 10% of resources, 50% of population has 50% of resources, the resources are distributed with absolute equality. But in most situations, the resources distributed to the bottom groups represent a proportionately lower share of resources.

The GINI coefficient is the ratio of the area between the line of absolute equality (the egalitarian line) and the actual distribution curve (Lorenz curve) and 0.5. The value of the Gini coefficient is restricted from 0 to 1. If everyone has the same share of resource (the most equal situation), the Lorenz curve will be simply the diagonal, the Gini coefficient is zero. But if one takes all the resources (the most unequal situation), the value of the Gini coefficient will be one. We can give an simple example. Suppose there are only two persons who share a given amount of income, the most equal distribution between them should mean that each person takes half of the income, the Gini coefficient will be zero. But if one of them takes all the income, and nothing is left for the other person, this will be the greatest inequality, the Gini coefficient is one. Any other alternatives of income distribution will give a Gini coefficient between zero and one. The bigger the Gini coefficient the larger the inequality of distributing income. The same concept applied for health resource distribution among provinces: The bigger the Gini coefficient, the larger is the inequality of health resource distribution are.

The formula(Amartya Sen, 1973) for calculation of the GINI coefficient is:

$$G = (1/2n^2\mu)\sum_{i=1}^{n}\sum_{j=1}^{n}|y_i - y_j|$$

$$= 1 - (1/n^2\mu)\sum_{i=1}^{n}\sum_{j=1}^{n}\mathrm{Min}(y_i, y_j)$$

$$= 1 + (1/n) - (2/n^2\mu)[y_1 + 2y_2 + \ldots\ldots + ny_n]$$

for $y_1 >= y_2 >= \ldots.. >= y_n$

where
y is the resources distributed in each population group;
μ is the mean of resources in each population group.

The value of the Gini coefficient shows the degree of inequality or gives some idea whether the inequality is "large" or "small".

5.4.2 Health resources distribution at equity level

According to the equity definition of equal access for equal needs, the absolute equity of resource distribution among provinces should ensure that everybody in any province has the same share of resources and the same opportunity of access. Here we assume that equal needs across provinces and accessibility to the health resources for the people within a province are the same. Then the optimal level equality of health resource (e.g. using health expenditure as a proxy of resource) distribution among provinces should be the national average, as:

$$NR = HEXP / TPOP$$

where
NR = health expenditure per capita in the country
HEXP = total health expenditure in the country
TPOP = total population in the country

For each province, there is:

$$PR_k = HEXP_k / TPOP_k$$

where
k = subscript index for province
PR_k = health expenditure per capita in province k
$HEXP_k$ = total health expenditure in province k
$TPOP_k$ = total population in province k

The condition for the absolute equality of resource distribution will be:

$$PR_k = NR, \quad \forall k$$

Where the province PR_k < NR, this indicates the resource distributed to this province is lower than the optimal level, and need to be increased. If PR_k > NR, this indicates the resource for the province is higher than optimal level, it could ideally transfer some resources to others. This analysis could help planners to adjust the resource distribution in order to reduce inequality between provinces.

Through using this inequality measure, we could find out how are the health resources allocated in terms of equal access, and whether the inequality of health care is "large" or "small". Moreover they also can be used to assess what influence alternative health care policies will have on resource allocation, how much equality can be promoted through resources redistribution.

5.5 Delay of information

The malaria morbidity model discussed above can be used to predict malaria morbidity rate in the following years. In that model we use one year lagged morbidity rate to forecast the current morbidity rate. If there is no such information network, this one year lagged data may not be accessible in time. So the prediction would be made by using the data from two or three years ago: this would decrease the accuracy of prediction. Policies which depend on this prediction could be inappropriate, e.g. if the prediction of morbidity rate is low but the rate actually is high in some areas, the measures would be too weak to control the outbreaks, so there will be an increased economic loss due to disease; and conversely, the resources put in disease control may be partially wasted.

The reduction of accuracy in estimation can be calculated through transformation of the morbidity model:

$$\log API_t = b_0 + b_1 \log API_{t-1} + \varepsilon_t$$

if the data API_{t-1} is not available, we have to use API_{t-2} then

$$\begin{aligned} \log API_t &= b_0 + b_1 \log API_{t-1} + \varepsilon_t \\ &= b_0 + b_1 (b_0 + b_1 \log API_{t-2} + \varepsilon_{t-1}) + \varepsilon_t \\ &= b_0 + b_1 b_0 + b_1^2 \log API_{t-2} + (b_1\varepsilon_{t-1} + \varepsilon_t) \end{aligned}$$

so the error term from this equation will be:

$$\xi_t = b_1\varepsilon_{t-1} + \varepsilon_t$$

Assume: $\mathrm{Var}(\varepsilon_{t-1}) = \mathrm{Var}(\varepsilon_t)$

so: $\mathrm{Var}(\xi_t) = (1+b_1^2)\ \mathrm{Var}(\varepsilon_t)$ .... (5.5.1)

The same steps can be continued to calculate the variance of error term of estimation if it is k years lagged data employed in regression model.

$$\xi_t = \varepsilon_t + b_1 \varepsilon_{t-1} + b_1^2 \varepsilon_{t-2} + b_1^3 \varepsilon_{t-3} + \ldots + b_1^k \varepsilon_{t-k}$$

where $\mathrm{Var}(\varepsilon_t) = \mathrm{Var}(\varepsilon_{t-1}) = \ldots = \mathrm{Var}(\varepsilon_{t-k})$

k = the number of years lag

$$Var(\xi_t) = (1+b_1+b_1^2+b_1^3+...+b_1^k)\ Var(\varepsilon_t)$$

if $b_1 = 1$, then

$$Var(\xi_t) = (k+1)\ Var(\varepsilon_t) \quad ....(5.5.2)$$

From equation 5.5.2, we can find that the variance of error term based on k years lagged data is k times greater than that using data of one year lag. Therefore, the longer the time lag of data used, the less will be the accuracy of prediction.

Without the information network, the prediction of disease is usually based on the data of several years ago. The accuracy of estimation will be reduced. This reduced accuracy of prediction will lead to irrational planning of health resouces allocation, and to increased economic loss due to resources wasted and higher morbidity and mortality of disease. These losses can be prevented by planning health resources more appropriately if better prediction can be made based on the more recent data obtained from the information network. Therefore, it can be thought of as one aspect of the benefits from establishing this information network.