Chapter 4

Results and discussion

4.1 Building and interpreting the multivariate model

4.1.1 Regression analysis of the models

The regression results of multivariate models that use data from different regions and at province level are shown in Tables 4.1 F-tests show that all these models can be accepted. R-square ranged from 0.48 to 0.89 in these four regions and in the whole province (Table 4.2) it was 0.535, Most of them are a little low: this means that 48% to 89% of the variation of dependent variables can be explained by these independent variables. The determinants included in the model may not completely explain all of the incidence rate, there could be some other determinants that have been left out, or some of the determinants cannot very well act as proxies of the disease. The R-square values vary so much in different regions, which means that the proxies of these determinants are different in these regions, and there could be some other determinants that could be better proxies.

4.1.2 Preventive medicine

The coefficient of preventive medicine is negative(Table 4.1)in all four regions and at the level of the whole province (Table 4.2). The negative coefficient means preventive medicine is negative for malaria transmission, and the regression analysis shows this to be at a significant level. Preventive medicine can reduce the incidence rate, through protecting the susceptible population just as anticipated. It means that the investment in preventive medicine can assist malaria control.

Table 4.1. Results of regression analysis (dependent variable = logINC)

Variables	North east	North west	South east	South west
Constant	-2.819	-7.603522	-4.744	-13.437
	5.022	5.720716	1.977	3.158
	0.577	0.1879	0.02	0.0001
Preventive	-2.037E-2	-1.3161E-2	-1.955E-2	-1.400E-2
medicine	4.626E-3	6.274E-3	5.657E-3	4.220E-4
	0.000	0.0393	0.01	0.001
Mosquito	-1.472E-2	-4.7952E-2	-7.602E-2	-7.415E-2
control	1.202E-2	2.68832E-2	1.089E-2	2.442E-2
	0.226	0.0780	0.000	0.076
Anti-relapse	3.278E-2	1.0728E-2	6.220E-4	2.521E-3
	9.441E-3	4.501E-3	1.769E-3	2.039E-3
	0.001	0.0197	0.727	0.220
Surveillance	4.910E-2	8.796E-3	1.358E-2	7.776E-3
	1.451E-2	2.210E-3	1.500E-3	1.936E-3
	0.001	0.0002	0.000	0.000
Farm	8.727E-2	2.903472	4.689	1.763
	1.092	5.186368	1.399	2.169
	0.937	0.5773	0.154	0.419
Mobile	-2.803E-2	1.0338E-2	2.481E-2	2.223E-3
	2.997E-2	8.886E-3	9.110E-2	5.157E-3
	0.353	0.2484	0.0089	0.668
GCP per	-1.830E-4	5.08E-4	-9.020E-2	-1.13E-5
capita	1.130E-4	4.22E-4	2.040E-4	1.960E-4
	0.111	0.2317	0.000	0.954
Rainfall	1.998E-3	1.894E-3	1.043E-3	2.277E-3
	2.738E-3	6.64E-4	2.300E-4	4.310E-4
	0.468	0.0056	0.000	0.000
Temperature	1.943E-1	2.545E-1	2.951E-1	5.335E-1
	1.293E-1	8.101E-2	6.376E-2	1.314E-1
	0.138	0.0024	0.000	0.000
R-squared	0.605	0.486	0.896	0.664
Prob	0.000	0.000	0.000	0.000
Sample	69	84	63	81

Note: the first line in each row is the coefficients value, the second line is the standard error, the third line is P value.

Table 4.2 Results of regression analysis (provincial model dependent variable = logINC)

Variables	Coefficients	Standard error	Prob
Constant	-5.006	0.841	0.0000
Mosquito control	-3.520E-2	0.013	0.0093
Preventive Medicine	-1.384E-2	5.41E-4	0.0110
Anti-relapse	4.688E-3	1.221E-3	0.0002
Surveillance	3.11E-4	5.06E-4	0.5388
Farm	1.232	0.626	0.0501
Mobile	1.871E-2	4.321E-3	0.0000
GCP per capita	-5.62E-5	8.30E-5	0.4990
Rainfall	1.625E-3	2.70E-4	0.0000
Temperature	0.239	3.7362E-2	0.0000
R-square	o.523		
Prob (F-test)	0.000		
SAMPLE	297		

4.1.3 Mosquito control

Mosquito control does reduce the malaria incidence rate just as expected, regression analysis showed this to be at a significant level in the one region and at provincial level

(α=0.05)(Table 4.1, Table 4.2). Mosquito control can reduce man--mosquito contact and thus reduce transmission, but the effect varies with different regions.

4.1.4 Surveillance

In theory, malaria surveillance can find patients earlier than only by passive case detection, they are given earlier treatment, and also find patients only with parasitaemia from the population in endemic areas, so as to effect a cure and to reduce the malaria transmission rate. But according to the regression analysis (Table 4.1), the positive coefficient means that greater surveillance will yield more patients. This is not a surprise. The experts of malaria control in Yunnan province have complained that the malaria case reporting system is underreporting the incidence rate. A survey in Yuan Jiang and Yuan Yang counties shows that missing reports are about 74.6% and 85.5%, respectively. In this case, increased surveillance will find more patients who may not be reported by the malaria case reporting system and they will be treated earlier. This process is also active for malaria control. Because of the situation mentioned above, surveillance in the model cannot explain the variation of incidence rate. More accurate data is needed to measure theeffect of the activity.

In order to test if there is any lagged effect of surveillance on incidence rate, we tried the lagged effect model, but the result (Apendix B) showed that the one year lagged surveillance was still positive.

4.1.5 Anti-relapse therapy

Anti-relapse therapy is focused on patients with a *P. vivax* infection history within one year. The aim of this activity is to prevent these people having a recurrence of symptoms and parasitaemia, thus reducing the transmission sources. In some high endemic focal sites, mass anti-relapse therapy was always conducted, it targets whole people in the community, in low endemic areas where malarias only scattered,

individual anti-relapse therapy is carried out on targeted persons mentioned above.

The coefficient of the variable of anti-relapse activity was positive in the models of all four regions and in the province as a whole (Table 4.1 and Table 4.2). The relationship between anti-relapse therapy and malaria incidence rate is thus: The anti-relapse therapy depends on the incidence rate within one year, the activity will affect the incidence rate in the new transmission season, this activity may have a lagged effect to the changed incidence. To improve this situation, we tried in a new model to use data at the provincial level. The results of the model show that one year lagged effect of anti-relapse therapy is positive (Appendix C), put one year lagged surveillance and anti-relapse therapy together in the model the coefficients of them are also positive(Apendix D). In fact, it should be negative relative to malaria transmission, the arguments are:

a. This activity has been overused, it cannot reflect the actual need, especially in some areas mass anti-relapse therapy has been conducted. People may keep the medicine that is used anti-relapse therapy for other use, such as self-treatment of a new infection, because the medicine is almost free; it can be used for primary treatment and patients can therefore avoid paying for treatment of a new malaria attack by using the anti-relapse medicine. The number of people receiving anti-relapse therapy is several times greater than the cases number (Appendix E).

b. The quality of the data is not good, it may be allocated incorrectly.

c. Anti-relapse therapy is only used for people with a P.vivax infection history. Irregularities in use of anti-relapse therapy may cause drug resistance of P.falcuparium, which makes it more difficult to cure and increases the overall incidence of malaria.

The model used in the study can not reflect the effect of surveillance and anti-relapse therapy, maybe we should try another model to solve the problem.

4.1.6 Rainfall and temperature

Rainfall and temperature are environmental factors which we anticipated should affect the transmission. In the four regions and the provincial area, rainfall and temperature were positive for malaria transmission(Table 4.1). This means that the variation of rainfall and temperature can effect the transmission, more rainfall and higher temperature can increase the incidence. But they are not statistically significant in the North east region. In North east region, the incidence rate is very low, more rainfall and higher temperature are unlikely to increase the incidence rate.

4.1.7 Mobile population

This determinant is not valid in the three regional models, but it is valid in the provincial model(Table 4.1, Table 4.2). The reason may be that the grouping process reduced the difference of the determinant among counties in a region, and then the significance was also reduced, or the sample size is not big enough. When we increase the scope to provincial level, the variations among counties are also increased, and show statisitcal significance. An effect of the mobile population on malaria transmission exits: it worsens the malaria control.

4.1.8 Economic income

In these models, the gross county production per capita is used as a proxy of economic income. The coefficients are negative in three regions. The coefficient of the variable shows it is not significantly related to malaria incidence in three regions and in the province model. Maybe this is true, but there are some other counties which are not included in the model. There are totally 128 counties in Yunnan province, all these counties were originally malaria endemic areas,

after several decades of efforts 18 counties had eradicated malaria by 1995. There are some intermittent transmission counties in the province which are not included in the model. Of course, gross county production per capita may not be a good proxy of economic income. The economic income is only part of the GCP, and the weights of economic income in GCP in different counties are various. It may be a major reason that GCP per capita is very high, but actually the average income of people is very low.

4.1.9 The proportion of farmers

The coefficient of proportion of farmers is supposed to give a measure of the difference in incidence risk between rural and urban populations. The statistical evidence from provincial suggest that rural people should suffer more risk than urban people. In four regions they are positive, but they are not statistically significent relative to malaria transmission, the reason could be samll sample size in regional level and grouping process reduced the difference.

4.1.10 Conclusion of the regression analysis

The regression analysis shows that the model can be accepted, the statistical results suggest that the variables of preventive medicine and mosquito control activities are negative to malaria transmission. Other variables such as temperature and rainfall are also related to malaria transmission. Proportion of farm population and mobile population are not sensitive in regional models because of the grouping process, but they are also effect the transmission of malaria. The proxy of variable GCP per capita may not be good in this model. The model cannot reflect the effect of surveillance and anti-relapse therapy using hypothesis data.

4.2 The result of analysis of allocative efficiency and equity

The marginal effect depends on the coefficient of control activities and incidence rate, while the former is also affected by unit price of activities and the quantity. Four

kind of malaria control activities have been included in the model, but surveillance and anti-relapse activities cannot reflect their effect on incidence rate in the model. So we use left two activities, preventive medicine and mosquito control to analyze the allocative efficiency and equity.

Table 4.3 The marginal effects of preventive medicine and mosquito control in four regions from 1993 - 1995

Region	year	ME of PRE	ME of MOSC
North east	1993	0.016	0.012
	1994	0.018	0.013
	1995	0.015	0.011
South east	1993	0.189	0.734
	1994	0.201	0.782
	1995	0.151	0.588
South west	1993	0.118	0.624
	1994	0.115	0.611
	1995	0.143	0.758
Norht West	1993	0.043	0.157
	1994	0.057	0.209
	1995	0.069	0.253

Mean ME of mosquito control is 0.3959 and the mean ME of preventive medicine is 0.0947. These imply that if we invest one more Yuan per capita to mosquito control or preventive

medicine, we can reduce incidence rate 0.3959 or 0.0947 per ten thousand population. The ME of preventive medicine and mosquito control(shown in Table 4.3) are low, because the incidence rate is very low. From the economics point of view, it may not be worth investment, but malaria is a serious communicable disease, and it is very easy to spread. In China, there is a cruel lesson from the history of schistosomiasis control failures. After great achievement had been reached, decision makers relaxed their vigilance, schistosomiasis control measures were slackened, schistosomiasis incidence rate increased dramatically, and it recurred in many places where schistosomiasis had been eradicated, it even appeared in some big cities. Serious social problems had been caused. We can not merely consider the current economic return from malaria control, since the return from malaria control is diminishing, and it is the result of several decades of efforts. There is a probability that malaria may cause more problems and hinder the development of economy. On the other hand, malaria incidence rate is also higher in some areas, the proportion of malaria to whole communicable disease is increasing(Table 3.1).

The aim of the malaria control program is gradually to eradicate the disease, not only to limit the transmission. There could be a long distance to reach the goal. It is more important to best use limited resources, as incidence rate become lower and lower.

4.2.1 The analysis of allocative efficiency

t-Test: Using data available in Table 4.4 to compare if there are any statistical differences between coefficient of preventive medicine(a1) and mosquito control(a2).

Table 4.4 Coefficient variance and covariance of a1 and a2

Region	Var(a1)	Var(a2)	Cov(a1a2)
North east	2.1399E-5	1.445E-4	2.80E-5
North west	3.936E-5	7.225E-4	3.94E-5
South east	3.380E-5	1.240E-4	1.52E-5
South west	1.780E-5	5.964E-4	2.38E-5

H_0 : a1=a2 α=0.05 in four regions

The result are showed in table 4.5. In south east and south west regions, there are statistical differences between the coefficients of preventive medicine(a1) and mosquito control(a2). In both south east and south west regions the coefficient of mosquito control are higher than the coefficient of preventive medicine.

Table 4.5 The result of comparison of coefficients(a1 and a2)

	North east	North west	South east	South west
t value	-0.5903	0.822.56	3.92	2.56
P	P>0.05	P>0.05	P<0.05	P<0.05

F test: using data available in Table 4.3 to compare if there are any statistical differences of MEs between preventive medicine and mosquito cnotrol in provincial level. The result is as below:

F= 7.51 P =0.0119

It means that there are difference between preventive medicine and mosquito control. The mean ME of mosquito control is 0.396, the mean ME of preventive medicine is 0.0947. The ME of mosquito control is higher than that of preventive medicine.

There are differences between these two MEs, because the incidence rate are same. The mean MEs of mosquito control are 0.7012 and o.6646 in south east and south west respectively, they are higher than those of preventive medicine 0 1804 and 0.1255. It means if we input more resources to mosquito control we can get greater utility and minimize the malaria incidence rate.

The allocation of resources in these two activities are also different(Appendix E) in whole province, the resources allocated in preventive medicine is 87.24 Yuan/10,000, in mosquito control is 68 46 Yuan/10,000. In south east and south

west regions, resources allocated in preventive medicine and mosquito control are 132.43, 21.45 and 66.78, 11.17 respectively.

More resources are allocated in preventive medicine than mosquito control during 1993-1995. If possible, we should invest more resources on mosquito control activity. The reasons of higher ME of mosquito control and lower ME of preventive medicine could be:

First, the adoption of integrated malaria control activities and resources allocation were mainly based on the epidemiological features and vectorial species of major vector mosquito in endemic areas before, just as mentioned in Chapter 3, various control activities were emphasized in different areas. The resting and feeding habits of vector mosquito is always one of the main rationale for focusing on which activity. However, the habits are not fixed. These may change, as circumstance vary. For example, when the number of domestic animals lessen, the opportunity that mosquito feed on man will increase. On the other hand, major vectors can also change when circumstance varied. While the adoption of emphasis is stable , or behind the variation of mosquito.

Second, whether the control activities are easy to be conducted could be another reason. Mosquito control is an important malaria control activities. In some areas, it is easier to be implemented, while in some areas, it is not easy. In China the mass campaign in malaria control played a very important role, mosquito control has always been chosen as a reason to launch a mass campaign, especially in urban areas. Mass campaign of mosquito control is easier to be launched in cities. such as in north east region. It contains 4 prefectures/cities, Kunming, Dongchuan, Chuxiong and Zhaotong. Both Kunming and Dongchuan are urban areas. But in south east and south west regions, most of these areas are rural areas, mosquito control is more different to be conducted, especially in some mountain areas, because of the limitation of transportation and the lack of other facilities. In some areas, staff have to draw support from horses and donkeys to carry out malaria control activities.

Third, the limitation of staff can also affect the implementation of mosquito control. Most of the work of mosquito control is conducted by the member of the anti-epidemic station of a county. In higher endemic areas, there could be not enough manpower to carry out mosquito control in every focal site, while preventive medicine can be delivered by other people.

Preventive medicine does protect susceptible population and has an effect reducing malaria incidence rate, but in economic terms, it takes more resources and get lower return compared with mosquito control in south east and south west regions in malaria control. Local government should adjust their policy. In these two regions if possible, government should improve mosquito control based on different reasons, supply essential facilities, invest more money on or move some money to this activity to increase the allocative efficiency

4.2.2 Analysis of allocative equity

The F-test: data showed in table 4.3 was used to do two way ANOVA analysis.

H_0 : $ME_{NE} = ME_{NW} = ME_{SE} = ME_{SW}$

F=5.54 P = 0.0062

It means that there are differences among these four regions. Following F-test, a Q test was used to analyze if there are differences among these regions pair by pair.

Table 4.6 The result of comparison of ME by regions

	North east	South east	South west
South east	.4267 (.0023)		
South West	.3809 (.0047)	-.0458 (.987)	
North west	.1172 (.825)	-.3095 (.134)	-.2637 (.241)

Note: The first line in each cell is the value of row - column. The second line in each cell is F value.

The result of the Q-test (Table 4.6) shows that there are differences among North east, South east and South west. The mean ME of North east region is lower than those two regions.

Because the incidence rate is higher in these two regions than in north east region, more resources are allocated in surveillance and anti-relapse therapy(Appendix E). Unfortunately we can not analyse the marginal effect of surveillance and anti-relapse therapy. Here we only consider the marginal effect of preventive medicine and mosquito control, the mean marginal effects of south east and south west are higher than north east. It means more resources are needed in these two regions compared with north east region.

The high prevalent area in Yunan province is along the international boundary line. There are 26 counties along the boundary line, they are distributed in the south east, south west and north west regions, almost half the patients of the province are from these counties, and 21 counties are in the south east and south west regions. If everybody should be treated equally in these two regions compared with people in north east region, or in other words, same social welfare weight should be put in every regions, more resources are needed in these two regions.

Wang Wenren (1993-1994) studied the malaria situation and control strategies along boundary areas in Yunnan province The result showed every year more than 4 million trips of foreigners and 2.5 million trips of residents pass the boundary line. It was estimated that foreigner brought in 13,560 malaria cases, local residents brought in from neighboring counties 4,312 cases to local areas, and mobile populations from other provinces took away 12,900 cases to other provinces.

Frequent commercial trade improves the economic status of the province and also brings more malaria transmission sources to the local areas. It is intended to open the gate widely in the boundary areas. It means the economic development will

come more and more to the province, and at the same time bring more and more problems to the local areas. With the development transportation and economy, malaria may easily spread to other counties or provinces. These regions become a forward position of anti-malaria activities, so more resources should be input to these areas.

The allocative equity used in the study is in accordance with allocative efficiency. There are two methods to improve the equity of resources allocation, i)to input more resources to the regions where the resources allocation is efficient, ii)to reallocate resources where the allocation of resources is far from ideal allocative efficiency. In south east and south west regions, the analysis of allocative efficiency showed that the resources allocation in preventive medicine and mosquito control are inefficiency. So government should improve the mosquito control based on different reasons. If there are not any more reources that can be input to these regions, government should move some resources from prevnetive medicine to mosquito control to increase the allocative efficiency, then improve the allocative equity. On the other hand, government should input more resources in these two regions, and input more resources on mosquito control.