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A Village-level Economic Evaluation of the Southwest Poverty Reduction Project

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A VILLAGE-LEVEL ECONOMIC EVALUATION OF THE SOUTHWEST

POVERTY REDUCTION PROJECT

By

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This research evaluates the post-program treatment effects of the Southwest Poverty Reduction Project (SWPRP), a large-scale ($463.55 million) rural development project jointly funded by the World Bank and the Chinese Government from 1995 to 2001. The SWPRP aimed at reducing poverty and increasing living standards for the absolute poor in southwest China. The treatment effects are measured by the changes in 21 indicators at the village level. The dataset for this research includes 327 project villages and 3887 non-project villages in Guangxi Zhuang Autonomous Region. Rigorous econometric methods are employed to remove selection bias. A probit model is established to investigate the selection rule of the project villages. In addition to the control function approach, different methods of propensity score matching such as nearest neighbor, caliper or radius, and kernel-based matching, are used to estimate the treatment effects, including the average treatment effect, average treatment effect on the treated, and average treatment effect on the untreated.

The evidence from the treatment effect estimations shows that the SWPRP achieved its overall objective but not necessarily all specific objectives. The evidence supports a statement of significant impacts on farming, off-farm employment, and infrastructure by the project investments, while there is no strong evidence to support a conclusion of significant impacts on primary education and rural healthcare services. The poverty rate in the project villages was reduced by about 3.0-3.3 percent and net income increased by about 24-26 Yuan. Further investigation of the specific treatment effects on individual villages expose that the treatment effects vary with land resources in the villages. Lastly, the project was successful in targeting the poorer villages but not necessarily the poorest.

This research also reveals some findings of practical relevance for social program design. The approach of integrated policies proves to be effective in large-scale poverty reduction. However, designers should be aware that households may trade off one activity against another to maximize their utility rather than simply follow the whole package of integrated activities. In addition, the minimization of operational costs of the project agents should not be detrimental to the effectiveness of the project.

Keywords: kernel-based matching, poverty, rural development, impact evaluation, China

JEL: D31, H43, I32, O22

DEDICATION

I would like to dedicate this research to my parents, Shengwei Mo and Qingxian Wei.

谨此献给我亲爱的父亲和母亲--莫胜位和韦庆仙。

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CHAPTER I

INTRODUCTION

The Southwest Poverty Reduction Project[1] (SWPRP) was a large-scale development project aimed at reducing poverty and increasing living standards for the absolute poor of southwest China. The project was funded jointly by the World Bank and by the Chinese government and targeted 1798 of the poorest villages. The project was implemented from June 1995 until December 2001. The project involved a total investment of $463.55 million which included low interest loans and grants for various development projects.

Any evaluation of the performance of the SWPRP should keep in mind the overall objectives of the project. The first objective[2] of the project was to demonstrate the effectiveness of approaching the task of poverty reduction on a large scale that integrated policies at the local and village level. Local integration has proven successful in projects of much smaller scale but has rarely been attempted at the scale of the SWPRP.

The second objective was to facilitate labor migration from the project villages, where the employment opportunities were few, to the urban areas where employment opportunities were much greater. During the project period, employment opportunities were much greater especially in the urban eastern provinces, due to intensive investment of capital from domestic and foreign sources. However, labor in remote rural areas had

[1] World Bank Project ID: P003639
[2] Report No: 13968-CHA (Agricultural Operation Division 1995, 23)

difficulty accessing these opportunities because of the lack of information and the high cost of commuting.

The third objective was to improve the capacity of poverty monitoring at both the national and local levels. Prior to the project, poverty was tracked by some individual governmental departments but there was no systematic monitoring at other levels.

The fourth stated objective, and the most important with regard to this study, was to "significantly reduce absolute poverty in 35 of the very poorest counties in southwestern China." [3] This was to be accomplished using village-level policies aimed at building infrastructure, providing education, improving health care services, and as mentioned above, improving labor mobility.

Previous attempts to measure the impact of the SWPRP include the Implementation Completion Report by the World Bank (Agricultural Operation Division 2003) and a recent World Bank report by Chen, Mu and Ravallion (2008). Citing the results of a survey by the National Statistics Bureau of China, the Implementation Completion Report indicates that the program was successful in increasing per capita income from 939 to 1422 Yuan and in reducing the poverty rate from 32 to 13 percent. However, these results are based merely by comparing pre-program and post-program respondents in the program area alone without comparison to a control group and without any attention to selection bias.

In a more rigorous study, Chen, Mu and Ravallion (2008) used the method of difference-in-difference matching in order to account for possible selection bias and examined the impact of the program by comparing participating and non-participating

[3]Report No:26132 (Agricultural Operation Division 2003, 2)

households. They showed that, relative to nonparticipants, the program significantly increased income, reduced poverty but did not increase consumption.

The research presented here differs from the above attempts by focusing on the village level impacts. One of the primary objectives of the project was to integrate policies and decision-making at the village level in order to reduce poverty. Program policies were targeted to villages and not individual households. Examining the results of the program at the village level provides a clearer picture of the benefits of integrative policies and the overall performance of the program. In addition, since the decision to participate in the program was made at the village level, examining the data at the village level allows a more careful consideration of any possible selection bias.

In this study we examine the impact of the SWPRP at the village level, not only by estimating per capita income and poverty rates, but also along several other indicators of well-being in rural China including housing type, livestock ownership, and agricultural production. Control function and matching techniques are used to calculate differences in these measures between participants and nonparticipants taking special care to account for selection bias. The adequacy of these methods is assessed and differences in the results will be studied. Finally, the village level effects are compared to the household level effects of Chen, Mu, and Ravallion (2008).[4]

The first step is to estimate a probit model for the project village selection process from a sample of 327 project villages and 3887 non-project villages. The purpose of this model is twofold. First, it is used to estimate the probability of participation, so called

[4] Chen, Mu, and Ravallion (2008) use difference-in-difference matching which compares pre-program and post-program outcome measures between the participating and non-participating households. Such pre- and post-data is not available at the village level which is being studied in this research and thus different estimation techniques will be employed. So, while the two studies are different in data and methodology, comparing the results should provide some additional information regarding the effects of the SWPRP.

propensity scores, for each individual village. Second, the results of the probit model are used to analyze the behavior of local project agents in determining which villages would be selected for participation in the project. We find that variables correlated with selection are also the same variables that indicate poverty. Therefore, it seems that the selection process was indeed successful in targeting poor villages. However, we also find that project agents selected villages with characteristics consistent with minimizing the operational cost of the program. As a result, the selected villages were not necessarily the poorest villages.

The second step is to estimate the average treatment effect (ATE), the average treatment effect on the treated (ATT), and the average treatment effect on the untreated (ATNT), using both the control function approach and the propensity score matching approach. Implementation of the control function approach was accomplished using a correlated random coefficient model (proposed by Heckman (1985)). This model allows us to investigate how the treatment effects vary with village characteristics. We find that the availability of land resources were the major source for heterogeneity of the treatment effects among participating villages. Propensity score matching was implemented using three different methods - nearest neighbor matching, caliper matching, and kernel-based matching. Each of these different methods produced similar results. We find that the SWPRP was successful in increasing net income per capita by about 24-26 Yuan and reducing the poverty rate by about 3.0-3.3 percent in 2000 when the investment in the project was completed.[5] Evidence of project success is also indicated by an increase in farming activities, off-farm employment, and rural infrastructure. However, our model

[5] The construction period of the SWPRP was officially considered from July 1995 to June 2001. However, in the financial management system of the World Bank, investments have to be fulfilled before the reimbursement. The investment in Guangxi was completed by 2000.

shows no evidence that the project had a significant positive impact on primary school enrollment or on the delivery of health care services in the project villages.

Our findings are similar to those of Chen, Mu and Ravallion (2008) but smaller in magnitude. This is expected because our estimated effects are at the village level, which includes both the participating and non-participating households, while their findings are at the household level. Our findings are of additional interest in that we demonstrate the effectiveness of the SWPRP strategy of targeting poor villages rather than the households.

In the next chapter, a brief profile of the SWPRP project is presented; a description of the affected Guangxi project area is provided; the dataset is described and the results of naïve comparisons of means are provided. In Chapter 3, the conceptual model for evaluating the project impacts and the methods used to account for selection bias are discussed. Chapter 4 presents the project village selection process and analyzes the probit results. In Chapter 5, the results of the correlated random coefficient model are reported and the variation in the specific treatment effects is discussed. Chapter 6 provides and discusses the estimation of the average treatments effects using three matching techniques. Finally concluding comments are provided as well as a comparison with previous research findings.

CHAPTER II

DESCRIPTION OF THE SOUTHWEST POVERTY REDUCTION PROJECT AND DATA FROM THE GUANGXI PROJECT AREA

The Southwest Poverty Reduction Project was designed to reduce poverty in three of China's undeveloped provinces. This research focuses specifically on one of the provinces, Guangxi Zhuang Autonomous Region (hereafter, Guangxi). This chapter provides a brief description of the overall project, a description of the Guangxi region, and a description of the dataset that will be used.

2.1 The Southwest Poverty Reduction Project

The Southwest Poverty Reduction Project (SWPRP) was a large-scale development project aimed at reducing poverty and increasing living standards for the absolute poor of southwest China. The project was funded jointly by the World Bank and by the Chinese government and targeted 1798 of the poorest villages in three provinces. The project was implemented from June 1995 until December 2001. The project involved a total investment of $463.55 million which included low interest loans and grants for various development projects.

The SWPRP invested in eight major components: rural primary education, rural basic healthcare services, rural infrastructure, labor mobility, agriculture, township and village enterprise (TVE),[6] institution building, and poverty monitoring. The details of

[6] According to the Township and Village Enterprise Law of the People's Republic of China, TVE refers to enterprises which provide support for agricultural production, owned collectively or by individual farmers, and based in townships and villages. An example would be a raw material processor.

these investments are indicated in Figure 2.1. In each component, the project aided the targeted areas with training, equipment, investment funds and technical service.

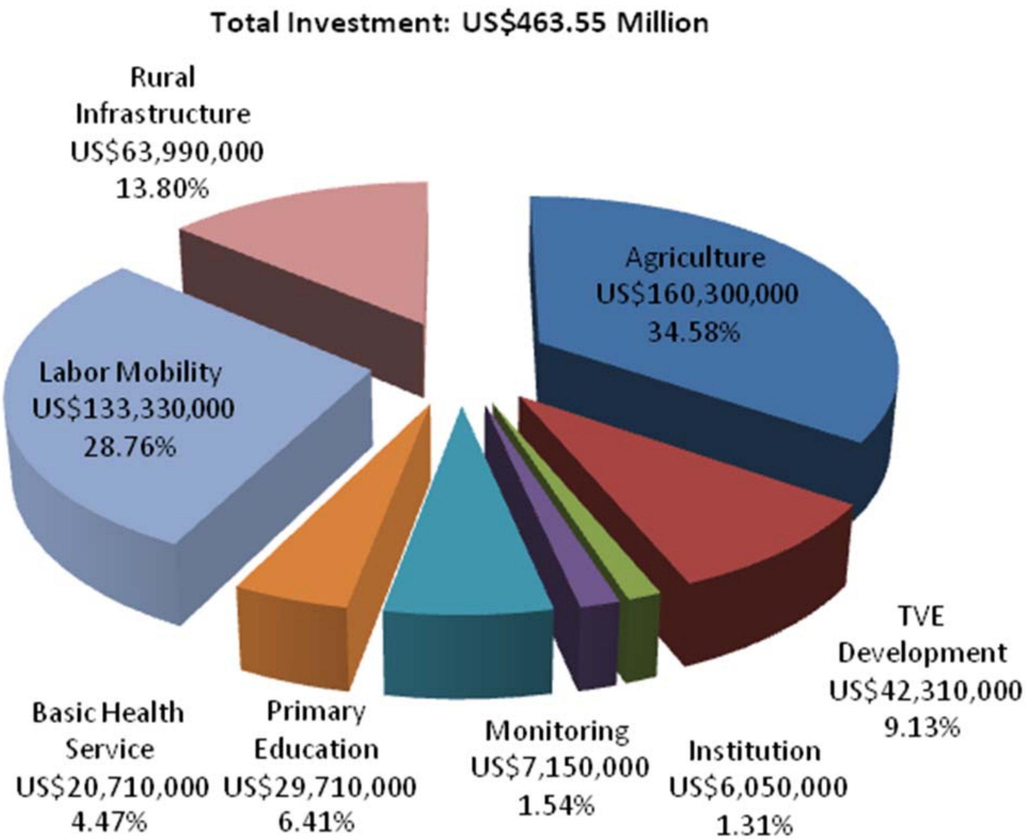

Figure 2.1 The Investment Components of the SWPRP

2.1.1 Education

The education component was designed to address the low educational attainment in the project villages. The official figures of the enrollment rate and the completion rate of children aged 7-15 in the project counties, prior to the project, was about 60 percent and 45 percent respectively (Agricultural Operation Division 1995, p. 14). These low numbers were assumed to be a result of the low quality in education delivery and difficult access to schools. To improve educational delivery and access, the project provided financial aid for school construction, equipment, teaching and school management training. In order to further encourage children from poor households to enroll and attend school, the project also subsidized tuition and nutrition. Unfortunately, according to the World Bank (Agricultural Operation Division 2003, p. 5-6), these subsidies proved ineffective in the project areas during the project period. Since no data, such as household income, was available to make an objective identification of the children from the poorer households, this portion of the project failed and was stopped soon after it began.

2.1.2 Healthcare

The healthcare component of the project was aimed at improving the accessibility of healthcare services to the poor. The problem of insufficient basic healthcare for the poor in rural China was due to two major issues: lack of local facilities and high cost of treatment at existing facilities. To address these issues, the project provided aid in establishing a health clinic in every project village. Doctors and nurses were trained and subsidized to serve in the clinics. Medical equipment was purchased and start-up funds were also provided for the purchase of medicine for each clinic. In addition to establishment of the clinics at the village level, equipment and training was also updated in hospitals at the township level. In order to help the poor in paying for their healthcare, the project attempted to establish a health cooperative at the village level. Households could choose to participate in the cooperative by paying a small registration fee, which would be matched by the project. Once registered, households would receive discounted services. Unfortunately, due to management challenges, this portion of the program was also halted shortly after its implementation (ibid, p. 6).

2.1.3 Infrastructure

The main issues to be addressed by the infrastructure component of the project were poor transportation and the shortage of drinking water. The World Bank (Agricultural Operation Division 1995, p. 16) reported that before the project more than 40 percent of the administrative villages in the project townships were without adequate access to roads and seasonal drinking water shortages plagued more than half of the project villages. The project improved transportation by constructing roads to the project villages that were without road access. In order to provide a supply of drinking water, the project provided subsidies for each household to purchase cement in order to construct a water tank which would store approximately 30 cubic meters of rain water.

2.1.4 Labor Mobility

Scarcity of arable land and the underdevelopment of a local industrial sector led to a large surplus of labor in the project villages; estimated to be as large as 33 percent prior to the project (ibid, p. 17). Conversely, intensive domestic and foreign investment led to rapid growth of industry and an excess demand for labor in the urban areas. However, due to lack of information and high transportation cost, laborers from the poor villages had difficulty accessing these off-farm employment opportunities. In order to alleviate these problems, the project provided training and financial support for transportation, and established a network to collect employment information and help companies recruit workers from the project villages.

2.1.5 Agriculture

Prior to the project implementation, agricultural activities in the project villages were basically for subsistence; only a small portion was used to exchange for necessities that could not be produced locally. Farming was carried out with limited arable resources using traditional technologies passed down for generations. According to project documents (ibid, p. 31), the aim of the agricultural component of the project was to update the farming industry so that a substantial and sustainable increase in farming income could be achieved. The project was designed to provide support for almost every agricultural activity including cropping and animal husbandry. To implement the agricultural component, local experts were hired to advise the project regarding agricultural production for food as well as cash. The primary emphasis was on tree, pig, cattle, and goat farming. The households in the project villages could choose the activities in which to participate according to their preferences and available resources. The technical training and other necessary support, such as improved crop variety, tree nurseries and financial credits were supplied based on the choices of the households.

2.1.6 Township and Village Enterprise (TVE)

A variety of agricultural products, including tropical fruit, tea, silk cocoon, herbal medicine, and forest products, were traditionally produced as raw materials for use in the manufacturing sector. The TVE component (ibid, p. 33) was designed to support local enterprises engaged in the processing of these agricultural products and at the same time to promote off-farm employment opportunities. Prior to the project, many of the existing TVEs used worn-out equipment and outdated technology passed down from the commune system. The project identified 95 agro-processing and 26 mining operations to receive project support based on the potential for job creation, commercial feasibility, environmental risk, skill training, and backward linkages to project households.

2.1.7 Institution Building and Poverty Monitoring

The purpose of these two components of the project (ibid, p. 34) was to improve and increase the capacity of government departments such as the Poverty Alleviation and Development Offices (PADOs) and the Project Management Offices (PMOs) at county, provincial and national levels in order to effectively manage the project and to monitor the effects of the project on reducing poverty.

2.2 The Guangxi Project Area

The overall project targeted poor rural villages in three provinces in southwest China, Guangxi Zhuang Autonomous Region, Guizhou Province, and Yunnan Province (see Figure 2.2). Within these provinces, the project covered 1,798 administrative villages in 290 townships in thirty-five project counties. This accounted for one-third of the administrative villages and one-half of townships within the project counties. The beneficiaries of the project included 2.8 million residents (604,000 households). Because of the availability of data, this research will focus on the effect of the project in the Guangxi Zhuang Autonomous Region.

A breakdown of the investments in Guangxi is shown in Figure 2.3. The total investment over the life of the project was approximately 1104.86 million Yuan (1 dollar ≈ 8.26 Yuan). Agriculture received nearly 45% of the project funds. The other largest spending categories were infrastructure, TVE, and labor mobility. As shown in Figure 2.4, the project covered only 12 counties in Guangxi. This included 515 villages in 91 townships and approximately 900,000 residents.

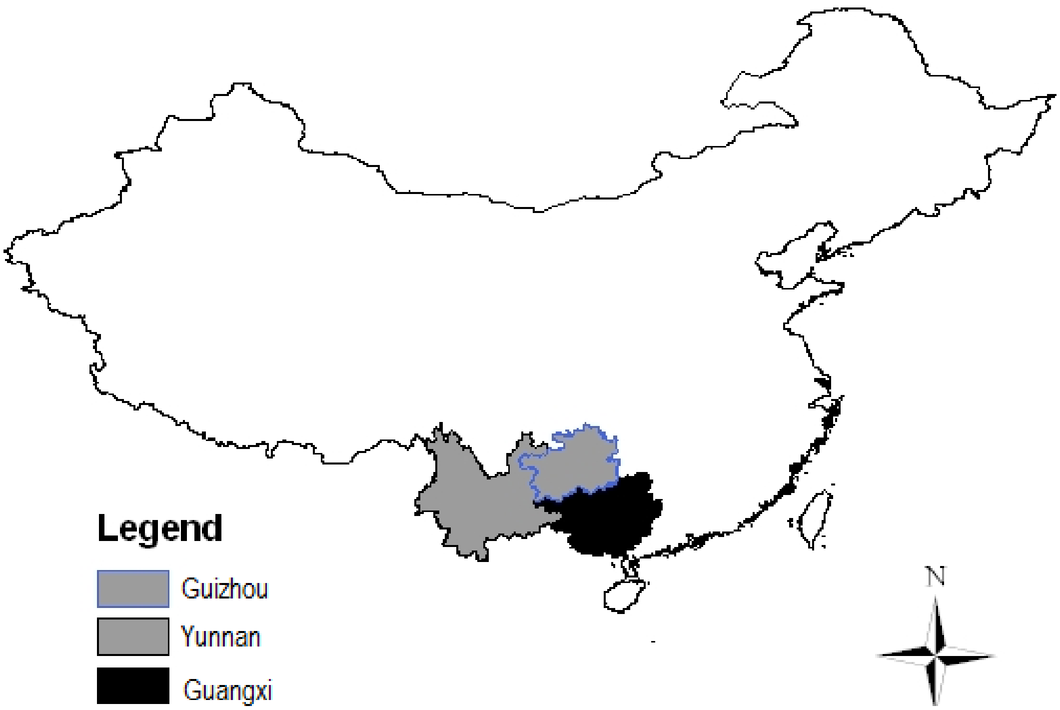

Figure 2.2 Map of China Showing the SWPRP Provinces

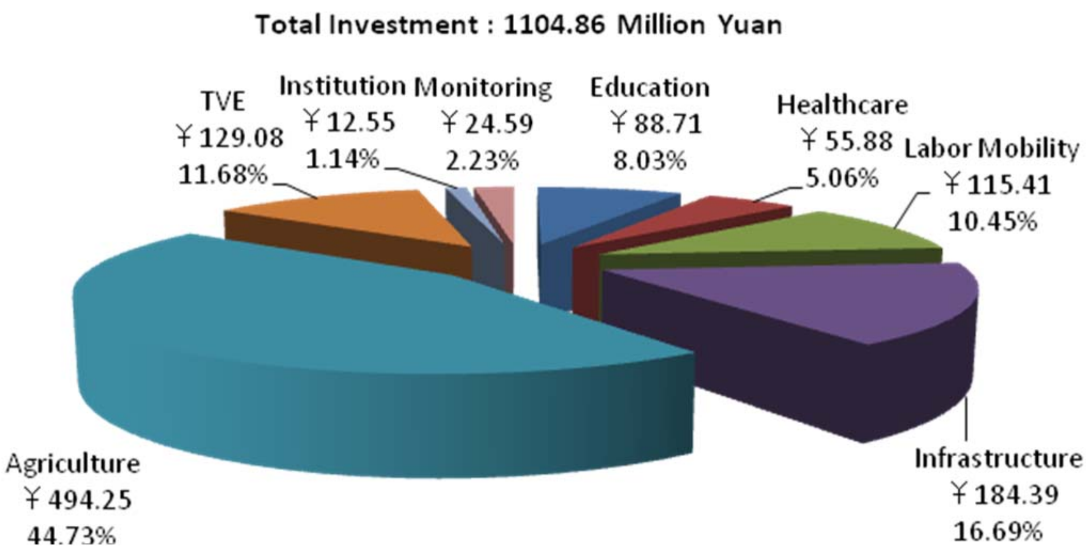

Figure 2.3 The Investment Components in Guangxi (Million Yuan)

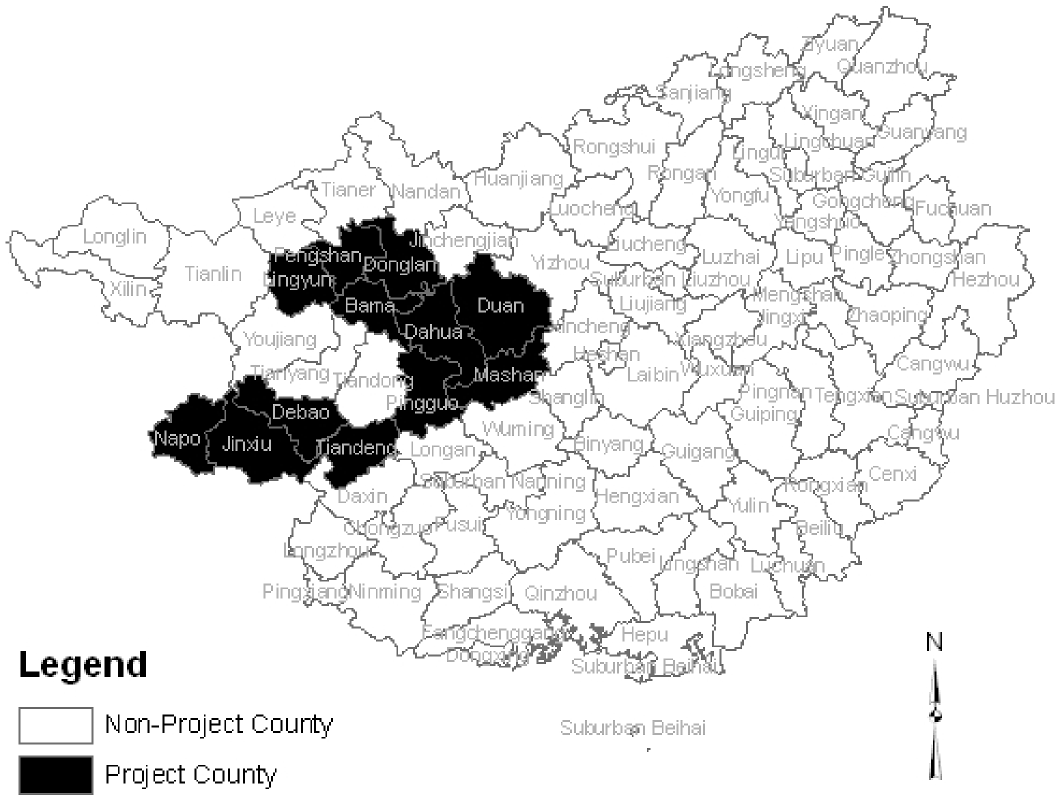

Figure 2.4 Map of Guangxi Showing the SWPRP Participating Counties

In the research presented here, a village refers to an administrative village. Administrative villages are the fundamental organizational units with defined boundaries in rural China. They have populations that range from one thousand to the tens of thousands. Within the administrative villages are “natural villages”, which refer to colonies of households ranging from several to over a hundred at particular geographic location. A township is comprised of several administrative villages and a county includes a number of townships. A city or prefecture governs several counties and a province or autonomous region includes a number of cities or prefectures. Provinces and autonomous regions are under the direct administration of the central government. These administrative layers are illustrated by the diagram in Figure 2.5.

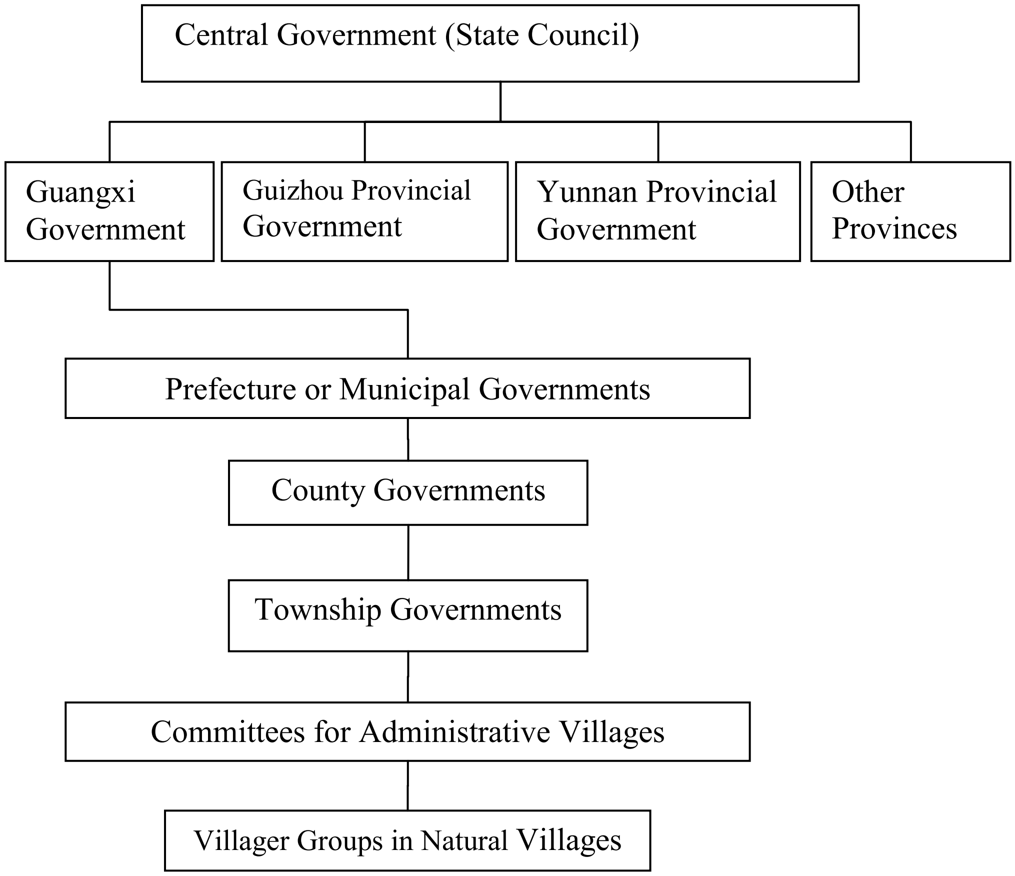

Figure 2.5 Diagram Showing the Public Administrative Layers in China

Specifically, targeting the "poorest of the poor" was central to the SWPRP. The Chinese Central Government defined a county as a being poor if its average annual income was below the poverty line (300 Yuan at the 1990 price) (Ravallion and Chen 2007, p. 5). Using this definition, 28 counties were identified in Guangxi as being poor. From these poor counties, 12 counties were selected for project participation in the SWPRP and within these 12 counties 515 administrative villages were selected to be eligible for aid under the project. The project villages are characterized by low income, lack of education and healthcare, scarcity of natural resources, mountain geography, and resided by ethnic minority. Details of the selection process are described in Chapter 4. Characteristics of the project area prior to the project are described below.

According the World Bank (Agricultural Operation Division 1995, p. 63), the annual net income per capita in Guangxi project counties ranged from 221 to 297 Yuan prior to the project. The population below the poverty line varies from 41.1 to 97.3 percent. Those living below the poverty line commonly suffered the cold and lack of food, especially between February and July. This is the so-called the hunger season because the grain stored from the previous year is running out and the new crop is not ready to harvest. Many of these households have to borrow food in order to survive. For a long periods living with low income, households failed to raise enough money to build a safe house. Due to these low income and lack of saving, a large proportion of the poor population lives in thatched houses which provide limited shelter. Needless to say, education and healthcare are luxury goods for the households in the project villages.

The World Bank project document (ibid, p. 63) also reported that the enrollment rate of the primary school varied from 70.6 to 93 percent in Guangxi project counties. The completion rate even was as low as from 56.1 to 78.8 percent. In China, primary school is compulsory education and financed by the government. At least one complete primary school was established in each administrative village to teach students from grades one to six. Several teaching points, branches of the complete primary school, might teach students of grade one to three in the large natural villages. The majority of teachers are hired by the government as permanent faculty for village schools. However, government-hired teachers might be reluctant to teach in remote villages due to the unfavorable living and teaching conditions. In these cases, local authorities have to raise funds from residents to hire temporary teachers. Inadequate funds lead to the employment of low quality temporary teachers. This is one of the major causes for the low education attainment in the project villages.

Healthcare services are available in the township hospitals. To reach these services, residents in the project villages have to travel an average of 12.7 kilometers. Meanwhile, the cost of medical care was high. In most case, healthcare service was not available in the project villages. A few villages have informal clinics operated by "bare-foot" doctors who are also part-time farmers. These clinics are not well equipped and the "bare-foot" doctors usually lack basic training.

Natural resources, including arable land and clean water, are scarce in the project villages. Farmland area per capita is 0.87 Mu[7] in the project villages. Farmland was allocated across households during the rural reforms of the early 1980s. Each resident share almost the same amount of farmland and the household size determines the total amount allocated to a household. Since the reform, this total amount remains fixed regardless of the change in household sizes. This relatively even distribution of farmland determined that all farms are small in size. Surface water is scarce. The majority of the project villages are not located close to rivers or lakes. Although the annual rainfall is as high as 1731 mm (ibid, p. 64), the rain water drains away easily through a well-developed underground river. The majority of the project villages lack an adequate supply of drinking water in the winter. In extreme cases especially those area within mountainous geography, residents have to travel as far as 4 kilometers to obtain drinking water in the winter.

The scarcity of natural resources is a serious problem especially when combined with the local geography. Villages in Guangxi can be geographically categorized into three types: flat land, hill, and mountainous villages. The mountainous regions are categorized as karst topography, which is characterized by limestone and underground

[7] Mu is a unit of land measure used in China; one Mu equals one fifteenth of a hectare or about 0.17 acres.

rivers. The majority of the project villages are of geography of this type. This geography is also prevalent in our dataset (96.7 percent, 316 out of 327 villages). In these mountainous villages, the natural villages are usually enclosed by steep rocky peaks or high slope mountains. These mountains form a football-stadium-like valley and the natural villages usually perch on the bottom or a side of the mountain. Though there is some flat land on the bottom, the majority of land is not cultivatable because of the steep slope and the rocky surface. This particular landscape, combining with the seasonal local weather, results in serious natural disasters. In the summer, the rainfall is concentrated and accounts for about 80 percent of the total annual waterfall. The rain water runs down the mountain slopes quickly and pools on the bottom of the small valley. When this happen, all crops on the flat land are flooded and lost. In the drought season of winter, the surface water disappears into the underground river. Meanwhile, top soil on the slope land is washed away by the heavy rains, which lead to the low productivity and low incomes in the villages. Improving the productivity and income in the mountainous villages is difficult because they are isolated by the mountains from receiving information regarding new technology and access to markets.

Other factors that isolate the project villages in Guangxi are the cultural differences. In China, Han is the majority ethnic group and the others such as Zhuang and Yao are in the minority. However, as shown in our dataset, the non-Han ethnic groups including Zhuang and Yao are the majority and account for 86.3 percent population of the project villages. The major differences among the ethnic groups are their languages. Although Chinese is taught in all schools in China, the non-Han minorities maintain their languages after school. In addition to the low quality of education in the minority areas, the non-Han laborers usually have lower Chinese language communicating skills. As a result, they have less opportunity to work outside their communities.

2.3 Description of the Data of Guangxi Project Area

Data for this research comes from a village-level survey of 327 project villages and 3887 non-project villages in 2000, the fifth year of the project. The survey was conducted by the Poverty Alleviation and Development Office (PADO) in Guangxi Zhuang Autonomous Region. The sample of project villages accounts for 63% of the 515 project villages in the region.

In order to evaluate the impact of the SWPRP, twenty-two outcome measures were chosen from the survey. These measures are listed in Table 2.1 along with the means and standard deviations of the project villages, the non-project villages and the pooled sample of project and non-project villages. In the table, incomes and poverty rates are computed at the 2000 price, and Chinese government adopts a poverty line of 826 Yuan since 2000. The table also shows the results of t-tests comparing the means of the outcome measures for the project and non-project villages.

The simple comparison of means indicates that villages participating in the SWPRP have significantly higher incomes, better housing, greater labor mobility, more livestock, and a more reliable water supply. However, these results also indicate that the project villages have lower school enrollment and reduced access to physicians.

It is important to note that the above simple comparison of means is a naïve comparison without any consideration of bias. Our dataset is in fact the observations on the treated and untreated sample from a quasi-experiment or non-experiment because the treated and the untreated sample have not been assigned randomly. The naïve comparison may suffer from the problem of invalidity. Mayer (1995) summarized nine possible internal threats and three external threats to the validity of non-experiments. The internal threats include (1) omitted variables, (2) trends of outcomes, (3) miss-measurement, (4) misspecification of variances (homogeneous or heterogeneous), (5) political economy, (6) selection, (7) attrition, (8) simultaneity, and (9) interaction between selection and assignments. The external threats are (1) interaction between treatment and selection, (2) interaction between setting and treatment, and (3) interaction between historical events and treatment. In the case of the SWPRP, some of these threats are likely to occur and lead to bias in impact evaluation.

Unobservability arises from the unobservable counterfactuals and omitted variables that might affect outcomes and project participation. The problem of counterfactuals will be discussed in more detail in later chapters. Examples of omitted variables are unobservable political influence, soil type, and local weather. Political influence is unobservable while soil type and local weather are observable but no data is available at the village level.

The project implementation spanned a period of six years. The outcome path of each village may have their own time trends. This time-variant property may cause bias in impact evaluation.

Miss-measurement may occur in the survey data as a result of estimation rather than measurement. For variables such as land and distance, the miss-measurement may be trivial. However, for variables such as crop production and income, data are estimated rather than actually measured. The households may fail to recall their production and income accurately since the survey is retrospective.

Project impacts may be heterogeneous among the individual villages. The impacts of the project are achieved through the interaction between the project investment and the village characteristics. The differences in investment activities and village characteristics may result in different outcomes in particular villages.

The problem of selection is obvious. The SWPRP targeted the poor villages by choosing the lower income villages. The project villages may be incomparable to the non-project villages. Politics might also play a role in the selection process of the project villages since the process involved many local representatives with different interests. This non-random assignment of project villages is the major source of bias.

The other possible source of bias is from historical events. Our dataset includes villages from two types of counties, the state-defined poor counties and the state-defined non-poor counties. The poor villages from the state-defined poor counties were eligible to receive aid from the central government prior to the SWPRP while the poor villages from the state-defined non-poor counties were not.

Attrition is not a problem in our dataset since no project village withdrew from the project.

Due to the cross-sectional dataset, we are not able to control for the time-variants and the error of miss-measurement. However, measures can be employed to minimize the bias from historical events, unobservability, heterogeneity, and selection bias. To control for the historic bias, we exclude the villages from the state-defined non-poor counties from the original dataset. The new dataset for the models established in later chapters includes 327 project villages and 2214 non-project villages from state-defined poor counties. In this research, models constructed by control function method and matching method are used to evaluate the project impact controlling for the possible bias from unobservability, heterogeneity, and selection bias. The subsequent chapters describe this bias in more detail and describe the modeling techniques that will be used to account for it.

Table 2.1 Descriptions and t-tests for the Indicators of Outcomes and Impacts

Variables	Pooled Sample		Non-project Villages		Project Villages		T Tests	
	Mean	Std Error	Mean	Std Error	Mean	Std Error	Mean Diff.	P-Value
Wealth and Income								
Net Income per Capita (Yuan)	708.72	2.41	705.77	2.48	743.82	9.29	38.06	<.0001
Income Per Household in Cash (Yuan)	2006.76	17.77	1984.71	18.60	2268.90	58.01	284.19	<.0001
Income Per Household in Kind (Yuan)	1874.02	33.20	1865.65	35.58	1973.45	64.63	107.79	0.39
Percentage of Households under the Poverty Line (826 Yuan)	49.72	0.42	49.97	0.43	46.72	1.46	-3.25	0.04
Percentage of Households Living in Brick-tiled Houses	40.90	0.55	39.84	0.57	53.57	1.86	13.73	<.0001
Percentage of Households Living in Thatched Houses	51.20	0.58	52.30	0.61	38.06	1.84	-14.24	<.0001
Percentage of Household with TV Set	29.18	0.36	29.47	0.37	25.74	1.26	-3.73	0.01
Off-farm Employment								
Percentage of Male Labor Employed Off-farm	22.03	0.29	21.26	0.30	31.25	1.14	9.99	<.0001
Percentage of Female Labor Employed Off-farm	18.18	0.24	17.62	0.25	24.83	0.94	7.21	<.0001
Agriculture								
Value of Agricultural Products per Capita (Yuan)	655.45	11.97	662.08	12.14	576.60	54.49	-85.48	0.06
Grain Production per Capita (KG)	251.82	1.83	253.78	1.94	228.55	4.78	-25.23	0.00
Food Crop Growing Area per Capita (Mu)	1.15	0.01	1.13	0.01	1.32	0.04	0.19	<.0001
Cash Crop Growing Area per Capita (Mu)	0.37	0.01	0.38	0.01	0.21	0.02	-0.17	<.0001
Pigs in Stock per Capita at the End of the Year (Head)	0.51	0.01	0.49	0.01	0.66	0.02	0.17	<.0001
Cattle in Stock per Capita at the End of the Year (Head)	0.26	0.00	0.26	0.00	0.25	0.01	-0.01	0.37
Goats in Stock per Capita at the End of the Year (Head)	0.17	0.01	0.14	0.01	0.54	0.11	0.40	<.0001
Infrasture Service								
Days Accessible by Vehicles	213.56	2.15	209.06	2.25	267.06	6.54	58.00	<.0001
Percentage of Population with Water Shortage	52.92	0.47	54.00	0.49	40.17	1.46	-13.83	<.0001
Education and Health Service								
Primary School Enrollment Rate	93.27	0.14	93.20	0.15	94.13	0.46	0.93	0.08
Population-Doctor Ratio	1012.74	14.09	995.77	14.84	1214.49	41.72	218.72	<.0001
Percentage of Immunized Children	89.63	43.45	89.90	39.90	86.46	24.69	-3.45	0.12

Note: Mu is a unit of land measure used in China; one Mu equals one fifteenth of a hectare or about 0.17 acres.

CHAPTER III

METHODOLOGY

To model the impact of the SWPRP, two issues need to be addressed at the outset --unobservability of counterfactuals and selection bias. This chapter describes these problems and the methodologies that are used to account for their presence.

3.1 Conceptual Model

The problem that the researcher faces is how to calculate the effect of a policy or program (usually called the "treatment" in the literature) on program participants in the absence of an explicitly formed control group.

To illustrate consider a policy maker evaluating the effectiveness of a voluntary public health program for villages in rural China. One obvious measure of effectiveness (if data were available) would be to compare the infant mortality rates between program participants and non-participants at some time after the program has been completed. However, such a simple comparison assumes that (1) there is no self-selection problem, i.e., the variables which affect the choice of whether or not to participate in the program do not affect the outcome measure; and (2) the variables that affect the outcome measure and the way that they affect the outcome measure are the same for participants and non-participants. For example, a self-selection problem may arise if the villages that choose to participate in the public health program were those villages with the better water and sewage systems. In this case, the effectiveness of the program would be biased upward. Further, it may be the case that those villages that participate in the program have a better education infrastructure, and as a result, while this did not affect their decision to participate in the program, this variable does affect the outcome measure differently in the participant population than it does in the non-participant population.

Instead of simply measuring the differences in outcomes between participants and nonparticipants, one could measure the effect of the treatment or policy as the difference in some outcome measure between the participants in the treatment and their "counterfactual" outcome measure, i.e., their hypothetical outcome measure if they had not participated in the program. Since it is impossible to observe data for individuals that are simultaneously both participants and non-participants, the counterfactual data must be estimated and is usually estimated using data from the non-participants. Again, however, researchers must account for selection bias.

In order to examine these issues further[8], consider measuring the treatment effect of program participation based on some measurable outcome y. The researcher can observe the outcome measure for the treated villages, y_i^1, and for untreated villages, y_i^0, where we assume

$$y_i^1 = \beta^1(X_i) + u_i^1 \qquad (3.1)$$

$$y_i^0 = \beta^0(X_i) + u_i^0 \qquad (3.2)$$

where $\beta^1(X_i)$ and $\beta^0(X_i)$ are general functional forms, not necessarily linear, relating the outcome measures to village level characteristics, X and where we assume $E[u_i^1] = E[u_i^0] = 0$. The superscript 1 and 0 represent the treated and untreated by the project. The subscript i denotes individual villages, i=1, 2, 3… n and n denotes the sample size. The impact of the program is given as the difference in outcome measures between the treated

[8] This discussion follows Blundell and Dias (2008).

and untreated villages. Allowing for possible heterogeneous effects across villages, this "treatment effect" is defined by

$$\alpha_i \equiv y_i^1 - y_i^0$$
$$= \beta^1(X_i) - \beta^0(X_i) + u_i^1 - u_i^0 \quad (3.3)$$

Participation in the program is determined by some selection rule. Let d be an indicator of participation where d=1 indicates participation and d=0 indicates nonparticipation. Further, suppose that participation is based on the following selection rule

$$\mathrm{d_i} = \begin{cases} 1 & \text{if } \mathrm{g(Z_i}, v_\mathrm{i}) \geq 0 \\ 0 & \text{otherwise} \end{cases} \quad (3.4)$$

where the function g(·) might represent the expected utility function of the program administrator and where Z and *v* are observable and unobservable variables (to the researcher) affecting the participation decision. Using d as an indicator, we can write an equation for the treatment effect on village i as

$$y_i = \mathrm{d_i} y_i^1 + (1 - \mathrm{d_i}) y_i^0 \quad (3.5)$$

or

$$y_i = \beta^0(X_i) + (\beta^1(X_i) - \beta^0(X_i) + u_i^1 - u_i^0)\mathrm{d_i} + u_i^0$$
$$= \beta^0(X_i) + \alpha_i \mathrm{d_i} + u_i^0 \quad (3.6)$$

where we further assume that u_i^1, u_i^0 and v_i are independent of Xi and Zi.

The goal of the researcher is to derive an estimate of the treatment effect, α_i, being careful to account for any bias that may arise in the estimation process. Inspection of equation (3.6) reveals that two types of bias may arise due to the selection process. The first occurs if u_i is correlated with d_i (or equivalently with either Z_i or v_i). This implies that some unobservable characteristics affecting the outcome measure also affect the selection into the program. The second form of selection bias occurs if α_i is correlated with d_i (or equivalently with either Z_i or v_i). This arises if villages are selected based upon their expected gains arising from participation. Several estimation methods have been suggested to account for these forms of bias. The three most common approaches are methods of matching, control function, and instrumental variables. Due to data limitations in this study, the use of instrumental variables will not be considered. The control function and matching approaches will be discussed in the next section.

Before proceeding it will prove useful to introduce some common alternative measures of program participation. Instead of estimating the individual effects of participation (α_i) most researchers estimate some form of average effect across a particular subpopulation. The most common measures used in the literature are described below.

The average treatment (participation) effect, ATE, measures the effect of the treatment on a randomly chosen village. Mathematically, for an individual village

$$\begin{aligned} ATE(X_i) &= E[\alpha_i|X_i] \\ &= E[(\beta^1(X_i) - \beta^0(X_i) + u_i^1 - u_i^0)|X_i] \\ &= \beta^1(X_i) - \beta^0(X_i) \end{aligned} \tag{3.7}$$

and for the population as a whole

$$\begin{aligned} \mathrm{ATE} &= E[\alpha_i] \\ &= \int \mathrm{ATE}(\mathrm{X_i})\mathrm{dF}(\mathrm{X}) \\ &\approx \frac{1}{\mathrm{n}}\sum_{\mathrm{i=1}}^{\mathrm{n}} \mathrm{ATE}(\mathrm{X_i}) \end{aligned} \tag{3.8}$$

The average treatment effect on the villages assigned to treatment, ATT, is defined as

$$\begin{aligned} TT(X_i, Z_i, \mathrm{d_i} = 1) &= E[\alpha_i|X_i, Z_i, \mathrm{d}_i = 1] \\ &= E[(\beta^1(X_i) - \beta^0(X_i) + u_i^1 - u_i^0)\big|X_i, Z_i, \mathrm{d}_i = 1] \\ &= \beta^1(X_i) - \beta^0(X_i) + E[(u_i^1 - u_i^0)\big|X_i, Z_i, \mathrm{d}_i = 1)] \\ &= \beta^1(X_i) - \beta^0(X_i) + \mathrm{E}[(u_i^1 - u_i^0)\big|\mathrm{X_i}, \mathrm{Z_i}, \mathrm{g}(\mathrm{Z_i}, v_\mathrm{i}) \geq 0] \\ &= \beta^1(X_i) - \beta^0(X_i) + \mathrm{E}[(u_i^1 - u_i^0)\big|\mathrm{g}(\mathrm{Z_i}, v_\mathrm{i}) \geq 0] \end{aligned} \tag{3.9}$$

The latter equality following from independence of u_i^1, u_i^0 and v_i from X_i and Z_i.

Integrating over X_i and Z_i for all those receiving treatment yields

$$\begin{aligned} ATT &= E[\alpha_i | d_i = 1] \\ &= \int ATE(X_i, Z_i, d_i = 1) dF(X, Z | d_i = 1) \\ &\approx \frac{1}{n_1} \sum_{i=1}^{n} d_i ATT(X_i, Z_i, d_i = 1) \end{aligned} \tag{3.10}$$

where n_1 is the number of villages receiving treatment and $n=n_1+n_0$, where n_0 is the number of villages not receiving treatment.

Lastly, the average treatment effect on a village that was not assigned to treatment, ATNT, is defined as

$$\begin{aligned} ATNT(X_i, Z_i, d_i = 0) &= E[\alpha_i | X_i, Z_i, d_i = 0] \\ &= E[(\beta^1(X_i) - \beta^0(X_i) + u_i^1 - u_i^0) | X_i, Z_i, d_i = 0] \\ &= \beta^1(X_i) - \beta^0(X_i) + E[(u_i^1 - u_i^0) | X_i, Z_i, d_i = 0] \\ &= \beta^1(X_i) - \beta^0(X_i) + E[(u_i^1 - u_i^0) | X_i, Z_i, g(Z_i, v_i) < 0] \\ &= \beta^1(X_i) - \beta^0(X_i) + E[(u_i^1 - u_i^0) | g(Z_i, v_i) < 0] \end{aligned} \tag{3.11}$$

Integrating over X_i and Z_i for all those not receiving treatment yields

$$\begin{aligned} ATNT &= E[\alpha_i | d_i = 0] \\ &= \int ATNT(X_i, Z_i, d_i = 0) dF(X, Z | d_i = 0) \\ &\approx \frac{1}{n_0} \sum_{i=1}^{n} (1 - d_i) ATE(X_i, Z_i, d_i = 0) \end{aligned} \tag{3.12}$$

The goal of this research is to estimate ATE, ATT, and ATNT for the outcome measures listed in Table 2.1 while accounting for selection bias. The next section describes the control function and matching methods that will be implemented.

3.2 Empirical Model and Estimation Methodology

3.2.1 Control Function Approach

This approach was developed by Heckman (1979,1996) and is sometimes called the Heckit procedure. Assuming the functions in (3.1) and (3.2) are linear, the outcome measures for the treated and the untreated are given by

$$y_i^1 = \beta^1 X_i + u_i^1 \tag{3.13}$$

$$y_i^0 = \beta^0 X_i + u_i^0 \tag{3.14}$$

For simplicity, we also assume that the selection rule given in (3.4) is linear,

$$d_i = \begin{cases} 1 & if \ \ \gamma' Z_i - v_i \geq 0 \\ 0 & if \ \ \gamma' Z_i - v_i < 0 \end{cases} \tag{3.15}$$

where γ is the coefficient in the selection function, and where u_i^1, u_i^0 and v_i are independent of X_i and Z_i and,

$$\begin{bmatrix} v_i \\ u_i^1 \\ u_i^0 \end{bmatrix} \sim N(0, \begin{bmatrix} 1 & \sigma_{1v} & \sigma_{0v} \\ \sigma_{1v} & \sigma_1^2 & \sigma_{10} \\ \sigma_{0v} & \sigma_{10} & \sigma_0^2 \end{bmatrix} \tag{3.16}$$

The treatment effect as measured by ATE is conditional only on the covariates X and not on the selection rule. Thus, estimation of the unconditional ATE follows that given in equation (3.8) repeated here as

$$ATE = \bar{X}(\beta^1 - \beta^0) \tag{3.17}$$

The estimation of the average treatment effect on the treated, ATT, is dependent upon the selection criteria. As presented in the previous section,

$$\begin{aligned} ATT(\alpha_i | d_i = 1) &= \int ATT(X_i, Z_i, d_i = 1) dF(X, Z | d = 1) \\ &\approx \frac{1}{n_1} \sum_{i=1}^{n} d_i ATT(X_i, Z_i, d_i = 1) \end{aligned} \tag{3.18}$$

where

$$\mathrm{ATT}(\mathrm{X_i}, \mathrm{Z_i}, \mathrm{d_i} = 1) = \mathrm{X_i}\left(\beta^1 - \beta^0\right) + \mathrm{E}[u_i^1 - u_i^0 | v_i \geq -\gamma' Z_i] \qquad (3.19)$$

Given the distributional assumptions above,

$$E[u_i^1 | v_i \geq -\gamma' Z_i] = \rho_1 \sigma_1 \frac{\phi(\ ' Z_i)}{\Phi(\gamma' Z_i)} \qquad (3.20)$$

and

$$E[u_i^0 | v_i \geq -\gamma' Z_i] = \rho_0 \sigma_0 \frac{\phi(\ ' Z_i)}{\Phi(\gamma' Z_i)} \qquad (3.21)$$

where $\rho_j = \frac{cov(u^j, v)}{\sigma_j} = \frac{\sigma_{jv}}{\sigma_j}$ is the correlation coefficient between u^j and v, j=1,0 and where $\phi(\cdot)$ and $\Phi(\cdot)$ are the standard normal density and distribution functions, respectively. Substituting these relations in the conditional measure

$$\mathrm{ATT}(\mathrm{X_i}, \mathrm{Z_i}, \mathrm{d_i} = 1) = \mathrm{X_i}\left(\beta^1 - \beta^0\right) + (\rho_1 \sigma_1 - \rho_0 \sigma_0) \frac{\phi(\ ' Z_i)}{\Phi(\gamma' Z_i)} \qquad (3.22)$$

which can be substituted in the equation below to obtain the unconditional measure

$$ATT(\alpha_i | \mathrm{d_i} = 1) \approx \frac{1}{\mathrm{n_1}} \sum_{\mathrm{i=1}}^{\mathrm{n}} \mathrm{d_i} \mathrm{ATT}(\mathrm{X_i}, \mathrm{Z_i}, \mathrm{d_i} = 1) \qquad (3.23)$$

Similarly, the conditional measure for the average treatment effect on the untreated is given by

$$\mathrm{ATNT}(\mathrm{X_i}, \mathrm{Z_i}, \mathrm{d_i} = 0) = \mathrm{X_i}(\beta^1 - \beta^0) + (\rho_1 \sigma_1 - \rho_0 \sigma_0) \frac{\phi(\ ' Z_i)}{1 - \Phi(\gamma' Z_i)} \qquad (3.24)$$

from which the unconditional measure can be calculated as

$$ATNT(\alpha_i | \mathrm{d_i} = 0) \approx \frac{1}{\mathrm{n_0}} \sum_{\mathrm{i=1}}^{\mathrm{n}} (1 - \mathrm{d_i}) \mathrm{ATNT}(\mathrm{X_i}, \mathrm{Z_i}, \mathrm{d_i} = 0) \qquad (3.25)$$

In order to estimate these treatment effects empirically, the following two-step procedure is implemented,

i. Obtain $\hat{\gamma}$ from a probit model on the selection into the program.

ii. Compute the selection terms $\frac{\phi(\hat{\ }' Z_i)}{\Phi(\hat{\gamma}' Z_i)}$ and $\frac{\phi(\hat{\ }' Z_i)}{1 - \Phi(\hat{\gamma}' Z_i)}$.

iii. Run the appropriate regressions for the treated and untreated groups with the inclusion of the appropriate selection-correction terms attained in step (ii).

iv. Given the results of the regressions, estimate the various conditional and unconditional treatment effect measures.

3.2.2 Matching Approach

The purpose of matching is to try to create an ex-post control group among the untreated by matching those in the untreated group with those that are most similar in the treated group. Theoretically, if all the assumptions are satisfied, the only difference between the matched groups is participation in the program of interest.

Matching occurs on the covariates, X. In order for the control group to be formed correctly it must be that the untreated outcomes and the treated outcomes are independent of the decision to participate. Formally, we require

$$y_i^0 \perp d_i | X_i \text{ and } y_i^1 \perp d_i | X_i \quad (3.26)$$

where the symbol "⊥" means "is independent from". Thus, for each observation in the treated set, we can look for elements in the untreated set with the same X characteristics. These matched untreated observations are then used to predict the unobserved counterfactuals $E[y_i^0|d_i = 1]$ and $E[y_i^1|d_i = 0]$ which are in turn used to calculate the treatment effects ATE, ATT, and ATNT.

Using X to create a matched group among the untreated is only possible if the covariates do not predict participation exactly, formally we require,

$$0 < Prob[d_i = 1|X] < 1 \quad (3.27)$$

Obviously, care must be taken to choose the appropriate set of covariates. An inappropriate choice may lead to a violation of (3.26), (3.27), or both.

Given a proper choice of X, matching typically involves the use of a "propensity score" defined as the probability of program participation,

$$P(X) \equiv Prob[d = 1|X] \quad (3.28)$$

which is commonly estimated using logit or probit. Rosenbaum and Rubin (1983) show, if assumption (3.26) holds, the following also holds.

$$y_i^0 \perp d_i|P(X_i) \text{ and } y_i^1 \perp d_i|P(X_i) \quad (3.29)$$

Observations in the untreated population are then matched with treated observations based on comparisons of propensity scores using several alternative techniques.

To illustrate, let P_i^1 and P_j^0 be the propensity scores associated with a treated observation i and an untreated observation j, respectively. In nearest neighbor matching, a given number of observations in the untreated population with P_j^0 closest to P_i^1 are selected as observation i's matched group. Under kernel-based matching, all untreated observations within a predefined neighborhood of P_i^1 are selected as the matched group. Once a matched group has been selected, the treatment measures ATT, ATE, and ATNT can be estimated and standard errors can be constructed.

Estimation of a probit model using maximum likelihood provides us with an estimate of the propensity score, the probability of participation in the program, given by

$$\begin{aligned}\hat{P}(X_i) &= Prob[participation_i] \\ &= \Phi[\gamma' X_i] \end{aligned} \quad (3.30)$$

where Φ is the standard normal distribution function, X_i is a set of variables for village i believed to influence the participation choice, and γ is the vector of estimated coefficents. The choice of the variables in the characteristic X will be discussed in Chapter 4.

Using the estimated propensity scores, several different matching methodologies will be employed to create the appropriate control groups for each village. Once the set of control villages is created, the average treatment effect will be calculated as

$$\begin{aligned} ATE &= \frac{1}{n}\sum_{i=1}^{n}\left(y_i^* - y_i^C\right) \\ &= \frac{1}{n}\sum_{i=1}^{n} ATE_i \end{aligned} \quad (3.31)$$

where n is the total number of villages, y_i^* is the outcome measure of a village (either a participant or nonparticipant) and y_i^C is the average (possibly weighted as discussed below) outcome measure of village i's control group. The average treatment effect on the treated will be computed as

$$\begin{aligned} ATT &= \frac{1}{n_1}\sum_{i=1}^{n_1}\left(y_i^1 - y_i^{C_0}\right) \\ &= \frac{1}{n_1}\sum_{i=1}^{n_1} ATT_i \end{aligned} \tag{3.32}$$

where n_1 is the number of villages participating in the program, y_i^1 is a participating village, and $y_i^{C_0}$ is that village's control group of nonparticipating villages. Finally, the average treatment effect among the nonparticipating villages will be calculated as

$$ATNT = \frac{1}{n_0}\sum_{i=1}^{n_0}(y_i^0 - y_i^{C_1}) \tag{3.33}$$

where n_0 is the number of villages participating in the program, y_i^0 is a participating village, and $y_i^{C_1}$ is that village's control group of participating villages.

This study will employ the following matching procedures: nearest neighbor matching, caliper matching, and kernel matching.

3.2.2.1 Nearest Neighbor Matching

In its simplest form, single nearest neighbor matching matches each participating village to the closest nonparticipating village where "closeness" is measured in terms of propensity score. The nearest neighbor becomes the control group for the participating village. Similarly, nearest neighbor controls are found for the non-participating villages as well. If village j is the closest nonparticipating village to participating village i, it is not necessarily the case that village i is also the closest participating village to village j.

Nearest neighbor matching can be carried out "without replacement" or "with replacement." Matching without replacement allows each village to be used as a control village only once. In this case, if a nonparticipating village is the nearest neighbor to two or more participating villages, it will only be matched to one participating village. The other participating villages will have to then be matched with nonparticipating villages that are further away and thus, less similar. This will result in an increased bias when estimating treatment effects. In contrast, matching with replacement allows each nonparticipating village to be used more than once. Thus each village is matched with its most similar village in the other group. The drawback to matching with replacement means that a potentially smaller sample of villages will be used as controls. This results in an increased variance of the treatment effect measures. The study will employ nearest neighbor matching "with replacement" in order to reduce the bias in the treatment effect measures.

The variance and bias of the treatment effect estimates is also affected by increasing the number of neighbors or matches. In M nearest neighbor matching, each village is matched with the closest M villages in the other group. The average outcome measure of these closest M neighbors becomes the control measure used in the calculation of the treatment effects. As M increases, observations that are further away (less similar) are matched which increases the bias but decreases the variance of the treatment effect estimates. The risk of increasing bias can be reduced by limiting the distance in which neighbors can be matched or by giving different weights to the matches based on their distance away. This study will examine the sensitivity of the results to changes in the number of neighbors used.

3.2.2.2 Caliper Matching

While M nearest neighbor matching uses the M closest observations in the other group as matches, without regard to distance, radius caliper matching matches all neighbors within a specified distance. Another form of caliper matching mentioned above is to match the M nearest neighbors within a specified distance. Caliper matching may increase the number of matched observations and at the same time avoid bad (far away) matches. Therefore, it can reduce the bias and decrease the variance of the treatement effect estimates. The size of the caliper (distance) must be chosen carefully. Too small a caliper may result in no matches and too large a caliper may result in poor matches. This study will examine the sensitivity of the results to the choice of caliper size.

3.2.2.3 Kernel-Based Matching

Rather than using only a predetermined number of "close" observations or the observations within a predefined "distance" to create a control group, kernel matching creates a control group from all or nearly all of the observations in the comparison group. Each participating village is matched with a weighted average of the villages in the comparison group. The weights are constructed based on some form of kernel, a function used to assign weights to observations in the comparison group based on their distance away from the treated observation of interest, where "distance" is defined as the difference between the villages propensity scores. For the purposes of this study, the weights for the comparison villages should decrease with distance from the particpating village and should sum to unity.

Given a participating village i, the weight associated with nonparticipating village j will be calculated as

$$w^0(i,j) = \frac{K(P(X_i),P(X_j),h)}{\sum_{j=1}^{n_0} K(P(X_i),P(X_j),h)} \tag{3.34}$$

where $K(P(X_i), P(X_j), h)$ is the kernel expressed as a function of the propensity score for village i, village j, and a "bandwidth" parameter, h. For this study, the Gaussian form of the kernel will be used,

$$K(P(X_i), P(X_j), h) = \frac{1}{h\sqrt{2\pi}} e^{-0.5\left(\frac{P(X_j)-P(X_i)}{h}\right)^2} \tag{3.35}$$

The bandwidth parameter determines how fast the weight decays as the distance from the participating village increases.

In order to calculate the ATE and the ATNT, the treated villages are used as the comparison group for the nontreated villages. Given a nonparticipating village i, the weight associated with a participating village j will be calculated as

$$w^1(i,j) = \frac{K(P(X_i),P(X_j),h)}{\sum_{j=1}^{n_1} K(P(X_i),P(X_j),h)} \tag{3.36}$$

For every participating village i, the corresponding counterfactual outcome measure will be calculated as

$$y^0(i) = \sum_{j=1}^{n_0} w^0(i,j) y_j^0 \tag{3.37}$$

and for every nonparticipating village i, the corresponding counterfactual outcome measure will be calculated as

$$y^1(i) = \sum_{j=1}^{n_1} w^1(i,j) y_j^1 \tag{3.38}$$

Define

$$E[Y_i^1] = \begin{cases} y_i^1 & if \, \mathrm{d_i} = 1 \\ y^1(i) & if \, \mathrm{d_i} = 0 \end{cases} \tag{3.39}$$

$$E[Y_i^0] = \begin{cases} y^0(i) & if \, \mathrm{d_i} = 1 \\ y_i^0 & if \, \mathrm{d_i} = 0 \end{cases} \tag{3.40}$$

The treatment effect parameters can then be estimated. By definition, the average treatment effect is

$$\begin{aligned}\widehat{ATE} &= \frac{1}{n}\sum_{i=1}^{n}\widehat{ATE}_i \\ &= \frac{1}{n}\sum_{i=1}^{n}(E[Y_i^1] - E[Y_i^0])\end{aligned} \quad (3.41)$$

The average treatment effect on the treated is

$$\begin{aligned}\widehat{ATT} &= \frac{1}{n_1}\sum_{i=1}^{n_1}\widehat{ATT}_i \\ &= \frac{1}{n_1}\sum_{i=1}^{n_1}(y_i^1 - y^0(i))\end{aligned} \quad (3.42)$$

The average treatment effect on the nontreated is

$$\begin{aligned}\widehat{ATNT} &= \frac{1}{n_0}\sum_{i=1}^{n_0}\widehat{ATNT}_i \\ &= \frac{1}{n_0}\sum_{i=1}^{n_0}(y^1(i) - y_i^0)\end{aligned} \quad (3.43)$$

In kernel matching, two important issues must be considered. First, as stated by Caliendo and Kopeinig (2008), "comparing the incomparable must be avoided." That is, the participant and nonparticipant propensity scores should be defined on a common support (Heckman, Ichimura and Todd 1997). The most common method to define the sample over a common support is to discard all observations whose propensity score lies below the minimum or above the maximum of the other group. For example, if the propensity scores of the treated sample lie between 0.4 and 0.8, and the scores for the untreated sample lie between within 0.3 and 0.7, the common support is the interval between 0.4 and 0.7. The second issue is the selection of the bandwidth parameter, h. While many suggestions can be made regarding the choice of h, (Jones, Marron and Sheather 1996), this study will follow Todd (1999) and choose a fixed bandwidth. The sensitivity of the treatment estimates with respect to the different bandwidth choices will be examined.

Two extensions of kernel matching will also be investigated: local linear matching (Heckman, Ichimura and Todd 1997) and regression-adjusted local linear matching (Heckman, Ichimura and Todd 1998). These methods follow the general kernel matching procedure above except with different weights.

3.2.3 Hypothesis Testing

After deriving the average treatment effects, their variances must be estimated in order to conduct statistical tests for significance. The variances for the treatment effect from matching estimators were investigated by Abadie and Imbens (2006a). They decomposed the variation between the estimated average treatment effect and its parameters into three components: the difference between the conditional treatment effect and the parameter, errors, and the bias caused by the matching discrepancy ($X_i \neq X_j$). Abadie and Imbens show the bias will vanish and be dominated by the first two components in a large sample. Their formulae for the sample variances of the matching estimator is

$$Var(ATE|P(X)) = \frac{1}{n^2}\sum_{i=1}^{n}\left(1+\frac{K_M(i)}{M}\right)^2 \sigma^2(P(X_i),\mathrm{d_i}) \qquad (3.44)$$

and

$$Var(ATT|P(X),\mathrm{d_i}) = \frac{1}{n_1^2}\sum_{i=1}^{n}\left(\mathrm{d_i}-(1-\mathrm{d_i})\frac{K_M(i)}{M}\right)^2 \sigma^2(P(X_i),\mathrm{d_i}) \qquad (3.45)$$

$$Var(ATNT|P(X),\mathrm{d_i}) = \frac{1}{n_0^2}\sum_{i=1}^{n}\left(\mathrm{d_i}\frac{K_M(i)}{M}-(1-\mathrm{d_i})\right)^2 \sigma^2(P(X_i),\mathrm{d_i}) \qquad (3.46)$$

where $K_M(i)$ is the number of times a unit is used as a match, $\sigma^2(P(X_i),\mathrm{d_i})$ is the outcome conditional variance for village i, M is the number of matched neighbors. To obtain the conditional variance involves a complicated computation. Abadie and Imbens proposed a matching estimator for the conditional variance $\sigma^2(P(X_i),d_i)$. In this estimator, unit i matches with a fixed number J of units from the same treatment sample. Then the conditional variance is

$$\sigma^2(P_i, \mathrm{d_i}) = \frac{J}{J+1}\left(Y_i - \frac{1}{J}\sum_{j=1}^{J} Y_j\right)^2 \tag{3.47}$$

where Y_i is the outcome measure at which the conditional variance is evaluated and Y_j is the jth nearest outcome measure from the same treatment sample. j=1,2…J is indexes for the matched outcomes measure.

In bootstrapping, a set of estimated treatment effects for each village is created. For example, in order to use bootstrapping to estimate the variance of the ATE measure, a set of ATEi, i=1...N would be created. This set would then be sampled repeatedly with replacement Z times to create other sets. For each of these sets, j=1...Z, the mean ATE, $\widehat{ATE_J}$ would be calculated. The variance of the ATE would then be calculated as

$$\sigma_{ATE}^2 = \frac{1}{Z}\sum_{j=1}^{Z}(\widehat{ATE} - \widehat{ATE_J})^2 \tag{3.48}$$

Variances for the other treatment measures would be calculated similarly.

Abadie and Imbens (2006b) argue that the non-smoothness of nearest neighbor matching causes bootstrapping to be invalid. It is unclear whether bootstrapping is valid for other types of matching such as caliper and kernel matching. In a related article, Imbens (2009) suggests that increasing the number of matches can solve the problem of the bootstrapping invalidity in nearest neighbor matching. “[T]hus, the bootstrap might be valid for kernel estimators.” (p.42). On the other hand, bootstrapping is a widely-used estimator and has been used by Heckman, Ichimura, & Todd (1997) and Chen, Mu, & Ravallion (2008). This study will estimate the variances for the nearest neibhbor matching, the caliper matching, and the kernel-based matching with the bootstrapping.

With the treatment effects estimated from the nearest neighbor, caliper and kernel-based matching estimators and the estimated variances, we will be able to carry out t tests. The null hypotheses for the t-tests will be that the SWPRP project did not produce an impact on the project villages, i.e., the treatment effect is zero. If the t-test is significant, we will reject the null hypothesis and conclude that the project did produce an impact on the project villages.

CHAPTER IV

SELECTION MODEL FOR PROJECT VILLAGES

As discussed in the previous chapter, both of the methodologies used to calculate treatment effects rely on the ex ante probability of each village being selected into the treatment group. In the control function approach, the probability is used in the creation of the selection correction terms; in the matching models, the probability is used as each village's propensity score. Since the ex ante probability of being treated is unknown, it must be estimated from the ex post decision of whether the village is treated or not, and from village characteristics thought to be important to the policy makers making the decision. Choice of these characteristics comes from an understanding of the actual selection process. A description of this process is provided below. Following this, the probabilistic estimation model is described and variable selection is discussed. The chapter concludes with a discussion of the estimation results.

4.1 An Institutional Background to the Process of Selecting Project Villages

The Southwest Poverty Reduction Project (SWPRP) was conceived during the "International Conference on Poverty Issues in China" held in Beijing in October 1992.[9] After agreeing to cooperate in an effort to reduce the incidence of poverty, agents from the World Bank and the Chinese Central Government worked together with local government officials to identify specific project areas. The SWPRP became an integral part of a much larger scale poverty reduction plan of the Chinese government, the so-

[9] World Bank, Agricultural Operation Division 1995, p. 7.

called 8-7 Poverty Reduction Plan.[10] However, while the 8-7 Poverty Reduction Plan targeted all state-defined poor counties in China, the SWPRP was much more limited in scale.

Agreement was made to focus the SWPRP's efforts in 35 counties in the adjoining portions of three provinces in Southwest China, Guangxi Zhuang Autonomous Region, Guizhou Province and Yunnan Province. In 1992, each of these counties was among the poorest of the poor with per capita annual incomes below 310 Yuan (US $37.50 equivalent) and per capita annual grain production below 220 kg. Within these 35 counties, the project focused on half of the townships with incomes below the county average, and, within each township, the project was supposed to focus on the administrative villages in the lowest quartile of income. This selection process resulted in SWPRP investment in 1798 administrative villages in 290 Townships of the 35 counties. In the Guangxi region, the project targeted 515 villages in 91 townships of 12 counties. The selected villages were supposed to be the poorest of the poor in the region; however, this may not have been so.

At the time of the project preparation, statistical data were available at the county and the township level but not at the village level. As a result, the decision of which villages were in the lowest income quartile was subjective. Selection was made through consultation and interviews with villagers, village heads, local teachers, and local government staff. Since these local groups would benefit from the project investment, they may have had an incentive to overstate their needs in order to improve their probabilities of selection. In addition, since project officials would be responsible for

[10] The 8-7 Poverty Reduction Plan was a plan by the Chinese Central Government to elevate 70 million rural residents from absolute poverty in eight years from 1993 to 2000.

project implementation, they had an incentive to choose those villages with characteristics that would result in lower operational costs and an increased probability of demonstrable project success.

The objective of the selection process is to select the poorest villages. However, availability of the data may not allow the process to achieve its objective effectively. The extent to which the selection process is biased is examined later in this chapter.

4.2 Probit Model for the Selection Process

In a sample including both the project villages and non-project villages, let d denote the treatment of the project. d=1 then represents villages that are selected into the project village subsample, and d=0 represents the villages that are not. Suppose the selection of the project villages is determined by a latent variable Y*, which may be the net benefit to the village including the social benefit, and in turn Y* is determined by a set of observed variables, Z, and the unobserved variables, V. The choice function can be written as

$$Y^* = g(Z) + V \tag{4.1}$$

Z includes all measured characteristics of the sample villages. v is unobservable to researchers but might be known by the decision makers. For example, the political influence is known by the decision makers, but it is unmeasurable for the researchers. In the case of the SWPRP, costs of the project participation for the villages are unavailable. In this research, costs are assumed to be constant across the villages, so the selection of project villages is based on potential benefits but not on the participating costs. The reason for the project villages to be selected is because the decision makers believe that the SWPRP can bring positive net benefits to the villages, so having positive net benefit is the rule governing the selection of the project villages. If the net benefits from the project participation of the villages are greater than zero, or Y*>0, the villages are eligible to be selected as project villages, but when $Y^* \leq 0$, the villages are ineligible. This rule can be presented in an indicator function by modifying equation (4.1).

$$\begin{cases} \text{d} = 1 & Y^* = g(Z) + V > 0 \\ \text{d} = 0 & Y^* = g(Z) + V \leq 0 \end{cases} \tag{4.2}$$

While the villages with Y*>0 are not always selected, they all have a probability to be included in the project, and the probability has the same distribution of Y*>0.

$$Pr(Y^* > 0) = Pr(g(Z) + V > 0) \tag{4.3}$$

Assuming that Z includes all variables that determine Y* and unobservable V is an error term with zero mean and normal distribution, Y* also distributes normally. Further, supposing $g(Z)$ is linear, or $g(Z) = \gamma Z$, the cumulative density function (cdf) is

$$P(Z) = Pr(\gamma Z + V > 0) = \Phi(\gamma Z) \tag{4.4}$$

where $\Phi(.)$ is the normal distribution function. The equation (4.4) can be estimated in a probit model before it is used to predict the probability of each village to be chosen as a project village. The data required for the probit model include selection outcomes (d) and characteristics or decision variables (Z).

The decision variables in Z must be chosen based on economic theory. However, Z must also satisfy the fundamental requirements for model identification. As discussed in Chapter 3, the identification of the matching approach relies on the assumption presented in (3.26), which requires the independence of outcomes and treatment assignments conditional on the observable variable Z. In the case of the SWPRP, assumption (3.26) requires random assignments of the project villages among the villages with the same characteristics so that the differences between the project villages and non-project villages are unbiased estimators for the treatment effects. The independence of the outcomes and treatment assignments is essential for the matching approach to eliminate the selection bias, and this independency is obtained by conditioning on Z. Hence, the choice of the variables in Z is an important step in the matching approach.

To implement assumption (3.26), two important issues must be considered in the choice of the variables in Z. First, matching makes no distinction between X (variables determining outcomes) and Z (variables determining selection). Therefore, Z and X are indifferent in this chapter and should include all the variables that determine both outcomes and participation. In other words, matching requires that all the variables that determine both outcomes and participation are observable. Heckman and Robb (1985) refers to the observability of all relevant variables in matching as the "selection on observables." It also means that, as pointed out by Heckman, Ichimura, Smith and Todd (1997), no unobservables that correlate with outcomes and project village selection are allowed. Second, as proposed by Heckman and Navarro-Lozano (2004), Z should include the variables that are not influenced by the treatment. In the case of the SWPRP, only relevant variables that are fixed or stable over time can be considerred in Z.

Consequently, variables in Z should be measurable, stable over time, involved in the process of the project village selection, and related to poverty. Table 4.1 describes nine measurable village characteristics that are thought to influence village selection. For each characteristic descriptive statistics are provided for the pooled sample and subsamples of treated and untreated villages. Results of a t-test for mean difference across the two subsamples are also provided.

Table 4.1 Description of Variables Used to Estimate Probability of Village Selection (Propensity Scores)

Variables			Pooled Sample		Non-project Villages		Project Villages		T Tests	
			Mean	Std Error	Mean	Std Error	Mean	Std Error	Mean Diff.	P-Value
Dummy for Mountainous Village (=1) (Percentage)	MOUNTAIN	x_1	85.48		84.54		96.64		12.10	
Percentage of Non-Han Minority Population	MINORITY	x_2	76.64	36.29	75.83	36.83	86.30	27.50	10.47	<.0001
Natural Village Size (Person)	VILSIZE	x_3	214.27	223.06	220.77	228.80	136.96	112.36	-83.81	<.0001
Farmland per Capita (Mu)	FARMLAND	x_4	1.13	0.69	1.15	1.09	0.87	1.23	-0.28	<.0002
Percentage of Irrigated Farmland	IRRILAND	x_5	27.06	24.40	28.03	24.66	15.50	17.44	-12.53	<.0001
Percentage of High-Slope Farmland (over 25 degree)	SLOPELAND	x_6	37.22	26.17	37.01	26.40	39.63	23.24	2.62	0.0823
Distance from County Town (KM)	CTYDIST	x_7	50.46	28.59	50.80	29.01	46.47	22.75	-4.33	0.0086
Distance from Township Market (KM)	MKTDIST	x_8	12.74	9.39	12.91	9.55	10.66	6.81	-2.25	<.0001
Illiteracy Rate (Percentage)	ILLITERACY	x_9	8.28	9.97	8.38	10.06	7.08	8.71	-1.30	0.0238

Note: Mu is a unit of land measure used in China; one Mu equals one-fifteenth of a hectare or about 0.17 acres.

The percentage of the non-Han minority population is an indicator that measures the population structure of the villages and also implies significant cultural differences. Population in Guangxi is comprised of different ethnic groups such as Han, Zhuang, Yao, Miao, Tong, Mulao and others. Han has the largest population in Guangxi and China. All other ethnic groups are minorities. Although each ethnic group has a primary region of inhabitation, different ethnic groups often reside in the same village despite language and cultural differences. The dataset collected does not allow us to compute the share of each ethnic group in a village, but it does allow us to compute the proportion of all non-Han as a minority group. As shown in Table 4.1, the mean of the percentage of non-Han ethnicities are 75.83 percent in the non-project villages and 86.3 percent in the sample of the project villages. The project villages have a higher percentage of non-Han population possibly indicating greater ethnic diversity. This seems to suggest that the ethnic minorities are given priority in the selection process. Ethnic minorities are not always in poverty; however, as discussed above, the majority of the ethnic minorities in Guangxi are found in the remote and mountainous regions, where resources are scarce. Therefore, to target the ethnic minorities in those regions one can also target the poor villages.

The natural village size measures how population is distributed inside a village. In this research, a village refers to the administrative village that consists of multiple natural villages. A natural village is a colony of households (from several to over a hundred) at a particular location. Natural villages are separated by mountains, rivers, or geographic distance, so their sizes are usually determined by geography. For example, residents in mountainous villages have to spread into small natural villages that are located at the bottom of mountain valleys or on mountain sides. The size of the valleys and the availability of resources such as land and water determine the size of the natural villages.

Being small in size may result in a disadvantage in economies of scale and a lack of infrastructure services because of higher construction costs. The average size of the natural villages in administrative villages can be an indicator for poverty, so the SWPRP is expected to target the villages that are comprised of smaller natural villages. This seems to be the case as evidenced by the difference in means in Table 4.1.

Illiteracy rate of the adult population measures the education level in the villages. It refers to the percentage of illiterate residents in the population ages 15 and over. The illiteracy rate roughly reflects the accumulated outcome of education in the past and does not likely influenced by the project since the children who enrolled in school with the project aids were under 15 year old by the time when the data collected in 2000. Better education might have resulted in the intellectual residents leaving the village since laborers with high school (12 years) or higher education are rarely found in the villages. On the other hand, good education also results in a higher school enrollment rate and a lower illiteracy rate. In Table 4.1, our dataset shows the mean of the illiteracy rates is 8.38 percent in non-project villages and 7.08 percent in the project villages. The difference is statistically significant at the 5 percent level. The project villages seem to have a better education history.

Land is a critical resource for rural residents. Besides the quantity of land, land quality also plays an important role in determining living standards. Three indicators for the land resources are the farmland per capita, the percentage of farmland with irrigation, and the percentage of high-slope farmland. The land with irrigation is usually flat and of high quality and therefore more productive. The high-slope farmland refers to the farmland with a slope greater than 25 degrees. The productivity is low on the high-slope land because the top soil is eroded by heavy rains. Farming on the high-slope land further exacerbates the erosion. However, the residents have to do so to survive despite the low marginal returns. A higher percentage of high-slope farmland indicates the scarcity of quality land, so the SWPRP should invest in the villages with less and lower-quality farmland. Table 4.1 implies that the project did so because the project villages have statistically significant less farmland and irrigated land and greater high-slope land.

Distances from county towns and township markets measure the remoteness of the villages. The remote villages usually lack infrastructure because of higher construction costs. The farther the villages locate away from the county centers and township markets, the higher the costs are for the transportation and other services to reach the villages. The geographic distances isolate the remote villages from technological progress, so the production process is still dominated by traditional technology. To target the poor, the SWPRP should target the villages farther from the county towns and township markets. However, evidence in Table 4.1 indicates that the project villages are on average close to both county towns and township markets.

In addition to the above variables, a dummy variable denoting mountainous geography is also included in the probit model. As shown in Table 4.1, 96.64 percent of the project villages have a mountainous geography and only 84.54 percent of the non-project villages do.

4.3 The Selection Model

A probit model for equation (4.4) is established using the Qlim Procedure in SAS. The coefficients of the probit model are estimated from a pooled sample of 2541 observations including 327 project villages and 2214 non-project villages. The dependent variable takes the value $d=1$ for the project villages and $d=0$ for non-project villages. The independent variables are chosen based on the economic theory described in the previous section. As argued by Rubin and Thomas (1996), the variables should not be excluded if they are theoretically relevant though statistically insignificant. Wooldridge (2005) suggest that one should include anything that helps predict participation. However, Heckman, Ichimura, Smith and Todd (1998) suggest that one should only include the statistically significant variables. Based on these works, our probit model includes all nine variables from Table 4.1. Table 4.2 presents the results of the probit model.

Table 4.2 Results of Probit Model

Parameter		Estimate	St. Error	
INTERCEPT	C	0.7071	0.2517	***
MOUNTAIN	x_1	0.4272	0.1631	***
MINORITY	x_2	-0.0018	0.0014	
VILSIZE	x_3	-0.0014	0.0003	***
FARMLAND	x_4	-0.9604	0.1070	***
IRRILAND	x_5	-0.0118	0.0018	***
SLOPELAND	x_6	-0.0051	0.0015	***
CTYDIST	x_7	-0.0029	0.0013	**
MKTDIST	x_8	-0.0200	0.0048	***
ILLITERACY	x_9	-0.0098	0.0039	**

Note: The significant levels are *--10%, **--5%, and ***--1%.

To evaluate the model, statistics such as the likelihood ratio, R^2, and condition index are computed for the probit model in Table 4.2. The likelihood ratio is 249.88. The critical value of Chi-squared distribution with 9 degrees of freedom is 21.67 at the 1 percent right-tail. The null (joint) hypothesis that all coefficients are zero is rejected at the 1 percent significant level. The R^2 is 0.0937. The condition index for multicollinearity is 19.4884 in the model. These statistics show that the model fits well considering it is established from cross-sectional data.

The predictability is evaluated by the "Hit or Miss Method" proposed by Heckman, Ichimura, Smith, and Todd (1998). In the Hit or Miss Method, the probabilities P(x) are predicted for each village in the pooled sample. This is compared to the proportion of project villages in the sample (0.1287). If P(x)>0.1287, then village is considered to be eligible for participation. Based on this test, the probit model predicts 1620 eligible villages, 240 of them are the project villages, accounting for 73.43 percent.

The results of the simple t-tests in Table 4.1 and the probit results in Table 4.2 indicate that selection into the project may have been based, in part, on factors other than poverty such as minimization of the cost of project operations. Since all villages in the sample are government defined poor villages, the potential conflict in objectives does not mean that poor villages were not selected for the project, but that those selected may not have been the poorest of the poor.

The three demographic variables in the probit model are the percentage of non-Han minorities (x_2), the size of natural villages (x_3), and illiteracy rate. As shown in Table 4.2, the coefficient on x_2 is negative and statistically insignificant. This result seems to imply that the ethnic structure does not play a significant role in the process of project village selection and contradicts the preset selection rule of targeting ethnic minorities by the World Bank and Chinese government. However, considering that the project and non-project villages in our sample both have a large percentage of non-Han minorities, it is reasonable that the coefficient on x_2 is statistically insignificant.

The natural village size (x_3) presents the population distribution inside administrative villages. As shown in Table 4.2, the coefficient on x_3 is negative and statistically significant. This result indicates that the villages composed of small natural villages are more likely to be selected as project villages. The small natural villages suffer several disadvantages for development. In addition to a lack of economies of scale, one of the most important disadvantages is the high cost of infrastructure construction. As a result, small natural villages often lack transportation, education, and healthcare services. The probit results indicate that the SWPRP project gives the priority to the villages composed of small natural village so that the poorer are targeted.

The other demographic variable is the illiteracy rate (x_9), which represents the education level in recent history, but not the present. Table 4.2 shows a statistically significant and negative coefficient on x_9, indicating the inverse relationship between the probabilities and the illiteracy rates. This is an unexpected result. Higher illiteracy rates are usually related with poorer villages. Therefore, the villages with a higher illiteracy rate should have a higher probability of selection. However, the SWPRP tends to choose the villages with low illiteracy rates or better education perhaps because villages with better education might require less cost for project implementation. This is evidence for operational cost minimization.

Farmland especially high quality farmland is a critical resource closely related to the living standards in the poor villages. As shown in Table 4.2, the quantity and the quality of farmland are all involved in the selection process. The SWPRP chooses villages with less farmland per capita (x_4) and less irrigated farmland (x_5). The coefficients on x_4 and x_5 are all negative and statistically significant, indicating the villages with less farmland and irrigated land are more likely to be selected. Therefore, the poorer are targeted. However, the project also avoids the villages with a high percentage of high-slope farmland (x_6). The coefficient on x_6 is negative and statistically significant, implying villages with a higher percentage of high-slope land, indicating poorer villages, have lower probabilities of selection. These results indicate a possible conflict in project village selection. On the one hand, the project generally gives more opportunities for selection to the villages with less farmland and less irrigated land, which usually represents the poorer villages. On the other hand, the project favors the villages with less high-slope farmland perhaps to assure demonstrable outcomes with lower operational costs.

The location characteristics of villages are represented by distances from the county towns (x_7), distances from the township markets (x_8), and types of geography (x_1). The results in Table 4.2 suggest that the project is willing to choose the villages close to the county towns and the township markets. The coefficients on x_7 and x_8 are negative and statistically significant. These imply that the project tends to exclude the villages far from the county towns and township markets. Given the fact that the transportation is normally worse to the distant villages, the operational cost must be higher. The project targets the poor villages close to the county towns and the township markets perhaps in an effort to minimize the operational costs.

Finally, dummy variables representing the mountain geography (x_1) is included in the model. As shown in Table 4.2, it has a positive and statistically significant coefficient. Villages located in mountainous regions have selection priority.

The probit model shows that the SWPRP successfully targets poor villages but not necessarily the poorest villages. The project tends to choose the villages that have less farmland and less irrigated land and are composed of small natural village in the mountain region. These characteristics are normally associated with poverty. Meanwhile, the project also tends to reduce the opportunity of selection for the villages far from the county towns and township markets with higher percentages of high-slope land and higher illiteracy rates. These behaviors do not result in the selection of the poorer villages and contradict the project objective of targeting the poorest. The minimization of the operational costs might be a reasonable explanation for the contradictory behaviors in the selection process. This minimization of operational costs might jeopardize the project objectives. However, it provides the possibility for researchers to construct a control sample from the poorer villages that are not selected into the project.

In next two chapters, the probabilities or propensity scores estimated from the probit model will be used in an effort to control for selection bias when estimating the impact of the SWPRP. Two very different methodologies will be implemented; first, the control function approach, then matching.

CHAPTER V

SPECIFIC TREATMENT EFFECTS

Evaluations of the Southwest Poverty Reduction Project (SWPRP) can be concentrated on either average treatment effects or specific treatment effects. The average treatment effects (ATEs) are the average returns from the project investment and are evaluated in the next chapter. This chapter focuses on the specific treatment effects on the individual villages. A structural model for specific treatment effect evaluation is borrowed from Heckman and Robb (1985) and Heckman and Vyctlacil (1998), which they refer to as the correlated random coefficient model (CRCM). In the CRCM, the treatment effects on specific villages are considered as a random variable and decomposed into a constant and slopes. The constant represents the ATE, and the slopes measure the deviations from the ATE for specific villages. The model allows the ATE to vary with village characteristics in conjunction with the treatment, so the treatment effects are heterogeneous. The empirical model of CRCM is estimated by the control function approach described in Chapter 3, in which the selection bias is removed by inclusion of the inverse Mill's ratio in the regression equation. The results of the model can be extrapolated to other villages if their characteristics are known, so, according to Ravallion (2008), this structural model is policy-relevant for development practitioners. Next, the correlated random coefficient model and its estimation are described. The results are used to investigate the specific treatment effects on the project villages.

5.1 The Correlated Random Coefficient Model

Models for social program evaluations have to consider unobservability of counterfactuals and selection bias. The correlated random coefficient model solves the problem of unobservability of the counterfactuals based on a switching regression equation and removes the selection bias by a control function. As before, treatment effects are defined as the differences between the observed outcomes and the counterfactuals or the potential outcomes if the treatment is not carried out. In the case of SWPRP, the treatment effects are the differences between two states of an indicator with and without the project. The problem of unobservability arises because only one of the two states of the indicators is observable in a particular village. The switching regression equation that can be traced back to Roy (1951) estimates the treatment effects as a parameter on the treatment dummy variable. However, the estimates of the parameter might be biased because the project villages have not been randomly assigned as shown in Chapter 4. For example, because the lower income villages are more likely to be selected as the project villages, the mean income of the project villages would be lower without the project. Heckman (1979) shows that selection bias is a function of the selection process and can be removed by including a control function into the switching equation. In addition, the CRCM allows the problem of heterogeneous treatment effects to be modeled by adding interaction terms into the equation.

To model the treatment effects, let y denote a potential outcome, which may be one of the 21 indicators in Table 2.1. y^1 represents the treated outcome and y^0 is the untreated outcome. Let d denote the treatment of the SWPRP; d=1 represents treatment while d=0 represents no treatment. The four potential outcomes can be written in conditional notation as

$y^1\|d=1$	the treated outcome of a project village,
$y^0\|d=1$	the counterfactual representing the untreated outcome of a project village,
$y^0\|d=0$	the untreated outcome of a non-project village,
$y^1\|d=0$	the counterfactual representing the treated outcome of a non-project village.

By choosing the appropriate counterfactual, the treatment effects, α_i, on the individual village i, is expressed as

$$\alpha_i = y_i^1 - y_i^0 \tag{5.1}$$

i =1, 2…n, where n is the total number of villages in the pooled sample.

At the population level, the average treatment effect (ATE) is the expectation over all individual villages.

$$ATE = E(\alpha_i) \tag{5.2}$$

However, the ATE is unobservable at the population level and needs to be estimated. The sample ATE is conditional on a set of the sample characteristics, denoted as X. The sample ATE can be computed in following equation.

$$\begin{aligned} ATE|X &= E(\alpha_i|X) \\ &= E(y_i^1 - y_i^0|X) \end{aligned} \tag{5.3}$$

Practically, interest may be on either the treatment effects of the project villages or the treatment effect of the non-project villages if they have been treated. The treatment effects are then conditional on these subsamples. The average treatment effects on the treated (ATT) are conditional on being in the treated sample (d=1), and the average treatment effects on the untreated (ATNT) are conditional on being in the untreated sample (d=0).

$$\begin{aligned} ATT &= E(\alpha_i|X, \mathrm{d} = 1) \\ &= E(y_i^1 - y_i^0|X, \mathrm{d} = 1) \end{aligned} \tag{5.4}$$

$$\begin{aligned} ATNT &= E(\alpha_i|X, \mathrm{d} = 0) \\ &= E(y_i^1 - y_i^0|X, \mathrm{d} = 0) \end{aligned} \tag{5.5}$$

The unobservability of the counterfactuals $y^0|X,d=1$ and $y^1|X,d=0$ do not allow equations (5.3), (5.4), and (5.5) to be calculated directly. For example, for project villages, it is possible to observe the incomes with the project ($y^1|X,d=1$), but the incomes without the project ($y^0|X,d=1$) are unobservable. Therefore, the treatment effects in equation (5.4) are unattainable. Similarly, for the non-project villages, the incomes without the project ($y^0|X,d=0$) are observable, but the incomes with the project ($y^1|X,d=0$) are not. Instead of estimating the treatment effects with the above equations, the method of control function estimates the treatment effects with a switching regression equation.

To construct the correlated random coefficient model (CRCM) for this study, take the income as an example represented by y. Without the SWPRP, the average incomes of individual villages, including the project villages and the non-project villages, are determined by a set of characteristics including, but not limited to, land resources, labor input, and weather. However, researchers cannot measure all of these characteristics. Only a subset of these characteristics, X, is observed by researchers, and the rest are not observable. For example, local weather may influence the incomes, but local weather data are not among the available dataset. Letting u denote the unobservable variables, the incomes can be expressed as[11].

$$y_i^1 = X_i\beta + \alpha_i + u_i^1 \tag{5.6}$$
$$y_i^0 = X_i\beta + u_i^0 \tag{5.7}$$

where β is a vector of coefficients including an intercept and α_i is the effect of the treatment on village i. These two equations can be expressed in a single equation.

[11] This section relies heavily on the discussion provided by Blundell and Dias.

$$y_i = \mathrm{d_i} y_i^1 + (1 - \mathrm{d_i}) y_i^0$$
$$= X_i\beta + \mathrm{d_i}\alpha_i + \mathrm{d_i}(u_i^1 - u_i^0) + u_i^0 \qquad (5.8)$$

where $\mathrm{d_i}$ represents selection into the program. We assume that selection follows the rule represented in equation (4.2) in Chapter 4.

If the selection into the program is nonrandom then ordinary least squares estimation of equation (5.8) will be biased. In order to see this more clearly, we rewrite equation (5.8) as

$$y_i = X_i\beta + \mathrm{d_i}\alpha_i + e_i \qquad (5.9)$$

where $e_i = \mathrm{d_i}(u_i^1 - u_i^0) + u_i^0$. In two important cases, OLS is an unbiased estimator for equation (5.9). First, under random selection, e_i is not correlated with $\mathrm{d_i}$. However, correlation between e_i and $\mathrm{d_i}$ may arise in the case that the term $\mathrm{d_i}(u_i^1 - u_i^0)$ in e_i is not zero. According to our results in Chapter 4, this is very likely. Second, OLS estimates would be unbiased if α_i was uncorrelated with $\mathrm{d_i}$. However, we may have α_i correlated with $\mathrm{d_i}$ which implies that selection is based on the expected gains to program participation. Because $\mathrm{d_i}$ is determined by X, α_i is not constant and is correlated with X. In either case, the non-participants and the participants will not be comparable and OLS will provide biased results.

In order to correct the bias in the first case, we employ a two-step method developed by Heckman (1979). In the first step, assuming a linear selection rule, the probability of selection into the program,

$$Prob(\mathrm{d_i} = 1) = Prob(\gamma Z_i + v > 0) \qquad (5.10)$$

is estimated using a probit model as shown in Chapter 4. The probit results are then used to create inverse Mill's ratios, $\lambda_i^1 = \frac{\phi(Z_i)}{\Phi(Z_i)}$ for the participant villages and $\lambda_i^0 = \frac{-\phi(Z_i)}{1-\Phi(Z_i)}$ for the non-participant villages. In the second step, OLS is used to regress y on X, d, λ^0 and λ^1,

$$y_i = X_i\beta + \delta d_i + d_i\eta_1\lambda_i^1 + (1 - d_i)\eta_0\lambda_i^0 \quad (5.11)$$

The estimated coefficient δ provides an unbiased estimate of ATE, which is assumed to be homogenous and will be identical to ATT and ATNT. Suppose $\eta_1 = \eta_0 = \eta$, the inverse Mill's ratios can be combined into one term,

$$gr_i = d_i\lambda_i^1 + (1 - d_i)\lambda_i^0 \quad (5.12)$$

To correct the bias in the second case, where the treatment effects are heterogeneous, we express the individual village treatment effect α_i as a linear function of the village's characteristics.

$$\alpha_i = \delta + \theta(X_i - \bar{X}) \quad (5.13)$$

We can perform OLS on

$$y_i = X_i\beta + \delta d_i + \theta d_i(X_i - \bar{X}) + \eta gr_i \quad (5.14)$$

which will result in an unbiased estimate of the population average treatment effect, δ, and the village specific treatment effect, $\delta + \theta(X_i - \bar{X})$. In addition, the average treatment effect on the treated and the average treatment effect on the untreated can be estimated as

$$ATT = \delta + \frac{1}{n_1}\sum_{d=1}\theta(X_i - \bar{X}) \quad (5.15)$$

And

$$ATNT = \delta + \frac{1}{n_0}\sum_{d=0}\theta(X_i - \bar{X}) \quad (5.16)$$

where n_1 and n_0 are the number of treated and untreated villages, respectively.

5.2 Estimation of the Empirical Models

The model in equation (5.14) is used to evaluate the treatment effect on the 21 indicators given in Table 2.1. The empirical model for each indicator is estimated by 2SLS. The first step is to derive the inverse Mill's Ratios from the probit model for the selection rule as described in Chapter 4. The second step is to estimate the outcome models for each indicator using equation (5.14) by OLS. The δ is the average treatment effect (ATE) and the $\delta + \theta(X_i - \bar{X})$ are the specific treatment effects. Before presenting the results, three issues need to be addressed.

The first issue is to determine the variable set of X and Z. In Chapter 4, we identify nine characteristic variables that may be associated with poverty and the project village selection process. They can all be included in X and Z. However, the exclusion restriction requires that at least one variable in X should be excluded in Z to avoid multicolinearity in equation (5.14). In the method of control function, the selection bias in outcome equation (5.14) is supposed to be a function of the characteristic variable Z, which also determines the outcome. In 2SLS, the equation (5.14) is estimated by including in the generalized term for inverse Mill's ratios (gr) to remove the selection bias. If Z linearly determines the selection process, gr is also linearly correlated to X. The parameters in equation (5.14) cannot be estimated consistently. However, this exclusion restriction is not necessary when selection function is not linearly determined. In our case, the probit function is a non-linear function and so the selection bias is not a linear function of Z. Therefore, this exclusion restriction is not necessary in our model.

The second issue is to determine the subset of X that correlates with the heterogeneous treatment effects. This requires one to determine interaction terms between the demeaned X and the treatment d in equation (5.14). Literature rarely addresses how to choose these variables. We arbitrarily assume that all variables in X linearly determine the specific treatment effects and are included in the interaction terms except x_1, the dummy variable for mountainous villages. In our sample, as shown in Table 4.1, 96.64 percent of project villages are mountainous villages. As a result, the interaction term, $d*x_1$, almost equals the dummy for treatment, d. Inclusion of both terms in equation (5.14) causes multicollinearity in the regression. By including all the rest of the variables, we are able to explore which of the variables cause heterogeneity in the specific treatment effects.

The third issue is to determine the common support to satisfy assumption (3.27) in Chapter 3. This research follows the method suggested by Imbens (2009). In that method, the predicted probabilities in Chapter 4 are used to identify the common support region, which is the overlapping region of the probabilities of the project and non-project villages. From the results of Chapter 4, the predicted probabilities range from 0.0130 to 0.5320 for the project villages and from 1.275E-53 to 0.5416 for the non-project villages. Therefore, the common support region is the overlapping region from 0.0130 to 0.5320. A trimmed sample for the outcome model is established by excluding the villages that have predicted probabilities smaller than 0.0130 or larger than 0.5320. After trimming, the sample includes 325 project villages and 1909 non-project villages.

As shown in Table 5.1, the models for the 21 indicators are different in goodness-of-fit. The R^2 value of the model for immunized children is 0.0148, indicating a low level of goodness-of-fit. A better goodness-of-fit occurs in the model for the food crop production, which has a R^2 value of 0.2713. The generally low R^2 might be due to the cross-sectional dataset.

Unbelievable results are found in Table 5.1. The coefficients on the row labeled "D" represent the average treatment effects (ATEs) on each indicator. Surprisingly, the ATEs on poverty rate and net income are as large as -47 and -107. These results suggest that on average the project reduces the poverty rate by 47 percent while at the same time decreases the net income by 107 Yuan per capita. Because poverty is measured by income in this research, the two results fail to support each other. An unreasonable result is also found in the ATE on food crop. On average, the project increases the food crop area by 2.5 Mu per household. One might question how this could happen in a household with about 5 Mu of farmland in total. The occurrence of these unreasonable results might be due to a misspecification of functional form. In this chapter, we arbitrarily specify the linear function for each regression model. Obviously, the linear function is not the appropriate function for every indicator to estimate the ATEs. In the next chapter, the matching approach is implemented, which does not rely on any functional form.

Although the control function approach is inappropriate for ATEs, it can still be used to investigate specific treatment effects. In Table 5.1, the coefficients of Dx_2-Dx_9 are the slopes of ATEs, which determines the specific treatment effects on village characteristics. The next section

Table 5.1 The Results of Correlated Random Coefficient Model

Variables		Poverty Rate %			Net Income (Yuan)			Income in Kind (Yuan)			Cash Income (Yuan)			Brick House %		
		Mean	S.Error		Mean	S.Error		Mean	S.Error		Mean	S.Error		Mean	S.Error	
INTERCEPT	C	35.0908	4.6988	***	781.0047	29.3112	***	2022.7868	243.7228	***	2356.9966	194.1455	***	76.0916	6.5228	***
TREATMENT	D	-46.7238	9.5808	***	-106.6521	59.7652	*	552.9643	496.9476		1004.7751	395.8601	**	-23.8673	13.3000	*
MILL RATIO	gr	21.4674	5.7222	***	49.1454	35.6953		-212.7035	296.8062		740.2120	236.4308	***	19.1300	7.9435	**
D*MINORITY	Dx_2	-0.1387	0.0587	***	-0.2821	0.3661		8.0123	3.0441	***	-7.0112	2.4249	***	-0.0947	0.0815	
D*VILSIZE	Dx_3	-0.0752	0.0162	***	-0.0944	0.1009		0.5594	-0.8391		1.5443	0.6684	**	-0.0699	0.0225	***
D*FARMLAND	Dx_4	-46.7281	7.6416	***	-153.3366	47.6685	***	612.6213	396.3641		503.9596	315.7369		24.5871	10.6080	**
D*IRRILAND	Dx_5	-0.3833	0.1174	***	-1.8477	0.7321	**	10.5496	6.0870	*	-11.9513	4.8488	**	0.0230	0.1629	
D*SLOPELAND	Dx_6	-0.1570	0.0784	**	-1.5084	0.4889	***	-11.0207	4.0650	***	-2.2903	3.2381		0.2379	0.1088	**
D*CTYDIST	Dx_7	-0.1929	0.0677	***	-1.6757	0.4224	***	-0.2099	-3.5119		0.9164	2.7975		0.0718	0.0940	
D*MKTDIST	Dx_8	-0.1083	0.2428		-2.8615	1.5146	*	28.2006	12.5936	**	-23.1501	10.0319	**	0.1098	0.3370	
D*ILLITERACY	Dx_9	-0.0600	0.1804		0.9490	1.1251		4.2995	9.3554		22.8624	7.4524	***	-0.6134	0.2504	**
MOUNTAIN	x_1	-1.0494	2.1267		-36.4878	13.2666	***	364.1876	110.3119	***	-134.9786	87.8726		9.4472	2.9523	***
MINORITY	x_2	0.0199	0.0227		-0.3777	0.1418	***	-3.4959	1.1787	***	-2.6342	0.9389	***	-0.1762	0.0315	***
VILSIZE	x_3	0.0053	0.0030	*	-0.0172	0.0190		0.0861	0.1580		0.4161	0.1259	***	0.0063	0.0042	
FARMLAND	x_4	0.0560	0.9540		13.0750	5.9509	**	5.8327	49.4815		4.8941	39.4161		3.3194	1.3243	**
IRRILAND	x_5	-0.0964	0.0309	***	0.9882	0.1925	***	7.3521	1.6005	***	-0.7737	1.2749		0.0163	0.0428	
SLOPELAND	x_6	0.0720	0.0224	***	-0.8915	0.1400	***	-3.3323	1.1643	***	-3.9830	0.9274	***	-0.0795	0.0312	**
CTYDIST	x_7	-0.0077	0.0187		0.0992	0.1165		-1.2252	0.9685		-2.7159	0.7715	***	-0.2150	0.0259	***
MKTDIST	x_8	0.1519	0.0593	**	-0.1423	0.3699		-4.2427	3.0759		2.2786	2.4502		0.0599	0.0823	
ILLITERACY	x_9	0.3676	0.0500	***	-0.4943	0.3116		-3.2409	2.5913		0.5860	2.0642		0.1964	0.0694	***
R^2		0.0845			0.0704			0.0583			0.0586			0.0992		

Note on significant levels: * —10%; ** —5%; and *** —1%.

Table 5.1 (Continued)

Variables		Thatched House %			HHs with TV %			Agri. Production (Yaun)			Grain Production (Kg)			Food Crop (Mu)		
		Mean	S.Error		Mean	S.Error		Mean	S.Error		Mean	S.Error		Mean	S.Error	
INTERCEPT	C	8.6066	6.8145		44.3370	4.1835	***	1174.5954	146.8441	***	373.8897	19.3321	***	1.6982	0.1103	***
TREATMENT	D	19.3393	13.8946		10.4281	8.5300		681.5896	299.4132	**	383.4668	39.4178	***	2.4903	0.2249	***
MILL RATIO	gr	-16.6704	8.2987	**	-4.1992	5.0946		-494.0443	178.8271	***	-222.0498	23.5426	***	-1.3054	0.1343	***
D*MINORITY	Dx_2	0.1601	0.0851	*	-0.0422	0.0523		3.6974	1.8341	**	0.6577	0.2415	***	-0.0017	0.0014	
D*VILSIZE	Dx_3	0.0431	0.0235	*	0.0337	0.0144	**	-0.2441	0.5056		0.3708	0.0666	***	0.0018	0.0004	***
D*FARMLAND	Dx_4	19.3920	11.0823	*	10.5573	6.8035		524.5972	238.8112	**	315.6629	31.4396	***	2.2267	0.1794	***
D*IRRILAND	Dx_5	0.0401	0.1702		0.1440	0.1045		6.0989	3.6675	*	2.9724	0.4828	***	0.0174	0.0028	***
D*SLOPELAND	Dx_6	0.1672	0.1137		0.1045	0.0698		4.0530	2.4492	*	1.1764	0.3224	***	0.0012	0.0018	
D*CTYDIST	Dx_7	-0.0760	0.0982		0.0048	0.0603		2.0385	2.1160		1.2240	0.2786	***	0.0044	0.0016	***
D*MKTDIST	Dx_8	0.0922	0.3521		0.0703	0.2162		14.2554	7.5877	*	4.1971	0.9989	***	0.0264	0.0057	***
D*ILLITERACY	Dx_9	0.7556	0.2616	***	0.2408	0.1606		1.3042	5.6367		1.8439	0.7421	**	0.0091	0.0042	**
MOUNTAIN	x_1	9.1029	3.0843	***	-7.7779	1.8935	***	24.5462	66.4634		37.5801	8.7499	***	0.3597	0.0499	***
MINORITY	x_2	0.1797	0.0330	***	-0.0069	0.0202		0.4316	0.7102		0.3684	0.0935	***	-0.0015	0.0005	***
VILSIZE	x_3	-0.0032	0.0044		0.0099	0.0027	***	-0.1930	0.0952	**	-0.0672	0.0125	***	-0.0007	0.0001	***
FARMLAND	x_4	3.9402	1.3835	***	2.7783	0.8493	***	33.2934	29.8128		0.2992	3.9249		0.1825	0.0224	***
IRRILAND	x_5	0.0123	0.0447		0.0373	0.0275		2.0352	0.9643	**	0.4870	0.1270	***	-0.0054	0.0007	***
SLOPELAND	x_6	0.1384	0.0326	***	-0.1222	0.0200	***	-4.6234	0.7015	***	-0.7474	0.0923	***	-0.0025	0.0005	***
CTYDIST	x_7	0.2229	0.0271	***	-0.1182	0.0166	***	-1.6639	0.5835	***	-0.4704	0.0768	***	-0.0014	0.0004	***
MKTDIST	x_8	0.0778	0.0860		0.1337	0.0528	**	-0.7060	1.8532		1.2355	0.2440	***	-0.0092	0.0014	***
ILLITERACY	x_9	-0.1250	0.0725	*	-0.2283	0.0445	***	-3.3123	1.5613	**	-0.2380	0.2055		-0.0051	0.0012	***
R^2		0.1055			0.1111			0.0379			0.1552			0.2713		

Table 5.1 (Continued)

Variables		Cash Crop (Mu)			Pig (Heads)			Cattle (Heads)			Goat (Heads)			Male Labor %			Female Labor %		
		Mean	S.Error		Mean	S.Error		Mean	S.Error		Mean	S.Error		Mean	S.Error		Mean	S.Error	
INTERCEPT	C	1.0010	0.1270	***	0.8734	0.0737	***	0.2360	0.0417	***	-0.0853	0.1419		22.5681	3.4251	***	20.7059	2.8678	***
TREATMENT	D	1.0804	0.2590	***	0.2636	0.1502	*	0.2866	0.0850	***	-1.0819	0.2893	***	-17.5971	6.9838	**	-4.0699	5.8473	
MILL RATIO	gr	-0.7581	0.1547	***	-0.1111	0.0897		-0.1823	0.0507	***	0.5928	0.1728	***	16.4225	4.1711	***	7.9657	3.4924	**
D*MINORITY	Dx_2	0.0020	0.0016		0.0008	0.0009		0.0007	0.0005		0.0035	0.0018	**	0.0606	0.0428		0.0037	0.0358	
D*VILSIZE	Dx_3	0.0006	0.0004		0.0004	0.0003		0.0003	0.0001	**	-0.0025	0.0005	***	-0.0121	0.0118		0.0283	0.0099	***
D*FARMLAND	Dx_4	0.4374	0.2066	**	0.2525	0.1198	**	0.2507	0.0678	***	-1.4545	0.2307	***	-7.5697	5.5703		0.6670	4.6638	
D*IRRILAND	Dx_5	0.0095	0.0032	***	0.0016	0.0018		0.0027	0.0010	**	-0.0156	0.0035	***	-0.0063	0.0855		0.0698	0.0716	
D*SLOPELAND	Dx_6	0.0027	0.0021		0.0013	0.0012		0.0008	0.0007		0.0039	0.0024	*	-0.0278	0.0571		0.0038	0.0478	
D*CTYDIST	Dx_7	0.0012	0.0018		0.0012	0.0011		0.0002	0.0006		0.0045	0.0020	**	0.0069	0.0494		0.1628	0.0413	***
D*MKTDIST	Dx_8	0.0175	0.0066	***	0.0093	0.0038	**	0.0027	0.0022		0.0014	0.0073		0.4291	0.1770	**	-0.4023	0.1482	***
D*ILLITERACY	Dx_9	0.0150	0.0049	***	0.0017	0.0028		0.0017	0.0016		0.0150	0.0054	***	-0.1374	0.1315		0.2579	0.1101	**
MOUNTAIN	x_1	-0.4173	0.0575	***	0.0414	0.0333		0.0635	0.0189	***	0.0594	0.0642		0.1203	1.5503		1.7661	1.2980	
MINORITY	x_2	-0.0008	0.0006		0.0031	0.0004	***	-0.0004	0.0002	*	0.0004	0.0007		0.0701	0.0166	***	0.0780	0.0139	***
VILSIZE	x_3	-0.0002	0.0001	**	-0.0003	0.0000	***	-0.0001	0.0000	***	-0.0001	0.0001		0.0118	0.0022	***	0.0080	0.0019	***
FARMLAND	x_4	0.1631	0.0258	***	0.0100	0.0150		0.0295	0.0085	***	-0.0010	0.0288		4.2786	0.6954	***	-2.8914	0.5822	***
IRRILAND	x_5	-0.0008	0.0008		0.0005	0.0005		0.0004	0.0003		0.0025	0.0009	***	-0.1314	0.0225	***	-0.0600	0.0188	***
SLOPELAND	x_6	-0.0008	0.0006		0.0001	0.0004		0.0002	0.0002		0.0019	0.0007	***	-0.0657	0.0164	***	-0.0993	0.0137	***
CTYDIST	x_7	-0.0012	0.0005	**	0.0010	0.0003	***	0.0010	0.0002	***	0.0007	0.0006		0.0098	0.0136		-0.0125	0.0114	
MKTDIST	x_8	-0.0013	0.0016		-0.0006	0.0009		0.0001	0.0005		0.0021	0.0018		0.0390	0.0432		-0.0180	0.0362	
ILLITERACY	x_9	-0.0013	0.0014		-0.0020	0.0008	***	-0.0005	0.0004		0.0013	0.0015		-0.0533	0.0364		-0.0811	0.0305	***
R^2		0.1008			0.0807			0.0826			0.0921			0.1360			0.1453		

Table 5.1 (Continued)

Variables		Car Access (Days)			Water Shortage %			Primary Enrol.Rate			Doctor Ratio (P/D)			Imm. Children %		
		Mean	S.Error		Mean	S.Error		Mean	S.Error		Mean	S.Error		Mean	S.Error	
INTERCEPT	C	95.3654	7.1029	***	32.8824	5.7235	***	101.6041	1.6888	***	1534.2884	156.1551	***	86.6115	7.5310	***
TREATMENT	D	1.3310	14.4826		1.4060	11.6702		1.5091	3.4434		213.6509	318.3983		-22.5717	15.3556	
MILL RATIO	gr	5.2792	8.6499		-6.2329	6.9701		-0.1791	2.0566		297.1209	190.1661		14.1256	9.1712	
D*MINORITY	Dx_2	-0.0796	0.0887		0.0202	0.0715		0.0261	0.0211		2.1918	1.9504		0.0723	0.0941	
D*VILSIZE	Dx_3	0.0008	0.0245		0.0190	0.0197		0.0114	0.0058	**	0.1281	0.5376		0.0179	0.0259	
D*FARMLAND	Dx_4	-14.6243	11.5513		4.8800	9.3081		1.3053	2.7465		283.9762	253.9536		7.0593	12.2475	
D*IRRILAND	Dx_5	-0.2131	0.1774		0.0565	0.1429		0.0034	0.0422		2.5335	3.9000		0.1309	0.1881	
D*SLOPELAND	Dx_6	0.0315	0.1185		0.1905	0.0955	**	0.0524	0.0282	*	3.4852	2.6045		0.0296	0.1256	
D*CTYDIST	Dx_7	0.0337	0.1023		0.0479	0.0825		0.0292	0.0243		1.5634	2.2501		0.0961	0.1085	
D*MKTDIST	Dx_8	-0.0921	0.3670		0.1257	0.2957		0.1144	0.0873		12.9934	8.0689		0.2661	0.3891	
D*ILLITERACY	Dx_9	-0.3333	0.2726		0.1838	0.2197		0.0343	0.0648		9.7145	5.9941		0.2790	0.2891	
MOUNTAIN	x_1	-3.8304	3.2148		1.8190	2.5905		1.0990	0.7644		304.5322	70.6777	***	-1.8068	3.4086	
MINORITY	x_2	-0.0597	0.0344	*	0.0902	0.0277	***	-0.0241	0.0082	***	-1.6543	0.7552	**	-0.0766	0.0364	**
VILSIZE	x_3	0.0019	0.0046		0.0100	0.0037	***	0.0003	0.0011		0.3568	0.1012	***	0.0237	0.0049	***
FARMLAND	x_4	-2.6878	1.4420	*	-0.6362	1.1620		0.2404	0.3429		31.9340	31.7032		2.3785	1.5290	
IRRILAND	x_5	-0.1361	0.0466	***	-0.0566	0.0376		0.0205	0.0111	*	-1.0260	1.0254		0.0407	0.0495	
SLOPELAND	x_6	-0.2167	0.0339	***	0.0893	0.0273	***	-0.0433	0.0081	***	-3.8392	0.7459	***	-0.0267	0.0360	
CTYDIST	x_7	-0.1428	0.0282	***	0.0371	0.0227		0.0453	0.0067	***	-0.0996	0.6205		0.0266	0.0299	
MKTDIST	x_8	-0.7770	0.0896	***	0.2810	0.0722	***	-0.0076	0.0213		4.5989	1.9707	**	-0.0054	0.0950	
ILLITERACY	x_9	-0.0836	0.0755		0.0673	0.0609		-0.1646	0.0180	***	-3.4318	1.6603	**	-0.0311	0.0801	
R^2		0.1300			0.0512			0.1027			0.0644			0.0148		

examines these slope coefficients to evaluate how the project impacts vary with village characteristics.

5.3 The Specific Treatment Effects

The motivations for any project intervention are based on the assumption that impacts can be generated through the interactions of the project investments and the local factors. Based on this motivation, the SWPRP combines a set of investment activities with the villages' characteristics in order to achieve the desired outcomes. The combinations of the project investments and the village characteristics are presented by the interaction terms in the correlated random coefficient model. A test of the significance of the coefficients on the interaction terms is a test of the null hypothesis that the project does not generate the treatment effects by interacting with the local village characteristics. The coefficients of the empirical models for the 21 outcome indicators are reported in Table 5.1. In the table, row D is the coefficient on the treatment, which is the ATE. Rows labeled Dx_k are the interactions of the demeaned x_k with the treatment d. x_k are defined as that in Table 4.1. The variable gr represents the inverse Mill's ratio. In order to give a clear picture of the specific effects, we summarize the significant effects in Table 5.2. The signs in Table 5.2 represent the direction on the specific treatment effects that are statistically significant.

Table 5.2 Interaction Impacts Between the Project Treatment and Village Characteristics

Indicators	TREATMENT D	D*MINORITY Dx_2	D*VILSIZE Dx_3	D*FARMLAND Dx_4	D*IRRILAND Dx_5	D*SLOPELAND Dx_6	D*CTYDIST Dx_7	D*MKTDIST Dx_8	D*ILLITERACY Dx_9
Wealth and Income									
Percentage of Households under the Poverty Line (826 Yuan)	-	-	-	-	-	-	-		
Net Income Per Capita (Yuan)	-			-	-	-	-	-	
Income Per Household in Cash (Yuan)	-	-	-		-			-	-
Income Per Household in Kind (Yuan)		-			+	-		+	-
Percentage of Households Living in Brick-tiled House	-		-	-		-			-
Percentage of Households Living in Thatched House		+	+	+					+
Percentage of Household with TV Set			+						
Agriculture									
Value of Agricultural Products Per Capita (Yuan)	+	+		+	+	+		+	
Grain Production Per Capita (KG)	+	+	+	+	+	+	+	+	+
Food Crop Growing Area Per Capita (Mu)	+		+	+	+		+	+	+
Cash Crop Growing Area per Capita (Mu)	+			+	+			+	+
Pigs in Stock Per Capita at the End of the Year (Heads)	+			+				+	
Cattle in Stock Per Capita at the End of the Year (Heads)	+		+	+	+				
Goats in Stock Per Capita at the End of the Year (Heads)	-	-	-	-	-	-	-		-
Off-farm Employment									
Percentage of Male Laborer Employed Off-farm	-							-	
Percentage of Female Laborer Employed Off-farm			+				+	-	-
Infrasture Service									
Days Accessible by Vehicles									
Percentage of Population with Water Shortage						+			
Education and Health Service									
Primary School Enrollment Rate			+			+			
Population-Doctor Ratio									
Percentage of Immunized Children									

5.3.1 Minority Villages

As shown in the "Dx_2" column in Table 5.2, the project yields better results in poverty reduction through improving agricultural production especially grain production. The sign of poverty rate on the row Dx_2 is negative and statistically significant, indicating that the poverty rate decreases as the percentage of non-Han minorities increases in the project villages. In addition, the coefficients corresponding to agricultural production and grain production are positive and statistically significant, indicating that the project is more successful in increasing food production in minority villages.

On the other hand, the project is less successful in improving cash income, income in kind, goat farming, and housing condition in minority villages. These results imply that the treatment effects are diminishing when the percentages of non-Han minorities increases. In other words, the higher the percentage of non-Han minorities in the villages, the smaller the treatment effects from the project in terms of cash income, income in kind, and goat farming. The positive slope on the percentage of thatched houses indicates that the project has smaller impact on the reduction of poor housing conditions in the minority villages.

The most interesting result is that by improving agricultural production in minority villages, poverty is reduced without increasing income. This may indicate a focus for future poverty reduction programs.

5.3.2 Natural Village Size

In villages comprised of larger natural villages, the project has a better result in reducing poverty and increasing TV possession, food crops, cash crops, cattle farming, off-farm employment of female labor, and the enrollment rate in primary school. The larger natural villages are normally associated with better geography and infrastructure. Therefore, the conditions favor agricultural development. This makes the larger natural villages wealthier prior to the project. As a result, more male laborers might already be working outside the village, so the significant impact of the project is to aid the female laborers in finding off-farm jobs. The alternative explanation might be that the female laborers in the larger natural villages are more open to accept the off-farm jobs because they are well informed of the outside world due to infrastructure such as a broadcast TV network and roads. The project is successful in increasing the number of TVs, and this might be due to the lower cost of TV services in the large villages. It is also successful in promoting the enrollment rates of the primary schools in large natural villages. The larger natural villages are more likely successful because they have better services in information and infrastructure.

5.3.3 Illiteracy Rate

The illiteracy rate does not significantly affect the ATEs on poverty rate. Investment in the villages with a high illiteracy rate does increase the food crop and cash crop production but does not increase income. As the project activities fail to increase cash income and income in kind, they also fail to improve the housing conditions in such villages. This may contribute to the insignificant outcomes in high illiteracy rate villages.

5.3.4 Land Resources

The results in Table 5.2 show that the project has a better performance in the villages with better land resources. The coefficients on the Dx_4, Dx_5, and Dx_6 are all negative and statistically significant in poverty rate, implying the ATE on poverty reduction can be accelerated in the villages with more land resources regardless of land quality. The results also show that the ATEs on farming activities such as food and cash crop growing and cattle farming are enhanced in the villages with more farmland (x_4) or more irrigated land (x_5) and, as a result, the ATEs on grain production and agricultural output are improved. The ATE on pig farming has a positive and significant slope on Dx_4. This suggests that the project promotes an expansion of agricultural production in the villages with better land resources. Meanwhile, in the villages with a high percentage of high-slope land (x_6), the ATEs on grain production and agricultural output are enhanced but the ATEs on farming activities are not. So, the project improves the productivity and the agricultural output rather than expanding the growing area in the villages with land scarcity. The access to roads and water are also significantly improved in the villages with high-slope land. Interestingly, land resources allow the project to achieve significant impacts in agricultural activities and outputs; these impacts do result in a reduction of poverty rate but not necessarily in an increase of net income.

5.3.5 Location

Similar to the land resources, the project has a better result in reducing poverty in the villages far from county towns (Dx_7), but the average net incomes do not increase. This implies a more equal distribution of income in the villages after the project. Such an effect on the income distribution is derived from increasing the production of grains and food crops and bringing more off-farm employment opportunities to female laborers.

As the distances from township markets (Dx_8) increase, the ATEs on the income in kind, food crop, cash crop, grain production, agricultural output also increase. However, these impacts do not improve the results in poverty reduction.

In this chapter, the correlated random coefficient models for 21 indicators are implemented controlling the selection bias with the inverse Mill's ratio from the selection model in Chapter 4. The results of the models indicate that the treatment effects of the project relate to villages' characteristics. These relationships provide evidence for the existence of the observed heterogeneous treatment effects and allow us to investigate the performance of the project in villages with different characteristics. Land and labor are found to be the key resources that cause the heterogeneity. In terms of poverty reduction, the project performs better in the villages with more land resources. However, in the villages with better land resources, the project fails to increase the average net income. That is to say, the reduction of the poverty rate has been derived from the re-distribution of incomes in the villages rather than from the increase of income. This is also shown by the project's failure to increase the average cash income and the average income in kind, although agricultural production is successfully improved in the villages with more farmland. More farmland allows the project to increase the food crop growing. The phenomenon that the poverty rate can be reduced without increasing the average income explains that, by extending the food crops, the project increases the income of the poorer and reduces in the income of the richer in the villages. In addition, the investments in the villages far from the county towns and larger natural villages also yield better results in poverty reduction. A major conclusion is that investing in agricultural activities plays a significant role in poverty reduction but not necessarily in increasing the average income in the villages.

CHAPTER VI

AVERAGE TREATMENT EFFECTS

Evaluating the average treatment effects of the SWPRP at the village level is at the center of this research. In this chapter, we estimate the average treatment effects using matching approaches to correct selection bias. Unlike the control function approach in Chapter 5, the matching approach does not require a specification of the functional form to model the outcomes. With the propensity scores estimated in Chapter 4, the propensity score matching estimators are established. The parameters including ATEs, ATTs, and ATNTs are then estimated. Discussion is focused on the ATTs so that the impacts of the SWPRP in the project villages are investigated in detail. To extrapolate the impacts on non-project villages, the ATEs and ATNTs are also discussed. We begin the chapter with a discussion of the various dimensions of village welfare that the SWPRP was designed to target and describe the variables in the dataset that can be used as indicators of project effectiveness. The matching results are then presented and concluding comments are provided.

6.1 Possible Effects and Measurement

The objective of the SWPRP is to tackle the problem of absolute poverty with a comprehensive approach that integrates resources and efforts at the village level. Such a comprehensive approach is expected to generate multidimensional impacts on the project villages. To detect the impacts, a set of indicators are required to measure the outcomes from different aspects. Besides measurable, the indicators must have internal validity or, in other words, have an effective response to the changes derived from the project intervention in the project villages. To identify this indicator set, the possible impacts are reviewed from income and wealth, farming, off-farm employment, development of infrastructure, education, and healthcare services.

6.1.1 Income and Wealth

The welfare of the households in the project villages should be a function of income and wealth. According to the Agricultural Operation Division (1995), the annual net income per capita is less than 320 Yuan (less than $40) in the poor villages before the SWPRP. By the local standard, the income is not enough to keep warm or free from hunger. Many previous efforts have been unsuccessful in improving wealth in this region. The SWPRP integrates a variety of activities at the village level to improve the households' capacity to generate income and wealth. If the intervention of the project is successful, responses should be found in the indicators related to income and wealth in the villages.

The indicators are identified by investigating how income and wealth are generated. The households in the poor villages obtain their incomes from two major sources, farming and off-farm employment. In addition, transfer payments and fishing and hunting provide other sources of income. However, the amounts from these sources are usually very small and not available in our dataset. The available measures for income sources are income from farming, and income from off-farm jobs.

Basically, farming in the poor villages is for subsistence. The majority of farm products are for self-consumption and only a small part of the farm products are sold for cash. The food crops such as corn and rice are basically for self-consumption. Even in the case of the excess production, households in the poor villages rarely sell the surplus. The most common way to make use of the excess grains is to feed more animals especially pigs. Because of inadequate markets, animal products such as pork are smoked and preserved for later consumption. However, this situation might change with the development of the local markets. Households might sell their pigs and buy pork from the markets. The cash crop farming such as herb medicine or sugar cane growing are all market oriented. In general, the income in the poor villages is derived from income in kind and cash income.

The income in kind is traditionally a major form of income. As shown in Table 2.1, the income in kind accounts for nearly half of the total income. More than three quarters[12] of the total income is derived from farming. This implies a quarter of total income is from off-farm employment, accounting for half of the cash income.

Cash is expended for commodities such as farming inputs, necessities, durable goods, and services such as education and healthcare. Farming inputs are required for every household engaged in farming. The amount of inputs usually depends on cash income. The households in the village with extreme scarcity of land resources do not produce enough food for subsistence, so they have to earn cash to buy food besides necessities such as salt, oil, and clothes. In this case, households without an off-farm job have to borrow food during the hungry season usually from February to June.

Housing is a necessity, and good housing conditions are a luxury good. [13] Poor households usually live in a thatched house walled by bamboo or grass weaving. The

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[12] The data shows that there are 4.5 members in each household. In Table 2.1, agricultural value is 655 Yuan per capita, which is about 2950 Yuan per household. The total income per household is the sum of cash income and income in kind, and is 3880 Yuan. Therefore, the agricultural value accounts for 76 percent of total income.

[13] Buying a house is considered an investment in urban areas. However, housing could not be an investment in a remote village. The value of a house in the remote village might depreciate rather than appreciate

better-off households are able to buy materials to build a house of brick-and-tile structure or even a concrete structure that provides comfortable living conditions. Adequate transportation is a critical component for the availability of building materials.

Needless to say, televisions are also luxury goods and ownership completely depends on cash income. Except for the cash income, the ownership of a television also depends on signal availability and electrical supply. The cost of cable TV is too high in a small and remote village.

Education and healthcare are luxury goods in the poor villages. Although no tuition is allow to be charged for primary and middle school education by the Compulsory Education Law of the People's Republic of China, students have to pay fees for textbooks and other supplies. These fees are a large expenditure for the poor households. Households with children in school have to plan for the fees by selling animals or working off farm before the enrollment of each semester. It is not rare for one child in a family to drop out, so the other children can attend school.

The intervention of the SWPRP intended to increase the agricultural inputs and off-farm employment. As a result, increases in net income, cash income, and income in kind would be expected. If this occurs, increases in luxury goods such as television ownership and housing conditions might also be found. With our available dataset, the project's impact on income and wealth is evaluated by examining the ATTs of variables including poverty rate, net income, cash income, income in kind, percentages of brick-and-tile structure, percentages of thatched housings, and the ownership of television in the project villages.

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because of the cost to maintain it.

6.1.2 Farming

Small scale farming is practiced by individual households for self-sufficiency. As shown in Table 2.1, farmland for each household is about 5 Mu (about 0.86 acres) on average. The small size of the farms can be traced to the land reforms in the 1950s and in the 1980s. Under these reforms, land was collectivized and then re-assigned almost evenly to each resident inside a village. Since the 1980s', the land area for each household has been constant although per capita land area varied with the change in family size. To support their families, households have to grow everything they need.

Despite the small scale, farming includes a variety of activities categorized into crop growing and animal farming. The major crops grown are rice on paddy land and corn, soybean, sweet potato, sugar cane and vegetables on upland. The rice requires irrigation and flat land and therefore could only be grown in a village with better land resources. The seasonal yield of rice is about 300 to 400 kilograms of grain per Mu. With good irrigation, rice is grown twice in a year. As a result, villages that grow rice are better off. The villages without irrigation have to live on corn grown on upland and are usually poorer. Due to low land quality, the seasonal yield of corn is about 200-300 kilograms of grain per Mu. Technically, corn can also be grown twice annually. However, the second crop depends heavily on rainfall in the fall. Normally, only one in three second crops are harvested. Corn is the staple food for the people and also for the animals in the poor villages.

Households raise animals such as pigs, goats, cattle or buffalo, and chickens. Pigs and goats are the major sources of cash for large expenditures such as school fees, healthcare, clothes, and festivals in households without off-farm income. Pig farming relies on corn and side-products such as sweet potatoes. Households usually have between 1 and 5 pigs due to the limited amount of land. Goat farming depends on availability of grass on the mountains and labor required to maintain the goats. In addition, cattle or buffalo are used to plough the land. One head of cattle or buffalo is normal in each household.

Technology in the poor villages is simple and labor intensive. The common variety of corn has been passed down from generations. Corn is cultivated by human labor and normally fertilized twice with animal manure. Animals are kept in dirty sheds and are allowed to roam around on fallow land. Pigs are fed twice a day with cooked food, a mixture of corn with green fodder such as sweet potato stems and leaves and wild vegetables. Cattle, buffalo, and goats graze on mountainsides and are fed with crop residuals. Farming with such traditional technology is unproductive.

To increase productivity, the SWPRP supported almost all the major farming activities with about 45 percent of its total investment. The activities include raising livestock (e.g. pigs, goats, and cattle) and growing food crops (e.g. rice and corn), fruits (e.g. longan, litchi, grapes, pomelo, and other subtropical fruits), cash crops (e.g. sugar cane, vegetables, and medical herbs), and forest products. Besides financial support, the project provides training to farmers and local technicians. The investment is expected to bring changes in food crop and cash crop growing and pig, cattle and goat farming. As a result, grain production and the value of agricultural production should increase. To verify the possible impacts on agricultural component, we examine the significance of the ATTs on agricultural output value, grain production per capita, food crop growing area, cash crop growing area, and the number of pigs, cattle, and goats in stock.

6.1.3 Employment

On average, off-farm employment provides about half of a household's cash income. For the households with young, skilled, and educated laborers, the share of cash income from off-farm employment is larger. Two types of off-farm jobs are engaged by rural laborers depending on the distance from home. The laborers who work near their homes commute between sites and homes. They might still farm while working full-time or part-time jobs. Therefore, they are considered as part-time off-farm employed. Their incomes from off-farm employment are lower. However, they are compensated with benefits from farming, being with their families, and taking care of their children and the elders. The laborers employed in urban areas far from their homes stop farming and leave their families. They are usually full-time off-farm employees and earn higher income. A part of their income is remitted back to support their families that remain on the farms. Notice that the laborers are still considered as residents of their original villages even though they are employed and live in the urban areas. Families are not encouraged to migrate with the laborers. As a result, the families, especially their children, stay in the villages to receive education. Off-farm laborers still keep their share of land in the village.[14] The other family members at home often cultivate the land. In essence, the land system serves as a social security system for the rural population. In the case of an economic recession, the unemployed rural laborers can return to their villages and earn their living from farming. Our dataset allow us to investigate the project's impact on the percentage of male and female laborers employed in urban areas.

[14] By the Law of Land Administration of the People's Republic of China, the land in a village is collectively owned by all residents in the village. In practice, land is allocated to every resident and cultivated by individual households in the village. The land might be re-allocated according changes in village population.

6.1.4 Rural Infrastructure

The SWPRP directly sought to improve two types of rural infrastructures, water supply and roads. As shown in Table 2.1, more than half of the residents in the poor villages in Guangxi still suffered from a water shortage[15] in 2000. The SWPRP addressed this problem by helping households to construct a water tank of about 30 cubic meters in size in order to store water for the dry season, which normally continues through fall and winter to early spring. The SWPRP provided help for the poor villages that did not have access to a road prior to the project.[16] As seen in Table 2.1, as of 2000, there were still about five months on average in a year when vehicles could not access the poor villages. The roads that are constructed with the aid from the SWPRP improved the transportation but did not solve the problem completely. The outcomes of the project in this infrastructure component are measured by the increase in days accessible by vehicles and the decrease in the percentage of population with water shortage in the project villages.

6.1.5 Education

Lack of quality primary education is one of the important factors that cause the problems of low enrollment and completion rate in the poor villages. To address these problems, the SWPRP provided financial support for primary school renovation and construction; tuition assistance and in-school nutritional supplements for poor students; the purchase of textbooks, instructional equipment and furniture; and teacher and school management training. However, the project stopped providing the in-school nutritional supplements because the schools lacked the necessary facilities for food preparation, so the project's results in this area are derived from the delivery of the other activities. To

[15] A village is categorized as having water shortage if it obtains drinking water beyond a horizontal distance over 1.5 kilometers or a vertical distance over 100 meters for more than 100 days in a year.

[16] A village is referred to as not having access to a road if the residents in the village have to walk longer than 30 minutes to the closest road.

measure the project's impact on education, the enrollment rate of primary school is the only indicator available in our dataset. However, this indicator only measures the change in primary school attendance. No indicator is available in our dataset to measure the improvement in education quality, which is very likely true since the project has a large investment in activities such as teacher training that should lead to an improvement in education quality.

6.1.6 Healthcare

Unavailability and unaffordability are the major healthcare problems in the project villages. More complete healthcare services are provided in township hospitals, which are about 17 kilometers on average away, so healthcare services are not available in most project villages. A few villages have informal clinics that run by "bare-foot" doctors who are also part-time farmers. Therefore, it is normal for the residents to travel for more than one hour for healthcare services. However, even if they have access, the cost of medical care in the township hospitals is too high for the poor residents to receive their services.

The SWPRP provided financial support to construct new healthcare facilities, to renovate the existing facilities, to train healthcare workers and birth attendants, to create clinics, and strengthen the access of disease prevention and control, maternal and child healthcare, and healthcare system management at the township and village levels. The impacts of the SWPRP intervention are expected to be multidimensional, so they must be measured with different indicators. However, the available data only allow us to measure the impacts in terms of the population-doctor ratio and the percentage of immunized children.

In sum, we identify 21 indicators to measure the outcomes associated with the SWPRP. In the next section, the impact of the project on these 21 indicators is evaluated through the matching method.

6.2 Nearest Neighbor and Caliper Matching

To implement the matching approach on the SWPRP is to match the project villages with the non-project villages and then to contrast the respective outcomes. To match is to search for similarities or closeness between the project villages and the non-project villages. Based on assumption (3.26), closeness is measured by differences in villages' characteristics, X. However, when X includes multiple variables Rosenbaum & Rubin (1983) show that the estimation bias does not converge with an increase in sample size. In order to obtain a converged estimator, they propose matching based on the closeness of propensity scores (3.29). This section describes nearest neighbor matching and caliper matching and their uses in evaluating the average treatment effects of the SWPRP using the propensity scores derived in Chapter 4. Kernel-based matching is described in the next section.

As in Chapter 3, let y denote a potential outcome, which is a potential outcome of one of the 21 indicators in Table 2.1. y^1 represents the outcome with the project and y^0 is the outcome without the project. Also, let d denote the treatment of the SWPRP, so d=1 represents villages that are treated and d=0 represents villages that are untreated. The treatment effect on village i is conditional on the propensity score $P(X_i)$, which is determined by the characteristics, X of village i.

$$\begin{aligned}\alpha_i &= [y_i^1 - y_i^0]|X_i \\ &= [y_i^1 - y_i^0]|P(X_i)\end{aligned} \tag{6.1}$$

Sample wide, the average treatment effect (ATE), the average treatment effect on the treated (ATT), and the average treatment effect on the untreated (ATNT) are defined as

$$\begin{aligned} \mathrm{ATE} &= \mathrm{E}\big(\alpha_i \big| \mathrm{P}(\mathrm{X}_i)\big) \\ &= \mathrm{E}([y_i^1 - y_i^0]|\mathrm{P}(\mathrm{X}_i)) \end{aligned} \tag{6.2}$$

$$\begin{aligned} \mathrm{ATT} &= \mathrm{E}(\alpha_i|\mathrm{P}(\mathrm{X}_i), d = 1) \\ &= \mathrm{E}([y_i^1 - y_i^0]|\mathrm{P}(\mathrm{X}_i), d = 1) \end{aligned} \tag{6.3}$$

$$\begin{aligned} \mathrm{ATNT} &= \mathrm{E}(\alpha_i|\mathrm{P}(\mathrm{X}_i), d = 0) \\ &= \mathrm{E}([y_i^1 - y_i^0]|\mathrm{P}(\mathrm{X}_i), d = 0) \end{aligned} \tag{6.4}$$

To calculate equation (6.2), (6.3), and (6.4), the counterfactuals of the project villages, $y_i^0|\mathrm{P}(\mathrm{X}_i), d = 1$, and the counterfactuals of the non-project villages, $y_i^1|\mathrm{P}(\mathrm{X}_i), d = 0$ must be estimated. Suppose assumption (3.29) holds, then $y_i^0|\mathrm{P}(\mathrm{X}_i), d = 1$ can be recovered from $y_i^0|\mathrm{P}(\mathrm{X}_i), d = 0$ and $y_i^1|\mathrm{P}(\mathrm{X}_i), d = 0$ from $y_i^1|\mathrm{P}(\mathrm{X}_i), d = 1$.

The variances of the treatment effects are estimated for statistical tests. The conventional method for variance estimation is bootstrapping. However, Abadie and Imbens (2006b) show that the bootstrapping method is not appropriate for nearest neighbor matching. Nevertheless, for the purpose of comparison across methods in this research, we estimate the variances for all estimators, including nearest neighbor matching, caliper matching and kernel-based matching, using the bootstrapping method.

In addition to conditioning on the propensity scores to satisfy assumption (3.29), steps are also taken to ensure that assumption (3.26) is satisfied. As mentioned in Chapter 5, we follow the suggestion by Imbens (2009) to obtain the common support by trimming the outliers in terms of the propensity scores. Strictly speaking, the common support is automatically derived in the caliper matching but not in nearest neighbor matching and kernel-based matching. To be consistent, the trimmed sample is used in all methods including control function, nearest neighbor, caliper, and kernel-based matching. Our trimmed sample includes 325 project villages and 1909 non-project villages.

6.2.1 Estimation of Nearest Neighbor Matching

In nearest neighbor matching, as discussed in Chapter 3, the project villages are matched with a number (M) of the non-project villages in their neighborhoods, i.e., with the closest propensity score. The number M is arbitrarily pre-determined and remains the same for each project village. In order to examine the sensitivity, M is set to 1,3,5,7, and 9 in this research. The distances between the project villages and their Mth closest non-project villages determine the widths of the neighborhoods in terms of the propensity scores. For example, if M is 3, the matched neighborhoods for each project village include 3 non-project villages. The widths of the neighborhoods vary at each project village and determined by the propensity score difference between the project villages and their 3rd closest non-project villages. In nearest neighbor matching, the matched neighborhoods contain a fixed number (M) of closest non-project villages and are different in widths at different project villages.

After the matched neighborhoods are constructed for each project village, the treatment effects at each project villages are computed by contrasting the outcomes between the project villages and the non-project villages in their matched neighborhoods. The average of these treatment effects at all project villages is the average treatment effect on the treated (ATT). To compute the ATNT, the places of the project villages and the non-project villages are exchanged. The neighborhoods of the project villages are constructed for each non-project villages. The outcomes of the non-project villages are contrasted to their matched project villages in the neighborhoods. The ATE is the average over the treatment effects at all villages including the project villages and the non-project villages. The results with different Ms are given in Table 6.1 for the ATEs, Table 6.2 for the ATTs, and Table 6.3 for the ATNTs.

To compare the results on the different Ms that determine the neighborhoods, we cannot find a clear pattern of relationship among the estimated treatment effects, variance, and number of matches (M). For example, in Table 6.2, as the number of matches (M) increases, the ATTs on some indicators such as poverty rate and income decrease and then increase while the ATTs on other indicators such as the value of agricultural products and the percentage of female labor employed off-farm increase and then decrease. Theoretically, variances should become smaller as the number of matches (M) increase. We cannot see such a pattern in our results. The standard error of the ATT on the poverty rate is 1.43 when M=1, falls to 1.1 when M=3, and increases to 2.7 when M=7, and falls again to 0.42 when M=9. This instability in variance might be due to the invalidity of the bootstrapping method as pointed out by Abadie and Imbens (2006b).

Table 6.1 Average Treatment Effects (ATE) Estimated from Nearest Neighbor Matching

Indicators	M=1			M=3			M=5			M=7			M=9		
	Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error	
Wealth and Income															
Percentage of Households under the Poverty Line (826 Yuan)	-3.0272	0.8713	***	-4.5122	2.0164	**	-5.0092	0.9373	***	-4.8959	1.5963	***	-5.1304	0.9884	***
Net Income Per Capita (Yuan)	2.3281	8.1812		8.0391	12.7142		4.3844	10.5337		11.3437	7.3683		15.5384	14.8756	
Income Per Household in Cash (Yuan)	183.3309	119.6913		174.0811	2.8295	***	205.3078	80.2413		203.9740	49.4487	***	195.0849	0.4654	***
Income Per Household in Kind (Yuan)	129.0824	29.6950	***	105.1253	98.7557		87.0667	101.0052		112.6651	24.7192	***	137.1217	460.6826	
Percentage of Households Living in Brick-tiled House	8.8734	1.6468	***	9.9476	3.4092	***	10.1668	2.5221	***	10.0385	0.0471	***	10.2319	3.1351	***
Percentage of Households Living in Thatched House	-8.3458	1.1452	***	-8.6934	0.0285	***	-8.9072	0.8457	***	-8.9265	0.4920	***	-9.0077	3.7438	**
Percentage of Household with TV Set	0.9224	2.4589		1.9563	0.6349	***	1.2269	3.7146		0.3590	2.1615		-0.2735	0.8413	
Agriculture															
Value of Agricultural Products Per Capita (Yuan)	-101.3917	61.0896	*	-40.8595	115.3373		-73.1882	102.9278		-93.1272	32.5443	***	-97.1777	3.4524	***
Grain Production Per Capita (KG)	-4.9545	5.0590		-3.8213	5.6380		-5.7579	0.4990	***	-6.6455	6.8434		-8.1981	2.7990	***
Food Crop Growing Area Per Capita (Mu)	0.1564	0.0796	**	0.1841	0.0227	***	0.1377	0.0031	***	0.1304	0.0695	*	0.1356	0.0436	***
Cash Crop Growing Area per Capita (Mu)	-0.0062	0.1387		-0.0454	0.1202		-0.0662	0.0101	***	-0.0789	0.0070	***	-0.0905	0.0440	**
Pigs in Stock Per Capita at the End of the Year (Heads)	0.0872	0.0367	**	0.0723	0.0282	**	0.0621	0.0177	***	0.0590	0.0216	***	0.0548	0.0676	
Cattle in Stock Per Capita at the End of the Year (Heads)	-0.0099	0.0112		-0.0104	0.0023	***	-0.0179	0.0022	***	-0.0242	0.0157		-0.0259	0.0119	**
Goats in Stock Per Capita at the End of the Year (Heads)	0.1414	0.0133	***	0.1490	0.1141		0.1387	0.0574	**	0.1422	0.1214		0.1583	0.0121	***
Off-farm Employment															
Percentage of Male Laborer Employed Off-farm	3.6784	2.8756		5.3523	3.2722		6.0281	0.0134	***	5.9599	0.1191	***	5.8825	0.1579	***
Percentage of Female Laborer Employed Off-farm	4.3785	1.2890	***	5.4021	2.0516	***	5.3475	0.2570	***	5.5004	4.1376		5.9895	2.0752	***
Infrasture Service															
Days Accessible by Vehicles	10.4888	6.9618		11.4798	5.1285	**	11.3252	1.0656	***	12.3064	9.4569		13.3264	3.9719	***
Percentage of Population with Water Shortage	-7.7762	2.7658	***	-8.3068	0.2489	***	-8.1625	1.9367	***	-7.9611	3.9497	**	-8.0509	4.4022	*
Education and Health Service															
Primary School Enrollment Rate	0.8884	0.6768		0.8950	0.2418	***	0.6377	0.2613	**	0.3909	1.5327		0.4177	0.0486	***
Population-Doctor Ratio	242.6122	69.0179	***	283.4648	74.9152	***	303.7764	33.2257	***	306.6051	22.1797	***	327.1526	146.4650	**
Percentage of Immunized Children	1.1375	4.8784		-1.0533	5.8252		-0.7559	2.7433		-0.8005	1.4765		-1.1330	4.0236	

Note: The standard errors in column S.Error are esimated by bootstrapping with 1000 replecations.
Significant levels: * —10%; ** —5%; and *** —1%.

Table 6.2 Average Treatment Effects on the Treated (ATT) Estimated from Nearest Neighbor Matching

Indicators	M=1			M=3			M=5			M=7			M=9		
	Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error	
Wealth and Income															
Percentage of Households under the Poverty Line (826 Yuan)	-5.1981	1.4335	***	-2.8183	1.1046	**	-2.5720	2.3322		-2.6727	2.6707		-3.1837	0.4193	***
Net Income Per Capita (Yuan)	17.6819	20.9492		16.4062	14.9743		14.2747	18.4648		18.1805	11.8694		23.5577	8.1239	***
Income Per Household in Cash (Yuan)	227.2038	231.1420		177.3797	150.8606		180.9195	104.2807	*	182.4723	65.9597	***	197.9425	15.1085	***
Income Per Household in Kind (Yuan)	144.7790	58.9320	**	157.2263	87.6201	*	120.8759	6.7809	***	143.8425	64.9365	**	145.2282	23.2252	***
Percentage of Households Living in Brick-tiled House	10.5721	3.0992	***	9.0068	0.5851	***	8.1931	1.4726	***	7.7582	3.9165	**	7.6617	0.7429	***
Percentage of Households Living in Thatched House	-10.7617	2.7148	***	-7.7301	4.3867	*	-7.2931	0.1691	***	-7.2040	3.2758	**	-7.0797	2.4988	***
Percentage of Household with TV Set	0.8324	1.9628		-0.4964	3.6993		-0.0471	1.5695		-0.0722	0.6538		-0.2829	0.2198	
Agriculture															
Value of Agricultural Products Per Capita (Yuan)	-85.2999	73.2367		-94.1707	7.6851	***	-100.3091	67.6635		-97.4747	61.9290		-86.5643	55.0547	
Grain Production Per Capita (KG)	2.3661	2.2407		-9.4283	11.9187		-4.3033	4.9349		-2.1460	4.1897		-1.1902	3.9858	
Food Crop Growing Area Per Capita (Mu)	0.2148	0.0788	***	0.2041	0.0242	***	0.1932	0.0696	***	0.2013	0.0477	***	0.2023	0.0270	***
Cash Crop Growing Area per Capita (Mu)	-0.0422	0.0361		-0.0351	0.0169	**	-0.0354	0.0070	***	-0.0341	0.0108	***	-0.0365	0.0188	*
Pigs in Stock Per Capita at the End of the Year (Heads)	0.0339	0.0076	***	0.0647	0.0201	***	0.0591	0.0106	***	0.0614	0.0246	**	0.0667	0.0536	
Cattle in Stock Per Capita at the End of the Year (Heads)	-0.0099	0.0144		-0.0106	0.0080		-0.0152	0.0200		-0.0165	0.0179		-0.0173	0.0108	
Goats in Stock Per Capita at the End of the Year (Heads)	0.2354	0.0167	***	0.2329	0.0574	***	0.2373	0.1085	**	0.2321	0.0703	***	0.2228	0.0918	**
Off-farm Employment															
Percentage of Male Laborer Employed Off-farm	3.3180	1.1611	***	3.2975	2.1150		3.6202	0.9669	***	3.4576	3.3565		3.3767	1.0614	***
Percentage of Female Laborer Employed Off-farm	3.3792	0.8100	***	3.4847	0.6656	***	3.7461	0.6324	***	3.5934	2.2475		3.4376	1.4846	**
Infrasture Service															
Days Accessible by Vehicles	12.7823	5.1541	**	13.9238	0.0146	***	12.6874	0.3893	***	12.8737	6.7879	*	13.3434	1.2857	***
Percentage of Population with Water Shortage	-11.3932	2.2345	***	-8.0573	5.1263		-7.9626	2.9823	***	-8.3638	4.5549	*	-9.0486	0.6790	***
Education and Health Service															
Primary School Enrollment Rate	0.0774	0.2653		-0.0410	0.2157		-0.0642	0.1191		0.0035	0.4417		0.1423	0.3286	
Population-Doctor Ratio	217.5048	102.6430	**	212.4089	83.5922	**	202.8038	91.1684	**	214.9489	42.3147	***	219.7022	98.0747	**
Percentage of Immunized Children	0.8578	0.9133		-3.8595	4.8538		-3.2489	0.7265	***	-3.6903	1.0474	***	-3.8218	2.6999	

Note: The standard errors in column S.Error are esimated by bootstrapping with 1000 replications.

Significant levels: * —10%; ** —5%; and *** —1%.

Table 6.3 Average Treatment Effects on the Untreated (ATNT) Estimated from Nearest Neighbor Matching

Indicators	M=1			M=3			M=5			M=7			M=9		
	Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error	
Wealth and Income															
Percentage of Households under the Poverty Line (826 Yuan)	-2.6576	1.1070	**	-4.8005	3.0868		-5.4242	5.1844		-5.2744	0.0689	***	-5.4618	1.8589	***
Net Income Per Capita (Yuan)	-0.2858	2.9815		6.6147	5.1827		2.7007	30.0388		10.1797	19.8702		14.1731	1.2607	***
Income Per Household in Cash (Yuan)	175.8617	179.8000		173.5195	147.0004		209.4599	132.8210		207.6346	40.7974	***	194.5984	18.4527	***
Income Per Household in Kind (Yuan)	126.4100	40.5630	***	96.2553	148.5910		81.3108	46.3459	*	107.3573	101.4217		135.7415	13.7385	***
Percentage of Households Living in Brick-tiled House	8.5842	1.1113	***	10.1078	0.5158	***	10.5029	0.8372	***	10.4267	1.2481	***	10.6695	2.2649	***
Percentage of Households Living in Thatched House	-7.9345	0.1124	***	-8.8574	3.2594	***	-9.1820	2.0581	***	-9.2197	1.2601	***	-9.3359	0.2426	***
Percentage of Household with TV Set	0.9377	1.8576		2.3738	6.5695		1.4438	0.0786	***	0.4324	0.1492	***	-0.2720	0.2088	
Agriculture															
Value of Agricultural Products Per Capita (Yuan)	-104.1312	54.4054	*	-31.7835	54.7021		-68.5710	35.9254	*	-92.3870	56.8413		-98.9846	67.4750	
Grain Production Per Capita (KG)	-6.2008	6.3262		-2.8667	5.3571		-6.0056	3.2326	*	-7.4115	1.0758	***	-9.3911	12.1867	
Food Crop Growing Area Per Capita (Mu)	0.1464	0.0104	***	0.1806	0.0007	***	0.1283	0.0047	***	0.1183	0.1306		0.1242	0.1051	
Cash Crop Growing Area per Capita (Mu)	-0.0001	0.0782		-0.0472	0.0048	***	-0.0715	0.0431	*	-0.0865	0.0416	**	-0.0997	0.0444	**
Pigs in Stock Per Capita at the End of the Year (Heads)	0.0963	0.0700		0.0736	0.0291	**	0.0627	0.0071	***	0.0586	0.0274	**	0.0528	0.0676	
Cattle in Stock Per Capita at the End of the Year (Heads)	-0.0099	0.0145		-0.0104	0.0078		-0.0183	0.0169		-0.0255	0.0089	***	-0.0274	0.0208	
Goats in Stock Per Capita at the End of the Year (Heads)	0.1254	0.0933		0.1347	0.1556		0.1219	0.2239		0.1269	0.1755		0.1473	0.0163	***
Off-farm Employment															
Percentage of Male Laborer Employed Off-farm	3.7398	1.5829	**	5.7022	4.5197		6.4380	3.7847	*	6.3859	0.4281	***	6.3091	1.8709	***
Percentage of Female Laborer Employed Off-farm	4.5486	0.3595	***	5.7286	2.9094	**	5.6201	2.5065	**	5.8250	0.0158	***	6.4240	1.5019	***
Infrasture Service															
Days Accessible by Vehicles	10.0984	7.8380		11.0637	2.8748	***	11.0933	1.9833	***	12.2098	7.4517		13.3235	1.3055	***
Percentage of Population with Water Shortage	-7.1604	6.4674		-8.3493	5.4183		-8.1965	2.7485	***	-7.8925	5.0262		-7.8810	1.8466	***
Education and Health Service															
Primary School Enrollment Rate	1.0265	0.6838		1.0543	0.8796		0.7572	0.7023		0.4569	0.8952		0.4646	0.0063	***
Population-Doctor Ratio	246.8866	132.0248	*	295.5618	166.7451	*	320.9667	26.9944	***	322.2092	64.9456	***	345.4456	223.8181	
Percentage of Immunized Children	1.1852	1.2407		-0.5756	1.5698		-0.3315	3.6439		-0.3085	2.3344		-0.6753	0.4466	

Note: The standard errors in column S.Error are esimated by bootstrapping with 1000 replications.
Significant levels: * —10%; ** —5%; and *** —1%.

6.2.2 Estimation of Caliper Matching

Caliper matching is used to prevent particularly bad matches that might occur in nearest neighbor matching. Nearest neighbor matching allows the widths of matched neighborhoods to vary freely. The widths of the neighborhoods might be too big so that the matching actually contrasts villages with very different characteristics. Calipers are used to limit matching within a tolerated distance. The size of the caliper is also determined arbitrarily.

As noted by Smith and Todd (2005), determining a priori the caliper size is difficult because a tradeoff occurs. A smaller caliper width excludes some observations that may be good matches and a large caliper width may include poor matches. The results of matching with the caliper set at 0.00005, 0.0001, 0.005, and 0.001 are reported in Table 6.4, 6.5, 6.6 for the ATEs, the ATTs, and the ATNTs respectively.

Similar to nearest neighbor matching, the findings here do not show a clear relationship among the caliper, treatment effects, and their variances. As shown in Table 6.5, when the size of caliper increases, ATTs on cash income starts with 342 Yuan, falls to 108 Yuan, and then increases to about 199 Yuan. The standard error is as small as 0.4 and as large as 112. In essence, caliper matching is a type of nearest neighbor matching, and this instability of the variances may also result from the failure of bootstrapping.

The results from nearest neighbor matching and caliper matching vary dramatically with the number of matches and the size of the caliper, both a priori decisions. Employing a different matching technique, kernel-based matching, which uses all observations as matches with appropriate weights, may lead to more consistent results. This method is used in the next section.

Table 6.4 Average Treatment Effects (ATE) Estimated from Caliper Matching

Indicators	Calper=0.00005			Calper=0.0001			Calper=0.0005			Calper=0.001			Calper=0.005		
	Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error	
Wealth and Income															
Percentage of Households under the Poverty Line (826 Yuan)	-5.9853	1.9840	***	-6.6358	3.7711	*	-11.2536	7.1705		-11.6081	7.9327		-8.853163	8.702242	
Net Income Per Capita (Yuan)	-0.4260	18.5729		-2.9812	15.7179		8.3022	4.3488	*	11.6261	1.1781	***	10.03806	9.261395	
Income Per Household in Cash (Yuan)	319.4623	249.1942		160.4484	104.6139		270.7179	263.4658		280.5983	101.4352		220.3749	55.11263	***
Income Per Household in Kind (Yuan)	-10.3319	150.2317		-81.4209	224.6798		-188.0310	336.7333		-161.9078	143.7136		-208.7079	252.9277	
Percentage of Households Living in Brick-tiled House	14.5243	10.3808		15.2020	10.5942		14.9931	13.3732		13.6662	7.3661	*	17.11965	8.19312	**
Percentage of Households Living in Thatched House	-16.5936	9.4608	*	-16.9904	13.0635		-17.8281	16.7259		-17.6533	12.1265		-20.08474	12.12837	*
Percentage of Household with TV Set	6.0394	8.3677		10.4064	6.7487		14.9974	13.3547		15.8311	15.2442		14.54216	9.519751	
Agriculture															
Value of Agricultural Products Per Capita (Yuan)	-90.6751	37.8100	**	-170.4892	28.9185	***	-142.8920	83.6019	*	-126.1537	36.7788	***	-60.8611	85.31759	
Grain Production Per Capita (KG)	0.2266	30.2062		-4.2283	2.3382	*	3.2618	4.6687		3.6700	0.2169	***	2.977792	2.956513	
Food Crop Growing Area Per Capita (Mu)	0.0384	0.1225		0.0256	0.0082	***	-0.0682	0.1243		-0.0883	0.0530	*	-0.088252	0.131343	
Cash Crop Growing Area per Capita (Mu)	-0.0289	0.0271		0.0051	0.0267		0.0003	0.0392		0.0028	0.0330		-0.017579	0.000193	***
Pigs in Stock Per Capita at the End of the Year (Heads)	-0.0094	0.0036	***	-0.0537	0.0849		-0.0718	0.0747		-0.0810	0.0822		-0.082168	0.046486	*
Cattle in Stock Per Capita at the End of the Year (Heads)	-0.0054	0.0480		-0.0092	0.0228		-0.0127	0.0221		-0.0167	0.0050	***	-0.011113	0.018869	
Goats in Stock Per Capita at the End of the Year (Heads)	0.0052	0.0095		0.0076	0.0090		-0.0499	0.0538		-0.0632	0.1222		-0.065287	0.055621	
Off-farm Employment															
Percentage of Male Laborer Employed Off-farm	3.0003	4.5045		1.6828	2.3154		1.9378	1.9754		1.1092	2.6600		2.032205	0.617089	***
Percentage of Female Laborer Employed Off-farm	3.5433	0.4311	***	5.3285	5.2962		5.1813	5.8898		5.0510	6.2348		5.393739	4.124411	
Infrasture Service															
Days Accessible by Vehicles	11.3857	5.1693	**	15.0447	9.8173		18.7958	15.4027		17.6750	19.9675		15.63558	5.919014	***
Percentage of Population with Water Shortage	-2.6059	0.5490	***	-2.2343	0.3318	***	-2.4108	1.7322		-0.6586	0.1218	***	2.245859	6.033747	
Education and Health Service															
Primary School Enrollment Rate	0.5500	0.9588		0.8446	1.4200		1.8548	1.8472		1.9880	2.4409		1.875504	3.080246	
Population-Doctor Ratio	53.2054	53.7605		96.4283	60.9719		175.5383	134.3379		155.2844	139.4541		119.0501	60.11946	**
Percentage of Immunized Children	4.5985	8.1440		1.7223	2.8906		2.4540	1.0029	**	1.9790	1.9050		1.290657	4.783388	

Note: The standard errors in column S.Error are esimated by bootstrapping with 1000 replications.
Significant levels: * —10%; ** —5%; and *** —1%.

Table 6.5 Average Treatment Effects on the Treated (ATT) Estimated from Caliper Matching

Indicators	Calper=0.00005			Calper=0.0001			Calper=0.0005			Calper=0.001			Calper=0.005		
	Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error	
Wealth and Income															
Percentage of Households under the Poverty Line (826 Yuan)	-2.5197	5.7200		-2.5967	1.9382		-3.8068	1.8599	**	-3.5123	2.3786		-2.9879	0.7477	***
Net Income Per Capita (Yuan)	14.5958	35.3702		4.5494	4.3846		15.3946	21.6785		19.5577	13.1839		22.6591	7.1764	***
Income Per Household in Cash (Yuan)	342.3210	0.3759	***	108.4397	112.3318		168.0011	17.6742	***	199.0965	72.2084	***	199.3158	12.0769	***
Income Per Household in Kind (Yuan)	186.2795	13.2488	***	172.5034	11.7231	***	154.5288	63.2474	**	153.9251	132.1687		147.3804	18.9235	***
Percentage of Households Living in Brick-tiled House	10.4538	3.1694	***	10.3407	1.2871	***	11.1606	2.9804	***	9.4106	0.9332	***	7.3095	2.4308	***
Percentage of Households Living in Thatched House	-9.3606	0.6114	***	-10.3062	1.2847	***	-9.6312	1.9046	***	-8.6685	0.6676	***	-7.0735	2.3541	***
Percentage of Household with TV Set	-1.5339	0.5964	**	1.2363	5.1174		0.6003	0.8666		0.1734	3.8221		-0.4070	0.5539	
Agriculture															
Value of Agricultural Products Per Capita (Yuan)	-56.2455	185.0128		-153.3147	140.7647		-92.7946	55.2955	*	-81.5971	68.5165		-93.0299	46.6938	**
Grain Production Per Capita (KG)	3.7602	32.4014		1.3953	11.6810		-2.0161	3.2149		-1.5983	10.1813		1.1708	0.3712	***
Food Crop Growing Area Per Capita (Mu)	0.2631	0.1038	**	0.2169	0.0983	**	0.2116	0.0973	**	0.2136	0.0952	**	0.2156	0.0083	***
Cash Crop Growing Area per Capita (Mu)	-0.0347	0.0117	***	-0.0504	0.0111	***	-0.0331	0.0382		-0.0376	0.0302		-0.0449	0.0090	***
Pigs in Stock Per Capita at the End of the Year (Heads)	0.0905	0.1014		0.0506	0.0112	***	0.0624	0.0336	*	0.0663	0.0483		0.0773	0.0198	***
Cattle in Stock Per Capita at the End of the Year (Heads)	-0.0094	0.0659		-0.0158	0.0057	***	-0.0137	0.0043	***	-0.0183	0.0086	**	-0.0175	0.0069	**
Goats in Stock Per Capita at the End of the Year (Heads)	0.1530	0.1281		0.2713	0.1971		0.2411	0.0811	***	0.2314	0.1170	**	0.2319	0.0046	***
Off-farm Employment															
Percentage of Male Laborer Employed Off-farm	2.2187	7.1322		1.6651	3.3567		3.6594	1.8207	***	3.2996	2.6330		3.0934	0.8964	***
Percentage of Female Laborer Employed Off-farm	1.8766	4.0880		3.5513	1.4840	**	3.1715	0.7813	***	3.0020	0.9214	***	3.5279	0.6896	***
Infrasture Service															
Days Accessible by Vehicles	8.9756	8.6360		11.5045	3.1539	***	14.6748	1.0288	***	13.2607	1.5514	***	12.5167	2.5749	***
Percentage of Population with Water Shortage	-9.3181	3.4790	***	-8.2591	0.1327	***	-8.9967	1.4373	***	-9.3225	1.7819	***	-8.9062	1.1890	***
Education and Health Service															
Primary School Enrollment Rate	-0.3817	0.4389		-0.1351	0.3691		0.5325	0.1974	***	0.5964	0.6933		0.2011	1.2486	
Population-Doctor Ratio	162.6673	114.9569		176.7203	6.1364	***	244.3568	91.7663	***	213.7197	102.2104	**	227.4030	12.7937	***
Percentage of Immunized Children	1.7914	6.1119		0.7619	5.1443		0.3342	1.6873		-1.6879	0.3255	***	-2.9064	0.1345	***

Note: The standard errors in column S.Error are esimated by bootstrapping with 1000 replications.
Significant levels: * —10%; ** —5%; and *** —1%.

Table 6.6 Average Treatment Effects on the Untreated (ATNT) Estimated from Caliper Matching

Indicators	Calper=0.00005			Calper=0.0001			Calper=0.0005			Calper=0.001			Calper=0.005		
	Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error	
Wealth and Income															
Percentage of Households under the Poverty Line (826 Yuan)	-8.5623	0.8103	***	-9.0540	7.4131		-13.4255	9.9175		-13.3802	9.0636		-9.8523	10.3249	
Net Income Per Capita (Yuan)	-11.5962	5.9754	*	-7.4899	31.4552		6.2335	14.3048		9.8898	4.5370	**	7.8881	12.1658	
Income Per Household in Cash (Yuan)	302.4647	451.2081		191.5874	256.5977		300.6769	358.2041		298.4392	106.0857	***	223.9622	66.7237	***
Income Per Household in Kind (Yuan)	-156.5301	269.7953		-233.4521	363.8734		-287.9442	411.5682		-231.0443	202.7694		-269.3664	298.9344	
Percentage of Households Living in Brick-tiled House	17.5510	15.9326		18.1126	16.7621		16.1109	16.8728		14.5977	8.8471	*	18.7908	10.0058	*
Percentage of Households Living in Thatched House	-21.9720	17.1218		-20.9925	20.7982		-20.2188	21.5218		-19.6201	14.7175		-22.3012	14.6007	
Percentage of Household with TV Set	11.6708	14.1583		15.8968	14.2143		19.1965	16.8608		19.2586	17.6029		17.0887	11.2183	
Agriculture															
Value of Agricultural Products Per Capita (Yuan)	-116.2766	78.4523		-180.7721	150.9404		-157.5038	90.3021	*	-135.9073	61.8585	**	-55.3812	108.3947	
Grain Production Per Capita (KG)	-2.4009	28.6546		-7.5953	3.7537	**	4.8012	4.8196		4.8233	2.1214	**	3.2856	3.5288	
Food Crop Growing Area Per Capita (Mu)	-0.1287	0.1241		-0.0890	0.0607		-0.1498	0.1142		-0.1544	0.0322	***	-0.1400	0.1545	
Cash Crop Growing Area per Capita (Mu)	-0.0246	0.0587		0.0383	0.0306		0.0100	0.0372		0.0116	0.0476		-0.0129	0.0017	***
Pigs in Stock Per Capita at the End of the Year (Heads)	-0.0836	0.0819		-0.1161	0.1414		-0.1110	0.1044		-0.1133	0.0858		-0.1093	0.0574	*
Cattle in Stock Per Capita at the End of the Year (Heads)	-0.0025	0.0339		-0.0052	0.0362		-0.0124	0.0318		-0.0164	0.0084	*	-0.0100	0.0210	
Goats in Stock Per Capita at the End of the Year (Heads)	-0.1046	0.1113		-0.1502	0.1247		-0.1348	0.0820	*	-0.1276	0.1727		-0.1159	0.0650	*
Off-farm Employment															
Percentage of Male Laborer Employed Off-farm	3.5815	2.4392		1.6934	6.4688		1.4357	2.1545		0.6297	2.7401		1.8514	0.8842	**
Percentage of Female Laborer Employed Off-farm	4.7827	2.4082	**	6.3926	10.0258		5.7675	7.6011		5.4996	7.5070		5.7116	4.9550	
Infrasture Service															
Days Accessible by Vehicles	13.1779	16.1222		17.1643	18.8468		19.9978	21.0741		18.6413	24.4669		16.1669	7.3852	**
Percentage of Population with Water Shortage	2.3852	3.3822		1.3729	1.2848		-0.4899	3.3532		1.2380	0.0075	***	4.1456	7.2500	
Education and Health Service															
Primary School Enrollment Rate	1.2428	2.0264		1.4312	2.5996		2.2404	2.3518		2.2926	2.8353		2.1607	3.3928	
Population-Doctor Ratio	-28.1894	2.0406	***	48.3554	111.9033		155.4662	154.7077		142.4928	150.8050		100.5925	73.1907	
Percentage of Immunized Children	6.6859	9.6082		2.2973	1.3680	*	3.0723	1.8282	*	2.7817	2.1810		2.0056	5.6237	

Note: The standard errors in column S.Error are esimated by bootstrapping with 1000 replications.
Significant levels: * —10%; ** —5%; and *** —1%.

6.3 Kernel-Based Matching

Nearest neighbor and caliper matching are based on strong assumptions. Apart from independency between outcome and treatment, the matching assumptions also require that all relevant variables are included in X. However, the inclusion of all relevant variables in X is not always guaranteed. For example, the local weather is a variable that should be included in the characteristic set of the project villages in the SWPRP. Unfortunately, such a dataset is unavailable at the village level. To relax the observability restriction, Heckman, Ichimura, and Todd (1997, 1998) proposed using kernel-based matching models including conventional kernel matching, local linear regression matching, and regression-adjusted local linear matching. In this section, these three methods are used to investigate the treatment effects of the SWPRP.

Kernel-based matching requires weaker assumptions than assumptions (3.26) for the nearest neighbor matching. Suppose the parameter to be evaluated is ATT, assumption (3.26), which requires both y^1 and y^0 are independent of the treatment d given X, under kernel-based matching, can be relaxed to

$$y^0 \perp d|X. \tag{6.5}$$

i.e., it only requires that the outcomes of the non-project villages be independent of the project village selection process. In other words, the counterfactuals of the project villages are required to have the same distribution as the outcomes of the non-project villages. This requirement is sufficient to estimate the ATT because the distribution of the project villages after the project is observable.

Assumption (3.26) can also be relaxed by invoking the assumption of additive separability between the observable and unobservable variables. Under the additive separability assumption, the outcomes are determined by two additively separate components, the observable and unobservable components. Suppose a linear functional form, the equation (3.1) and 3.2) can be rewritten as

$$y_i^1 = X_i\beta + U_i^1 \tag{6.6}$$
$$y_i^0 = X_i\beta + U_i^0 \tag{6.7}$$

where $U_i^1 = \alpha_i + u_i^1$ and $U_i^0 = u_i^0$. As before, u1 and u0 denote the unobservable variables and i is the index for the villages. Combining (6.6) and (6.7) with (3.26) and the additive separability assumption derives,

$$y_i^1 \perp d|X = X_i\beta + U_i^1 \perp d|X \tag{6.8}$$
$$y_i^0 \perp d|X = X_i\beta + U_i^0 \perp d|X \tag{6.9}$$

Assumption (3.26) becomes

$$U^1, U^0 \perp d|X \tag{6.10}$$

Assumption (6.10) requires the independency of the unobservables on the treatment, e.g. local weather conditions. The regression-adjusted local linear matching discussed later is based on this assumption. In which, the observable component $X_i\beta$ will be removed and the residuals (U^1 and U^0) are matched to estimate the treatment effects.

In contrast to the weaker independence condition, kernel-based matching requires stricter overlapping of the treated and untreated subsamples, compared to nearest neighbor matching and caliper matching. Theoretically, the kernel-based matching might estimate each counterfactual using all observations in the control sample. If the control sample includes outliers, shown by Heckman, Ichimura, and Todd (1997, 1998), the kernel-based matching is a biased estimator. To be consistent, the dataset for kernel-based matching is trimmed as in Chapter 5. The same dataset for the control function approach and matching approach discussed above is also used in the following kernel matching, local linear regression matching, and regression-adjusted local linear matching.

6.3.1 Kernel Matching

Both nearest neighbor matching and caliper matching estimate the counterfactuals using only the closest villages in the control sample and equal weights are assigned to each matched village in the neighborhoods. For example, a project village i is matched with the M non-project villages in its nearest neighborhood. The counterfactual of the project village can be calculated using

$$\begin{aligned} E[y_i^1|X, d=0] &= \sum_{j=1}^{M} \frac{1}{M} (y_j^0\,|X, d=0) \\ &= \sum_{j=1}^{M} w_{ij} (y_j^0\,|X, d=0) \end{aligned} \tag{6.11}$$

where, j is the index for the villages in the nearest neighborhood and j=1,2…M. The weight for each village is 1/M. In nearest neighbor matching, M is pre-determined and the distance of each non-project village from the project village varies. Therefore, these non-project villages of different distances are given the same weight 1/M. In caliper matching, M varies and the width of the nearest neighborhood is held constant. This results in that the weights are constant for each non-project village in the same neighborhood but vary in different neighborhoods. Giving different villages the same weights implies the assumption that all the villages in the neighborhood bear the same information and that the villages beyond the nearest neighborhood are uninformative and can be excluded. This seems an unreasonable assumption.

Kernel matching does not rely on these assumptions. In conventional kernel matching, the weights are determined by the distances and all villages in the control sample are used to estimate the counterfactuals for project villages. As given in Chapter

3, the weights ($w_{ij} = 1/M$) in equation (6.11) are replaced by the weights derived from a kernel function

$$w_{ij} = \frac{K(\frac{p_i - p_j}{h})}{\sum_{j=1}^{M} k(\frac{p_i - p_j}{h})} \quad (6.12)$$

where, h is the bandwidth, which can vary or be constant. To avoid complications, we use a constant bandwidth in this research. The choice of the bandwidth h is discussed below. p_i and p_j present the propensity scores for village i and j. M equals the sample size of the non-project villages, n_0. Different forms of kernel function can be specified. However, this research uses the Gaussian function as given in (3.35).

$$K\left(\frac{p_i - p_j}{h}\right) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(\frac{p_i - p_j}{h})^2} \quad (6.13)$$

The counterfactual estimated in weighted form was given in Chapter 3 and repeated below,

$$E[y_i^0 | d = 1] = \sum_{j=1}^{n_0} w_{ij} [y_j^0 | d = 0] \quad (6.14)$$

The kernel weight is in fact the kernel regression written in the weight form.

$$\underset{(\mu_0)}{\text{Arg min}} \ \sum_{j=1}^{n_0} [y_j - \mu_0]^2 K\left(\frac{p_j - p_i}{h}\right) \quad (6.15)$$

where p_j is the propensity score of a non-project village and p_i is the propensity score of a village at which the counterfactual is to be estimated. The regression in equation (6.15) is a point-wise estimator for the counterfactual of village i. Solving the minimizing problem in (6.15) for μ_0 derives the estimator in equation (6.14). The estimated μ_0 is the estimator for the counterfactual $E[y_i^0 | P(X), d = 1]$.

Similarly, a kernel regression can be established for $y_i^1 | P(X), d = 1$. The counterfactual $E[y_i^1 | P(X), d = 0]$ can then be predicted from the kernel model using the P(X) of the non-project villages.

In kernel regression, the bandwidth h must be pre-determined. Jones, Marron, and Sheather (1996) show that the variance is large if h is too small and that the bias is large if h is too large. At the same time, they also indicate that h can be smaller if the sample size is large. In the case of propensity scores, the values are restricted between 0 and 1. Todd (1999) suggests either a fixed bandwidth from 0.2 to 0.4 or to vary the bandwidth at each observation according to the density. However, Heckman, Ichimura, & Todd (1998) use a fixed bandwidth of 0.06 in their evaluation of a labor training program. For the convenience of comparison across methods, a fixed bandwidth is applied in the kernel matching, local linear regression matching, and regression-adjusted local linear matching. Sensitivity will be examined by comparing the results of h=0.02, 0.08, 0.2, 0.4, and 0.6.

With the counterfactuals and the measured outcomes, the treatment effects in equation (6.2), (6.3), and (6.4) are calculated. The results for different indicators are given in Table 6.7, 6.8, and 6.9. The interpretation of these results is discussed in section 6.5. In comparison with the results of nearest neighbor matching and caliper matching, the estimates of the treatment effects and the variances are quite consistent across different bandwidths. The variances converge to a smaller value when the bandwidths increase. Therefore, they are not very sensitive to the bandwidths. This conclusion holds for the ATE, ATT, and ATNT.

Table 6.7 Average Treatment Effects (ATE) Estimated from Kernel Matching

Indicators	Bandwidth=0.02			Bandwidth=0.08			Bandwidth=0.2			Bandwidth=0.4			Bandwidth=0.6		
	Coef.	S. Error		Coef.	S. Error		Coef.	S. Error		Coef.	S. Error		Coef.	S. Error	
Wealth and Income															
Percentage of Households under the Poverty Line (826 Yuan)	-4.4105	2.0609	**	-5.2800	1.7224	***	-5.6013	1.7288	***	-5.1508	1.7006	***	-4.7087	1.6735	***
Net Income Per Capita (Yuan)	1.5173	19.2705		11.4993	15.9224		13.7397	13.3200		9.5190	12.3274		9.9650	11.9050	
Income Per Household in Cash (Yuan)	193.3024	70.5582	***	201.4704	62.6138	***	221.4403	60.0466	***	214.7539	60.0660	***	223.8321	59.5838	***
Income Per Household in Kind (Yuan)	82.8090	104.4537		161.7537	113.3874		184.1831	99.6934	*	147.9214	84.6441	*	118.0080	79.4205	
Percentage of Households Living in Brick-tiled House	9.4610	3.1761	***	10.4183	2.6577	***	10.7898	2.4532	***	10.0251	2.3558	***	9.8206	2.2709	***
Percentage of Households Living in Thatched House	-8.2924	3.1140	***	-9.0703	2.6037	***	-9.9017	2.4064	***	-9.6738	2.3019	***	-9.7093	2.2349	***
Percentage of Household with TV Set	1.6036	1.7534		0.4902	1.6146		1.7021	1.5876		1.5533	1.5160		1.3712	1.4602	
Agriculture															
Value of Agricultural Products Per Capita (Yuan)	-78.2889	75.8009		-105.9338	49.3318	**	-107.6225	43.2996	**	-98.6619	45.0504	**	-103.9455	45.1544	**
Grain Production Per Capita (KG)	-4.1917	7.6723		-4.4534	6.7390		-1.8533	6.5609		-4.3885	6.2185		-7.8045	6.0111	
Food Crop Growing Area Per Capita (Mu)	0.1600	0.0567	***	0.1707	0.0529	**	0.1960	0.0524	***	0.2118	0.0462	***	0.2110	0.0457	***
Cash Crop Growing Area per Capita (Mu)	-0.0516	0.0584		-0.0882	0.0311	***	-0.0988	0.0236	***	-0.1036	0.0219	***	-0.1071	0.0216	***
Pigs in Stock Per Capita at the End of the Year (Heads)	0.0740	0.0332	**	0.0637	0.0320	**	0.0748	0.0399	*	0.0638	0.0314	**	0.0607	0.0279	**
Cattle in Stock Per Capita at the End of the Year (Heads)	-0.0120	0.0105		-0.0227	0.0110	**	-0.0253	0.0107	**	-0.0288	0.0095	***	-0.0312	0.0097	***
Goats in Stock Per Capita at the End of the Year (Heads)	0.1395	0.0574	**	0.1424	0.0517	***	0.1337	0.0459	***	0.1526	0.0474	***	0.1607	0.0446	***
Off-farm Employment															
Percentage of Male Laborer Employed Off-farm	5.4586	2.0773	***	6.2533	1.5232	***	7.0958	1.4351	***	7.4533	1.3538	***	7.7097	1.3661	***
Percentage of Female Laborer Employed Off-farm	5.1964	1.6354	***	5.9238	1.5528	***	6.3937	1.3029	***	6.3834	1.1449	***	6.3388	1.0955	***
Infrasture Service															
Days Accessible by Vehicles	11.1257	3.7539	***	12.6902	2.9267	***	13.3114	2.6002	***	13.4563	2.3840	***	14.5279	2.2779	***
Percentage of Population with Water Shortage	-8.0792	2.2774	***	-8.9212	2.1167	***	-9.9258	1.9049	***	-9.9226	1.8433	***	-9.7710	1.8258	***
Education and Health Service															
Primary School Enrollment Rate	0.8599	0.8557		0.5647	0.8187		0.7374	0.7220		0.6490	0.6576		0.7179	0.5996	
Population-Doctor Ratio	290.4881	64.6051	***	291.5902	62.0041	***	279.9670	54.8537	***	279.2927	51.0867	***	286.5497	51.0034	***
Percentage of Immunized Children	-0.8594	2.2393		-0.6271	2.5614		-0.7169	2.6747		-1.5540	2.0257	***	-1.7512	1.8257	***

Note: The standard errors in column S.Error are esimated by the bootstrapping with 1000 replications.
Significant levels: * —10%; ** —5%; and *** —1%.

Table 6.8 Average Treatment Effects on the Treated (ATT) Estimated from Kernel Matching

Indicators	Bandwidth=0.02			Bandwidth=0.08			Bandwidth=0.2			Bandwidth=0.4			Bandwidth=0.6		
	Coef.	S. Error		Coef.	S. Error		Coef.	S. Error		Coef.	S. Error		Coef.	S. Error	
Wealth and Income															
Percentage of Households under the Poverty Line (826 Yuan)	-2.9246	1.7015	*	-2.8161	1.6208	*	-2.4722	1.5876		-1.6871	1.5980		-0.9902	1.5870	
Net Income Per Capita (Yuan)	22.4683	11.4793	*	25.1980	11.0312	**	26.8948	10.9716	**	26.6659	10.8966	**	26.0848	10.7409	**
Income Per Household in Cash (Yuan)	196.4759	67.9652	***	214.8655	65.8363	***	227.7501	66.0991	***	237.9326	65.1456	***	254.4713	64.7028	***
Income Per Household in Kind (Yuan)	123.9570	77.7757		129.9844	75.0467	*	122.7582	75.3933		102.4508	75.1200		75.3793	76.1095	
Percentage of Households Living in Brick-tiled House	8.1196	2.2576	***	8.8333	2.1579	***	9.3868	2.1130	***	9.8413	2.1121	***	9.9660	2.0880	***
Percentage of Households Living in Thatched House	-7.6685	2.2992	***	-8.2584	2.1967	***	-8.6927	2.1712	***	-9.1456	2.1636	***	-9.3315	2.1309	***
Percentage of Household with TV Set	0.0391	1.4474		-0.3502	1.4129		-0.2481	1.4351		-0.2909	1.3773		-0.3912	1.3684	
Agriculture															
Value of Agricultural Products Per Capita (Yuan)	-85.1847	62.7467		-87.7079	61.0431		-90.8110	60.8201		-87.4747	60.8746		-83.4856	60.4850	
Grain Production Per Capita (KG)	-1.2641	5.3407		-1.9776	5.1540		-3.3711	5.3293		-6.7169	5.2034		-10.4917	5.2701	**
Food Crop Growing Area Per Capita (Mu)	0.2065	0.0439	***	0.2016	0.0427	***	0.1992	0.0437	***	0.1849	0.0425	***	0.1741	0.0423	***
Cash Crop Growing Area per Capita (Mu)	-0.0404	0.0205	**	-0.0430	0.0197	**	-0.0417	0.0193	**	-0.0470	0.0197	**	-0.0542	0.0199	**
Pigs in Stock Per Capita at the End of the Year (Heads)	0.0686	0.0271	**	0.0762	0.0259	***	0.0799	0.0257	***	0.0778	0.0255	***	0.0771	0.0255	***
Cattle in Stock Per Capita at the End of the Year (Heads)	-0.0194	0.0094	**	-0.0193	0.0090	**	-0.0196	0.0098	**	-0.0222	0.0089	**	-0.0262	0.0088	**
Goats in Stock Per Capita at the End of the Year (Heads)	0.2302	0.1070	**	0.2402	0.1070	**	0.2547	0.1022	**	0.2698	0.1071	**	0.2843	0.1070	**
Off-farm Employment															
Percentage of Male Laborer Employed Off-farm	3.1679	1.3616	**	3.5928	1.3133	***	3.7490	1.2843	***	3.9453	1.2924	***	4.0382	1.2822	***
Percentage of Female Laborer Employed Off-farm	3.5504	1.1337	***	3.6518	1.0937	***	3.5889	1.0663	***	3.5337	1.0737	***	3.6092	1.0649	***
Infrasture Service															
Days Accessible by Vehicles	13.0713	2.1769	***	13.3662	2.1075	***	13.6606	2.0657	***	13.7932	2.0644	***	14.2584	2.0445	***
Percentage of Population with Water Shortage	-8.7957	1.8271	***	-8.9674	1.7534	***	-9.0135	1.7268	***	-8.7392	1.7354	***	-8.6172	1.7184	***
Education and Health Service															
Primary School Enrollment Rate	0.1241	0.5418		0.1185	0.5159		0.0825	0.5111		0.1451	0.5168		0.1864	0.5171	
Population-Doctor Ratio	239.6651	55.9122	***	238.4022	52.7175	***	240.6141	49.8317	***	246.8694	51.1312	***	251.0741	50.6474	***
Percentage of Immunized Children	-2.6585	2.1462		-3.1063	2.1827		-2.5628	1.9905		-2.1418	1.8599		-1.9165	1.7705	

Note: The standard errors in column S.Error are esimated by the bootstrapping with 1000 replications.
Significant levels: * —10%; ** —5%; and *** —1%.

Table 6.9 Average Treatment Effects on the Untreated (ATNT) Estimated from Kernel Matching

Indicators	Bandwidth=0.02			Bandwidth=0.08			Bandwidth=0.2			Bandwidth=0.4			Bandwidth=0.6		
	Coef.	S. Error		Coef.	S. Error		Coef.	S. Error		Coef.	S. Error		Coef.	S. Error	
Wealth and Income															
Percentage of Households under the Poverty Line (826 Yuan)	-4.6634	2.2689	**	-5.6995	1.8103	***	-6.1340	1.9846	***	-5.7404	1.7608	***	-5.3418	1.7208	***
Net Income Per Capita (Yuan)	-2.0495	21.6370		9.1671	17.3707		11.5001	13.3584		6.5998	12.8626		7.2206	12.3048	
Income Per Household in Cash (Yuan)	192.7621	76.6438	**	199.1899	65.3508	***	220.3661	48.7356	***	210.8078	61.4174	***	218.6158	60.6520	***
Income Per Household in Kind (Yuan)	75.8038	115.4073		167.1623	124.5041		194.6404	98.3650	**	155.6626	88.2915	*	125.2654	81.6134	
Percentage of Households Living in Brick-tiled House	9.6893	3.5475	***	10.6881	2.8598	***	11.0287	3.5510	***	10.0564	2.4522	***	9.7959	2.3441	***
Percentage of Households Living in Thatched House	-8.3986	3.4680	**	-9.2085	2.7907	***	-10.1075	2.9653	***	-9.7637	2.3831	***	-9.7736	2.2970	***
Percentage of Household with TV Set	1.8699	1.9465		0.6333	1.7278		2.0341	1.4760		1.8673	1.5836		1.6713	1.5099	
Agriculture															
Value of Agricultural Products Per Capita (Yuan)	-77.1149	84.7144		-109.0366	50.0584	**	-110.4846	38.0710	***	-100.5664	43.4237	***	-107.4287	43.3369	**
Grain Production Per Capita (KG)	-4.6901	8.5534		-4.8749	7.2798		-1.5949	6.3976		-3.9922	6.5235		-7.3470	6.2430	
Food Crop Growing Area Per Capita (Mu)	0.1521	0.0628	**	0.1654	0.0567	***	0.1954	0.0595	***	0.2164	0.0480	***	0.2173	0.0471	***
Cash Crop Growing Area per Capita (Mu)	-0.0535	0.0667		-0.0959	0.0341	***	-0.1085	0.0185	***	-0.1133	0.0229	***	-0.1161	0.0224	***
Pigs in Stock Per Capita at the End of the Year (Heads)	0.0750	0.0361	**	0.0616	0.0341	*	0.0739	0.0441	*	0.0614	0.0332	*	0.0579	0.0288	*
Cattle in Stock Per Capita at the End of the Year (Heads)	-0.0107	0.0115		-0.0232	0.0118	**	-0.0263	0.0110	**	-0.0299	0.0098	**	-0.0320	0.0101	**
Goats in Stock Per Capita at the End of the Year (Heads)	0.1241	0.0564	**	0.1258	0.0459	***	0.1131	0.0463	**	0.1326	0.0433	**	0.1396	0.0397	**
Off-farm Employment															
Percentage of Male Laborer Employed Off-farm	5.8486	2.3459	**	6.7062	1.6294	***	7.6656	1.6362	***	8.0506	1.4023	***	8.3348	1.4082	***
Percentage of Female Laborer Employed Off-farm	5.4766	1.8268	***	6.3106	1.7020	***	6.8712	1.1699	***	6.8686	1.1905	***	6.8035	1.1256	***
Infrasture Service															
Days Accessible by Vehicles	10.7945	4.2329	**	12.5751	3.1819	***	13.2519	2.4753	***	13.3989	2.4938	***	14.5738	2.3613	***
Percentage of Population with Water Shortage	-7.9573	2.4955	***	-8.9133	2.2585	***	-10.0811	1.4967	***	-10.1241	1.9080	***	-9.9675	1.8794	***
Education and Health Service															
Primary School Enrollment Rate	0.9852	0.9559		0.6406	0.8991		0.8488	0.4710	*	0.7348	0.6953		0.8084	0.6248	
Population-Doctor Ratio	299.1405	70.6896	***	300.6453	66.2814	***	286.6667	60.4776	***	284.8126	52.2641	***	292.5893	51.9678	***
Percentage of Immunized Children	-0.5531	2.4140		-0.2050	2.7571		-0.4027	3.4696		-1.4540	2.1136		-1.7231	1.8778	

Note: The standard errors in column S.Error are esimated by the bootstrapping with 1000 replications.
Significant levels: * —10%; ** —5%; and *** —1%.

6.3.2 Local Linear Regression Matching

Attention should be paid to the boundary observations under kernel matching. Unlike the interior points on the overlapping region, which are smoothed from two sides, the boundary points are smoothed from one side. Fan (1992) finds that bias may occur at the boundary points because kernel matching does not converge at the same order as the interior points. Furthermore, the kernel regression does not converge at the same order at the points with different densities. Fan shows that the local linear regression is more efficient.

Heckman, Ichimura, and Todd (1998) proposed to incorporate the local linear regression in matching. To estimate the counterfactuals for the project village, the model runs a weighted regression of the outcomes of the non-project villages on the propensity scores.

$$\underset{(\mu_0, \mu_1)}{Arg \min} \sum_{j=1}^{n_0} \left[y_j - \mu_0 - \mu_1 (p_j - p_i)\right]^2 K\left(\frac{p_j - p_i}{h}\right) \tag{6.16}$$

where p_j is the propensity score of a non-project village and pi is the propensity score of a village at which the counterfactual is to be estimated. The bandwidth is the same as the one used with conventional kernel matching. The regression in equation (6.16) is a point-wise estimator for the counterfactual of village i. To solve the argument minimizing problem in (6.16), a complicated equation for the weight is given by Heckman, Ichimura, and Todd (1998) as

$$w_{ij} = \frac{K_{ij} \sum_{l=1}^{n_0} K_{il}(p_l - p_i)^2 - [K_{ij}(p_j - p_i)][\sum_{l=1}^{n_0} K_{il}(p_l - p_i)]}{K_{ij} \sum_{l=1}^{n_0} K_{il}(p_l - p_i)^2 - (\sum_{l=1}^{n_0} K_{il}(p_l - p_i))^2} \tag{6.17}$$

The weights calculated with equation (6.17) are used to estimate the counterfactuals for the project villages in equation (6.11). A similar procedure is used to estimate the counterfactuals for the non-project villages.

With the estimated counterfactuals, the treatment effects are computed in equation (6.14). The estimated treatment effects are given in Table 6.10, 6.11, and 6.12. In local linear regression matching, the estimated ATTs are stable with different bandwidth sizes. Similar to the findings by Jones, Marron and Sheather (1996), the variances are larger when the bandwidth is either too small or too large. However, this trend is only found in ATTs. The variances of ATEs and ATNTs decline with the bandwidth size. The sample size of the project villages and the non-project villages may play a role in the difference of variances.

Table 6.10 Average Treatment Effects (ATE) Estimated from Local Linear Regression Matching

Indicators	Bandwidth=0.02			Bandwidth=0.08			Bandwidth=0.2			Bandwidth=0.4			Bandwidth=0.6		
	Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error	
Wealth and Income															
Percentage of Households under the Poverty Line (826 Yuan)	-2.9446	13.1659		-3.5247	2.4512		-4.3270	2.0217	**	-5.2269	1.9536	***	-5.4409	1.8474	***
Net Income Per Capita (Yuan)	2.8261	104.0910		12.7988	22.1515		11.7604	18.0415		16.0020	15.5623		13.4142	14.8586	
Income Per Household in Cash (Yuan)	175.7670	438.5778		200.2766	73.6668	***	192.3701	65.3030	***	208.3710	64.5541	***	201.6907	61.5622	***
Income Per Household in Kind (Yuan)	93.7835	711.3890		35.6363	109.4559		83.8307	130.3166		155.9819	123.7500		172.5100	111.0907	
Percentage of Households Living in Brick-tiled House	8.4529	21.3217		9.1400	3.2372	***	9.5683	2.9164	***	10.7322	2.7109	***	10.7274	2.6860	***
Percentage of Households Living in Thatched House	-7.1405	19.6739		-7.9704	3.2670	**	-8.0059	2.8674	***	-9.2545	2.6027	***	-9.4731	2.6419	***
Percentage of Household with TV Set	0.5851	19.7239		1.3572	2.5694		0.2335	1.9183		1.1668	1.7643		1.3647	1.7461	
Agriculture															
Value of Agricultural Products Per Capita (Yuan)	-101.2490	611.9674		-97.2523	86.6447		-108.2186	60.1549	*	-113.9348	46.5942	**	-103.4500	45.5010	**
Grain Production Per Capita (KG)	-6.4332	50.3903		-5.8114	8.5125		-7.1569	7.5235		-2.8171	7.1527		-1.1538	7.0145	
Food Crop Growing Area Per Capita (Mu)	0.1442	0.2487		0.1584	0.0700	**	0.1493	0.0584	**	0.1640	0.0571	***	0.1790	0.0558	***
Cash Crop Growing Area per Capita (Mu)	0.0095	0.3057		-0.0092	0.0869		-0.0485	0.0598		-0.0742	0.0395	*	-0.0821	0.0340	**
Pigs in Stock Per Capita at the End of the Year (Heads)	0.0934	0.2404		0.0864	0.0412	**	0.0631	0.0326	*	0.0783	0.0421	*	0.0765	0.0396	*
Cattle in Stock Per Capita at the End of the Year (Heads)	-0.0123	0.0662		-0.0156	0.0125		-0.0205	0.0120	*	-0.0221	0.0114	*	-0.0235	0.0107	**
Goats in Stock Per Capita at the End of the Year (Heads)	0.1573	0.2636		0.1426	0.0545	***	0.1519	0.0578	***	0.1377	0.0542	**	0.1480	0.0599	**
Off-farm Employment															
Percentage of Male Laborer Employed Off-farm	4.0247	15.2728		5.4745	2.4047	**	5.7580	1.8238	***	6.3707	1.6704	***	6.5140	1.5225	***
Percentage of Female Laborer Employed Off-farm	4.5237	15.9194		4.9887	1.9281	***	5.2701	1.8710	***	5.9710	1.6110	***	6.1884	1.4472	***
Infrasture Service															
Days Accessible by Vehicles	10.8281	18.6992		12.1551	4.2740	***	12.0077	3.3090	***	12.7260	3.0209	***	12.0729	2.9088	***
Percentage of Population with Water Shortage	-6.8467	16.3991		-7.0134	2.6958	***	-7.6861	2.3245	***	-9.0611	2.2548	***	-9.6059	1.9866	***
Education and Health Service															
Primary School Enrollment Rate	0.6791	8.9131		0.8177	0.9995		0.4853	0.9792		0.6960	0.8033		0.5889	0.8117	
Population-Doctor Ratio	239.0216	671.5927		293.7150	76.9754	***	298.3084	69.3759	***	287.4565	64.5035	***	278.5817	58.2258	***
Percentage of Immunized Children	-0.3812	20.5990		-0.6659	2.1759		-0.3882	2.5311		-0.1582	2.7394		-0.6725	2.7544	

Note: The standard errors in column S.Error are esimated by the bootstrapping with 1000 replications.
Significant levels: * —10%; ** —5%; and *** —1%.

Table 6.11 Average Treatment Effects on the Treated (ATT) Estimated from Local Linear Regression Matching

Indicators	Bandwidth=0.02			Bandwidth=0.08			Bandwidth=0.2			Bandwidth=0.4			Bandwidth=0.6		
	Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error	
Wealth and Income															
Percentage of Households under the Poverty Line (826 Yuan)	-3.1839	1.6832	*	-3.3106	1.5622	**	-3.0961	1.5958	*	-3.0558	1.6104	*	-3.2098	1.6079	**
Net Income Per Capita (Yuan)	22.2911	11.1656	**	25.4405	10.4987	**	23.9265	10.6843	**	23.1401	10.4056	**	23.4127	10.7183	**
Income Per Household in Cash (Yuan)	188.6938	65.2913	***	203.2590	62.3519	***	199.5367	63.3162	***	200.8246	61.8522	***	200.7243	63.0508	***
Income Per Household in Kind (Yuan)	123.7536	74.4245	*	122.2675	73.3299	*	110.4686	71.8585		110.1787	76.5375		116.8994	71.4517	
Percentage of Households Living in Brick-tiled House	7.8939	2.3559	***	7.9921	2.2065	***	8.1319	2.2094	***	8.1496	2.1133	***	8.3131	2.2075	***
Percentage of Households Living in Thatched House	-7.4669	2.3906	***	-7.6279	2.1573	***	-7.7075	2.2239	***	-7.7173	2.1172	***	-7.9082	2.2212	***
Percentage of Household with TV Set	0.0101	1.5184		-0.2365	1.5162		-0.4471	1.4599		-0.5115	1.4430		-0.4929	1.4657	
Agriculture															
Value of Agricultural Products Per Capita (Yuan)	-84.9390	60.0933		-89.0289	58.0114		-95.9223	59.0753		-96.2008	56.1518	*	-97.0867	59.1388	
Grain Production Per Capita (KG)	-1.4049	5.5446		-1.6144	5.1622		-2.0841	5.3175		-2.2739	5.0741		-2.0532	5.2735	
Food Crop Growing Area Per Capita (Mu)	0.2053	0.0445	***	0.2062	0.0426	***	0.2028	0.0427	***	0.2026	0.0424	***	0.2042	0.0426	***
Cash Crop Growing Area per Capita (Mu)	-0.0393	0.0198	**	-0.0416	0.0199	**	-0.0420	0.0191	**	-0.0456	0.0191	**	-0.0468	0.0192	**
Pigs in Stock Per Capita at the End of the Year (Heads)	0.0672	0.0266	**	0.0740	0.0262	***	0.0719	0.0258	***	0.0714	0.0268	***	0.0721	0.0258	***
Cattle in Stock Per Capita at the End of the Year (Heads)	-0.0195	0.0098	**	-0.0180	0.0095	*	-0.0189	0.0094	**	-0.0195	0.0092	**	-0.0197	0.0094	**
Goats in Stock Per Capita at the End of the Year (Heads)	0.2299	0.1049	**	0.2329	0.1040	**	0.2366	0.1049	**	0.2363	0.1041	**	0.2356	0.1050	**
Off-farm Employment															
Percentage of Male Laborer Employed Off-farm	3.2842	1.3371	**	3.4560	1.2897	***	3.7306	1.2784	***	3.8540	1.2951	***	3.9613	1.2736	***
Percentage of Female Laborer Employed Off-farm	3.6215	1.1213	***	3.6682	1.0587	***	3.7582	1.0811	***	3.8762	1.0871	***	3.9528	1.0843	***
Infrasture Service															
Days Accessible by Vehicles	12.8974	2.1857	***	13.2156	2.1217	***	12.9855	2.0454	***	13.0085	2.0083	***	13.1441	2.0497	***
Percentage of Population with Water Shortage	-8.7653	1.7341	***	-8.9374	1.7435	***	-8.8810	1.6745	***	-8.9572	1.7739	***	-9.0992	1.6855	***
Education and Health Service															
Primary School Enrollment Rate	0.1030	0.5597		0.0901	0.5247		0.0941	0.5264		0.1303	0.5195		0.1375	0.5237	
Population-Doctor Ratio	236.4919	53.3295	***	236.9959	51.4717	***	233.2477	50.2136	***	231.3280	51.6850	***	233.0097	50.2226	***
Percentage of Immunized Children	-2.3891	2.1362		-2.8323	2.0546		-3.0978	2.2129		-3.3227	2.2029		-3.4079	2.2831	

Note: The standard errors in column S.Error are esimated by the bootstrapping with 1000 replications.
Significant levels: * —10%; ** —5%; and *** —1%.

Table 6.12 Average Treatment Effects on the Untreated (ATNT) Estimated from Local Linear Regression Matching

Indicators	Bandwidth=0.02			Bandwidth=0.08			Bandwidth=0.2			Bandwidth=0.4			Bandwidth=0.6		
	Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error	
Wealth and Income															
Percentage of Households under the Poverty Line (826 Yuan)	-2.9039	15.3713		-3.5612	2.7384		-4.5365	2.1962	**	-5.5966	2.0920	***	-5.8207	1.9658	***
Net Income Per Capita (Yuan)	-0.4878	121.6332		10.6467	25.1363		9.6892	20.0108		14.7868	17.0584		11.7120	16.0779	
Income Per Household in Cash (Yuan)	173.5663	511.7472		199.7689	80.3204	**	191.1500	69.1837	***	209.6558	67.9243	***	201.8553	64.2609	***
Income Per Household in Kind (Yuan)	88.6812	831.6599		20.8877	121.1995		79.2956	145.4896		163.7798	136.0506		181.9774	121.4823	
Percentage of Households Living in Brick-tiled House	8.5481	24.9157		9.3354	3.5920	***	9.8129	3.1742	***	11.1719	2.9223	***	11.1384	2.8650	***
Percentage of Households Living in Thatched House	-7.0849	22.9831		-8.0287	3.6327	**	-8.0567	3.1206	***	-9.5162	2.7969	***	-9.7395	2.8132	***
Percentage of Household with TV Set	0.6830	23.0580		1.6286	2.8935		0.3494	2.1091		1.4525	1.8952		1.6810	1.8765	
Agriculture															
Value of Agricultural Products Per Capita (Yuan)	-104.0258	714.9402		-98.6523	97.3377		-110.3121	64.2582	*	-116.9540	47.7868	**	-104.5333	45.3791	**
Grain Production Per Capita (KG)	-7.2892	58.8284		-6.5259	9.4953		-8.0206	8.2394		-2.9096	7.7591		-1.0007	7.5470	
Food Crop Growing Area Per Capita (Mu)	0.1338	0.2906		0.1502	0.0786	*	0.1401	0.0638	**	0.1575	0.0617	**	0.1747	0.0602	***
Cash Crop Growing Area per Capita (Mu)	0.0178	0.3574		-0.0037	0.1004		-0.0496	0.0685		-0.0790	0.0444	*	-0.0881	0.0377	**
Pigs in Stock Per Capita at the End of the Year (Heads)	0.0978	0.2812		0.0885	0.0455	*	0.0616	0.0354	*	0.0794	0.0459	*	0.0773	0.0431	*
Cattle in Stock Per Capita at the End of the Year (Heads)	-0.0111	0.0775		-0.0152	0.0137		-0.0208	0.0130		-0.0225	0.0121	*	-0.0241	0.0113	**
Goats in Stock Per Capita at the End of the Year (Heads)	0.1449	0.3061		0.1273	0.0519	**	0.1375	0.0531	***	0.1209	0.0481	**	0.1331	0.0545	**
Off-farm Employment															
Percentage of Male Laborer Employed Off-farm	4.1508	17.8642		5.8181	2.7233	**	6.1031	2.0135	***	6.7991	1.8026	***	6.9486	1.6351	***
Percentage of Female Laborer Employed Off-farm	4.6773	18.6194		5.2135	2.1657	**	5.5275	2.0860	***	6.3277	1.7704	***	6.5690	1.5672	***
Infrasture Service															
Days Accessible by Vehicles	10.4758	21.8406		11.9745	4.8426	**	11.8412	3.6642	***	12.6779	3.3018	***	11.8906	3.1522	***
Percentage of Population with Water Shortage	-6.5201	19.1710		-6.6858	2.9959	**	-7.4827	2.5557	***	-9.0788	2.4324	***	-9.6921	2.1299	***
Education and Health Service															
Primary School Enrollment Rate	0.7772	10.4269		0.9415	1.1233		0.5519	1.0922		0.7924	0.8807		0.6658	0.8846	
Population-Doctor Ratio	239.4523	785.9003		303.3712	85.8599	***	309.3847	75.9799	***	297.0122	69.1886	***	286.3401	62.0983	***
Percentage of Immunized Children	-0.0393	24.0703		-0.2971	2.3231		0.0731	2.7238		0.3806	2.9746		-0.2069	2.9703	

Note: The standard errors in column S.Error are esimated by the bootstrapping with 1000 replications.
Significant levels: * —10%; ** —5%; and *** —1%.

6.3.3 Regression-Adjusted Local Linear Matching

Returning to the common assumption that the outcomes are determined by a set of characteristic variables X, all the matching methods discussed above do not use the information carried by the characteristic variables directly. For example, Chapter 5 demonstrates that the land quantity and quality are involved in the determination of outcomes. To solve the problem, Heckman, Ichimura, and Todd (1997, 1998) propose a regression-adjusted local linear matching.

The regression-adjusted local linear matching incorporates the functional form of the outcome equation and the additive seperability into the matching estimator. The procedure to carry out the matching estimation starts with the estimation of the outcome equation for the project village sample.

$$y^1 = \beta X + U_i^1 \quad (6.18)$$

where $U_i^1 = \alpha_i + u_i^1$. The equation (6.18) is estimated using the partial regression method. In this method, (a) y^1 and X are regressed on the propensity scores P(X) respectively. (b) The residuals of y^1, denoted by $\tilde{y}^1$, are regressed on the residuals of X, denoted by $\tilde{X}$, to estimate $\tilde{\beta}$. (c) The $\tilde{\beta}$ is inserted in equation (6.18) to calculate $\tilde{U}^1$.

$$\tilde{U}^1 = y^1 - \tilde{\beta} X \quad (6.19)$$

The same procedure is used to obtain $\tilde{U}^0$ from the non-project village sample. $\tilde{U}^1$ and $\tilde{U}^0$ are used to estimate the treatment effects following the same procedure as the local linear regression matching. The results are given in Table 6.13, 6.14, and 6.15. Again the treatment effects are stable with bandwidth size. The variances converge at an appropriate bandwidth and are generally larger when the bandwidth is either too small or too large for the ATTs, while they generally decline for the ATEs and ATNTs.

Table 6.13 Average Treatment Effects (ATE) Estimated from Regression-adjusted Local Linear Matching

Indicators	Bandwidth=0.02			Bandwidth=0.08			Bandwidth=0.2			Bandwidth=0.4			Bandwidth=0.6		
	Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error	
Wealth and Income															
Percentage of Households under the Poverty Line (826 Yuan)	-3.2550	12.8747		-3.8100	2.1978	*	-4.3408	1.7926	**	-4.7886	1.8169	***	-4.8389	1.7701	***
Net Income Per Capita (Yuan)	2.6600	95.9183		13.3557	22.4026		12.7299	18.2041		16.1119	15.3316		13.0936	14.2100	
Income Per Household in Cash (Yuan)	165.4823	497.1269		188.1703	71.9301	***	187.6639	63.8816	***	198.3969	63.1715	***	193.4874	62.6027	***
Income Per Household in Kind (Yuan)	131.9662	870.8797		74.0109	106.2898		116.3200	128.6761		165.5681	117.5602		172.3527	108.1567	
Percentage of Households Living in Brick-tiled House	6.6815	22.5572		7.5487	3.8145	**	8.5246	3.0872	***	9.7721	2.7184	***	9.8022	2.5299	***
Percentage of Households Living in Thatched House	-5.8832	18.5537		-6.7827	3.8695	*	-7.2895	3.0453	**	-8.4462	2.5800	***	-8.5915	2.4373	***
Percentage of Household with TV Set	0.6663	20.2604		1.1281	2.5121		0.0581	1.9151		0.6411	1.7482		0.8683	1.6909	
Agriculture															
Value of Agricultural Products Per Capita (Yuan)	-95.9995	570.9558		-86.6580	77.6456		-98.5640	52.4545	*	-108.8446	43.5964	**	-99.1569	40.6685	**
Grain Production Per Capita (KG)	-0.2705	28.5820		0.1366	5.7708		-1.5789	6.2485		0.3395	5.8136		0.7598	5.8550	
Food Crop Growing Area Per Capita (Mu)	0.2076	0.2526		0.2163	0.0801	***	0.2029	0.0543	***	0.2077	0.0485	***	0.2160	0.0455	***
Cash Crop Growing Area per Capita (Mu)	0.0013	0.2913		-0.0181	0.0821		-0.0515	0.0558		-0.0729	0.0377	*	-0.0765	0.0313	**
Pigs in Stock Per Capita at the End of the Year (Heads)	0.1007	0.2959		0.0968	0.0414	**	0.0754	0.0322	**	0.0926	0.0419	**	0.0906	0.0419	**
Cattle in Stock Per Capita at the End of the Year (Heads)	-0.0029	0.0756		-0.0056	0.0128		-0.0115	0.0125		-0.0138	0.0113		-0.0157	0.0105	
Goats in Stock Per Capita at the End of the Year (Heads)	0.1546	0.2733		0.1422	0.0531	***	0.1532	0.0561	***	0.1479	0.0525	***	0.1608	0.0576	***
Off-farm Employment															
Percentage of Male Laborer Employed Off-farm	3.5859	14.7286		4.9654	2.3833	**	5.1269	1.7546	***	5.5187	1.6204	***	5.5732	1.5216	***
Percentage of Female Laborer Employed Off-farm	4.2849	14.9482		4.6203	1.8009	**	4.7836	1.7366	***	5.2358	1.4956	***	5.3689	1.3309	***
Infrasture Service															
Days Accessible by Vehicles	12.4365	23.6412		12.8935	3.9533	***	12.8792	3.4234	***	12.9703	3.0659	***	12.0074	2.9324	***
Percentage of Population with Water Shortage	-7.5042	25.6282		-7.4925	2.9759	**	-8.2195	2.6571	***	-9.3118	2.3315	***	-9.5891	2.1212	***
Education and Health Service															
Primary School Enrollment Rate	0.5508	9.1873		0.7136	0.9266		0.3445	0.8743		0.3814	0.7554		0.2611	0.7431	
Population-Doctor Ratio	245.0937	645.4188		289.5032	75.3159	***	295.7626	65.5343	***	272.7527	60.3801	***	263.9718	57.7830	***
Percentage of Immunized Children	-0.2978	21.6716		-0.5663	2.0570		-0.1172	2.5191		0.2101	2.7499		-0.1730	2.5694	

Note: The standard errors in column S.Error are esimated by the bootstrapping with 1000 replications.
Significant levels: * —10%; ** —5%; and *** —1%.

Table 6.14 Average Treatment Effects on the Treated (ATT) Estimated from Regression-adjusted Local Linear Matching

Indicators	Bandwidth=0.02			Bandwidth=0.08			Bandwidth=0.2			Bandwidth=0.4			Bandwidth=0.6		
	Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error	
Wealth and Income															
Percentage of Households under the Poverty Line (826 Yuan)	-3.1699	1.6517	*	-3.3413	1.5478	**	-3.1453	1.5183	**	-3.0482	1.5333	**	-3.0928	1.5348	**
Net Income Per Capita (Yuan)	22.3941	10.5644	**	25.5005	10.4416	**	24.4697	10.3351	**	23.8593	10.1469	**	23.9220	10.1674	**
Income Per Household in Cash (Yuan)	192.4312	63.5576	***	206.0664	62.2704	***	204.6650	61.6422	***	207.2479	61.2206	***	207.6533	61.3468	***
Income Per Household in Kind (Yuan)	118.2269	71.9787		119.7457	69.0339	*	111.0873	69.8542		111.5103	72.3350		115.8155	71.7069	
Percentage of Households Living in Brick-tiled House	8.2138	2.1920	***	8.2316	2.1659	***	8.4263	2.1543	***	8.4620	2.0651	***	8.5987	2.0649	***
Percentage of Households Living in Thatched House	-7.7150	2.1901	***	-7.7920	2.2195	***	-7.9439	2.2135	***	-7.9609	2.0835	***	-8.0882	2.0844	***
Percentage of Household with TV Set	0.1096	1.4516		-0.1556	1.4254		-0.2750	1.4247		-0.3104	1.3798		-0.3032	1.3862	
Agriculture															
Value of Agricultural Products Per Capita (Yuan)	-85.7048	56.6038		-87.2933	55.4283		-92.8957	55.3349	*	-92.1589	55.2372	*	-92.5125	55.3832	*
Grain Production Per Capita (KG)	-2.3333	4.9194		-2.2156	4.7818		-2.2346	4.8064		-2.2028	4.6451		-2.1481	4.6099	
Food Crop Growing Area Per Capita (Mu)	0.1945	0.0377	***	0.1960	0.0361	***	0.1922	0.0359	***	0.1920	0.0364	***	0.1937	0.0363	***
Cash Crop Growing Area per Capita (Mu)	-0.0374	0.0201	*	-0.0413	0.0207	**	-0.0412	0.0207	**	-0.0435	0.0196	**	-0.0430	0.0195	**
Pigs in Stock Per Capita at the End of the Year (Heads)	0.0649	0.0269	**	0.0705	0.0249	***	0.0676	0.0251	***	0.0672	0.0260	***	0.0682	0.0261	***
Cattle in Stock Per Capita at the End of the Year (Heads)	-0.0214	0.0099	**	-0.0197	0.0098	**	-0.0207	0.0097	**	-0.0211	0.0092	**	-0.0210	0.0092	**
Goats in Stock Per Capita at the End of the Year (Heads)	0.2290	0.1028	**	0.2315	0.1092	**	0.2338	0.1093	**	0.2336	0.1033	**	0.2344	0.1034	**
Off-farm Employment															
Percentage of Male Laborer Employed Off-farm	3.4017	1.3323	**	3.5896	1.3032	***	3.8422	1.2898	***	3.8749	1.2788	***	3.8851	1.2784	***
Percentage of Female Laborer Employed Off-farm	3.7200	1.0692	***	3.7812	1.0411	***	3.8850	1.0421	***	3.9405	1.0303	***	3.9319	1.0296	***
Infrasture Service															
Days Accessible by Vehicles	12.7811	2.1308	***	12.9525	2.0318	***	12.8429	2.0163	***	12.8606	1.9907	***	12.8922	1.9943	***
Percentage of Population with Water Shortage	-8.6723	1.8458	***	-8.7625	1.7219	***	-8.7359	1.7136	***	-8.7761	1.7611	***	-8.8088	1.7593	***
Education and Health Service															
Primary School Enrollment Rate	0.1501	0.5358		0.1591	0.5053		0.1812	0.5018		0.2101	0.5057		0.1924	0.5057	
Population-Doctor Ratio	238.8585	54.0364	***	237.6477	53.1164	***	235.8145	52.4383	***	233.7114	50.2320	***	234.3439	50.1625	***
Percentage of Immunized Children	-2.3974	2.0674		-2.8495	1.9626		-3.0551	2.1107		-3.1877	2.1923		-3.1801	2.1971	

Note: The standard errors in column S.Error are esimated by the bootstrapping with 1000 replications.
Significant levels: * —10%; ** —5%; and *** —1%.

Table 6.15 Average Treatment Effects on the Untreated (ATNT) Estimated from Regression-adjusted Local Linear Matching

Indicators	Bandwidth=0.02			Bandwidth=0.08			Bandwidth=0.2			Bandwidth=0.4			Bandwidth=0.6		
	Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error		Coef.	S.Error	
Wealth and Income															
Percentage of Households under the Poverty Line (826 Yuan)	-3.2695	15.0589		-3.8897	2.4350		-4.5443	1.9270	**	-5.0849	1.9395	***	-5.1361	1.8775	***
Net Income Per Capita (Yuan)	-0.6997	112.1854		11.2881	25.5037		10.7312	20.3130		14.7929	16.8051		11.2501	15.4105	
Income Per Household in Cash (Yuan)	160.8944	580.7268		185.1235	77.9275	**	184.7696	67.5496	***	196.8900	66.2834	***	191.0758	65.3858	***
Income Per Household in Kind (Yuan)	134.3052	1018.0233		66.2248	118.3776		117.2108	143.4150		174.7713	129.2774		181.9779	117.6675	
Percentage of Households Living in Brick-tiled House	6.4207	26.3805		7.4325	4.2842	*	8.5413	3.3859	**	9.9952	2.9385	***	10.0071	2.7035	***
Percentage of Households Living in Thatched House	-5.5713	21.6779		-6.6109	4.3335		-7.1781	3.3184	**	-8.5288	2.7725	***	-8.6771	2.5881	***
Percentage of Household with TV Set	0.7610	23.6920		1.3466	2.8282		0.1148	2.0961		0.8031	1.8848		1.0677	1.8102	
Agriculture															
Value of Agricultural Products Per Capita (Yuan)	-97.7522	667.3787		-86.5498	87.0261		-99.5290	55.4426	*	-111.6853	44.2285	**	-100.2881	40.2552	**
Grain Production Per Capita (KG)	0.0807	33.3407		0.5370	6.2008		-1.4673	6.7403		0.7723	6.2185		1.2549	6.2528	
Food Crop Growing Area Per Capita (Mu)	0.2098	0.2955		0.2197	0.0914	**	0.2048	0.0600	***	0.2103	0.0524	***	0.2198	0.0487	***
Cash Crop Growing Area per Capita (Mu)	0.0079	0.3406		-0.0142	0.0948		-0.0532	0.0636		-0.0780	0.0422	*	-0.0822	0.0346	**
Pigs in Stock Per Capita at the End of the Year (Heads)	0.1068	0.3460		0.1013	0.0461	**	0.0767	0.0350	**	0.0969	0.0457	**	0.0944	0.0456	**
Cattle in Stock Per Capita at the End of the Year (Heads)	0.0003	0.0883		-0.0032	0.0140		-0.0099	0.0136		-0.0126	0.0121		-0.0148	0.0111	
Goats in Stock Per Capita at the End of the Year (Heads)	0.1420	0.3190		0.1270	0.0488	***	0.1395	0.0500	***	0.1334	0.0457	***	0.1483	0.0518	***
Off-farm Employment															
Percentage of Male Laborer Employed Off-farm	3.6172	17.2269		5.1996	2.6920	*	5.3456	1.9157	***	5.7986	1.7415	***	5.8606	1.6215	***
Percentage of Female Laborer Employed Off-farm	4.3811	17.4776		4.7632	2.0175	**	4.9366	1.9293	**	5.4563	1.6393	***	5.6135	1.4384	***
Infrasture Service															
Days Accessible by Vehicles	12.3779	27.6241		12.8835	4.4785	***	12.8854	3.8054	***	12.9890	3.3546	***	11.8567	3.1823	***
Percentage of Population with Water Shortage	-7.3053	29.9690		-7.2763	3.3312	**	-8.1316	2.9289	***	-9.4030	2.5264	***	-9.7220	2.2703	***
Education and Health Service															
Primary School Enrollment Rate	0.6190	10.7489		0.8080	1.0403		0.3723	0.9697		0.4106	0.8244		0.2728	0.8044	
Population-Doctor Ratio	246.1552	754.8979		298.3314	83.8552	***	305.9686	71.0966	***	279.3993	64.4727	***	269.0158	61.2230	***
Percentage of Immunized Children	0.0596	25.3592		-0.1776	2.2053		0.3830	2.7058		0.7886	2.9885		0.3389	2.7628	

Note: The standard errors in column S.Error are esimated by the bootstrapping with 1000 replications.
Significant levels: * —10%; ** —5%; and *** —1%.

6.4 Assumption Verification

All methods in this research are based on two important assumptions, (3.26) and (3.27). In assumption (3.26), the treatment is required to be independent of the outcomes conditional on the characteristic variables X, which determine the outcomes and the treatment. Assumption (3.27) requires overlapping of the treated and the untreated samples. The two assumptions are satisfied when the treated sample and untreated sample are randomly drawn from the same population. If the two assumptions are satisfied, treatment effects are identified. Since the project villages of the SWPRP are not randomly assigned, the two assumptions may be violated. Therefore, to verify the assumptions is crucial to this research.

Effective methods for a direct verification of the two assumptions are not yet completely developed in literature. However, an indirect test to verify assumption (3.26) is suggested by Heckman, Ichimura, and Todd (1998). Their test is based on the idea that the mean of the counterfactuals of the treated sample must equal the mean of the untreated sample if assumption (3.26) holds. In their method, assumption (3.26) is verified by testing the null hypothesis that the counterfactual mean of the project villages, $E[y^1|d = 0]$, equals the outcome mean of the non-project villages, $E[y^0|d = 0]$.

$$H_0: E[y^1|d = 0] = E[y^0|d = 0] \tag{6.20}$$

A problem occurs in this test because the counterfactual $E[y^1|d = 0]$ is unobservable, so the null hypothesis cannot be tested directly. However, there are some non-project villages that have a propensity score that equals or is “similar” to the project villages, so they are eligible for treatment but are not treated by the project. Their outcomes can be used to estimate the counterfactuals of the project villages. Therefore, testing the equality between the mean of these eligible villages from the non-project sample and the mean of the other non-project villages is equivalent to testing the null hypothesis. If the null hypothesis fails to be rejected, it indirectly proves the independence of the treatment on the outcomes.

To carry out the test, the non-project villages are first separated into two groups. One group includes the non-project villages that have the propensity scores greater than the percentage of treated in the sample, 0.1287. These are considered to be eligible to be treated by the SWPRP. This group is referred to as "treated" group. The other group includes the non-project villages that have a propensity score that is smaller than 0.1287 and are considered to be ineligible. This group is referred to as "untreated" group. A dummy variable T is created for the "treatment." T=1 is assigned to villages in the "treated" group, and T=0 is assigned to the villages in the "untreated" group. The variable T is used to re-estimate the propensity scores. With the re-estimated propensity scores, the villages in the "treated" group are matched with the villages in the "untreated" group with their five nearest neighbors. Then the "treatment effects" of the 21 indicators are estimated and given in Table 6.16. The results show that none of the "treatment effects" in the table are statistically significant from zero. Thus, assumption (3.26) holds. By conditioning on the characteristics X, the outcomes are independent of the project village selection.

Table 6.16 Independence Test

Indicators	ATE		ATT		ATNT	
	Coef.	S.Error	Coef.	S.Error	Coef.	S.Error
Wealth and Income						
Percentage of Households under the Poverty Line (826 Yuan)	-7.5748	9.1627	-6.6361	10.7990	-7.8705	11.6379
Net Income Per Capita (Yuan)	22.3943	66.7971	83.5075	66.4069	3.1378	87.2699
Income Per Household in Cash (Yuan)	-428.8320	501.4194	-1539.1523	1051.4686	-78.9749	335.4221
Income Per Household in Kind (Yuan)	-621.6552	403.9061	-52.2848	399.6650	-801.0613	520.5553
Percentage of Households Living in Brick-tiled House	9.1149	13.1037	-22.5845	15.3473	19.1032	15.3665
Percentage of Households Living in Thatched House	-6.6413	12.7677	6.6943	16.8111	-10.8433	15.4199
Percentage of Household with TV Set	-6.0917	8.0297	-0.2292	13.0596	-7.9389	8.7627
Agriculture						
Value of Agricultural Products Per Capita (Yuan)	-262.8509	207.0191	-54.4739	225.6024	-328.5096	264.7566
Grain Production Per Capita (KG)	-55.5465	31.5226	-44.5633	30.5447	-59.0072	41.7211
Food Crop Growing Area Per Capita (Mu)	0.0412	0.2576	-0.0765	0.2143	0.0783	0.3482
Cash Crop Growing Area per Capita (Mu)	-0.1641	0.1438	0.1133	0.1238	-0.2514	0.1855
Pigs in Stock Per Capita at the End of the Year (Heads)	-0.1571	0.1130	-0.0267	0.1797	-0.1982	0.1236
Cattle in Stock Per Capita at the End of the Year (Heads)	-0.0261	0.0618	0.0647	0.0684	-0.0547	0.0776
Goats in Stock Per Capita at the End of the Year (Heads)	0.0228	0.1399	0.0034	0.2711	0.0290	0.1298
Off-farm Employment						
Percentage of Male Laborer Employed Off-farm	-3.7157	6.0610	7.9327	8.2859	-7.3860	6.9302
Percentage of Female Laborer Employed Off-farm	-2.4810	5.2588	3.6202	7.1757	-4.4034	6.2403
Infrasture Service						
Days Accessible by Vehicles	16.7635	14.5639	3.5103	19.3087	20.9395	17.6045
Percentage of Population with Water Shortage	-0.5812	9.8556	-11.7467	11.9431	2.9370	12.2133
Education and Health Service						
Primary School Enrollment Rate	-2.8270	3.0253	-1.3794	3.1131	-3.2832	3.9554
Population-Doctor Ratio	376.0235	351.6303	185.9665	451.0852	435.9096	433.4536
Percentage of Immunized Children	-0.9298	11.3983	-4.5016	15.6362	0.1957	13.7562

To verify assumption (3.27), we examine overlap of the propensity score distributions of the project villages and the non-project villages. In Chapter 5, we find the overlap region is from the propensity score 0.0130 to 0.5320. The trimmed sample containing the villages with propensity scores in the region is used to estimate the treatment effects in Chapter 5 and this chapter. The use of the trimmed sample assures the condition of (3.27). However, the satisfaction of assumption (3.27) does not assure a balance in the distributions between the project village sample and the non-project village sample. Matching is the method to derive the balance of the distribution. The result of the balanced distribution is examined by comparing the distributions of the treated and untreated samples before and after matching.

To compare the distributions, a frequency distribution of the propensity scores is graphed for project and non-project villages before and after matching. Figure 6.1 and 6.2 illustrate the distributions of the project villages and the non-project villages before matching. Obviously, the two graphs have different distributions. The graph for the non-project villages (Figure 6.2) skews toward the right much more than that of the project villages' graph (Figure 6.1). The density is about 7 percent in the first column of Figure 6.1, denoting the propensity scores between 0.0 and 0.05, for the project village sample while it is about twice in the first column of Figure 6.2 for the non-project village sample. Inversely, the densities at the other columns of Figure 6.1 are all larger than the densities of Figure 6.2. Figure 6.3 and 6.4 illustrate the distributions of the project villages and the non-project villages after matching. Apparently, two graphs have similar densities at all points on the propensity score ranges.

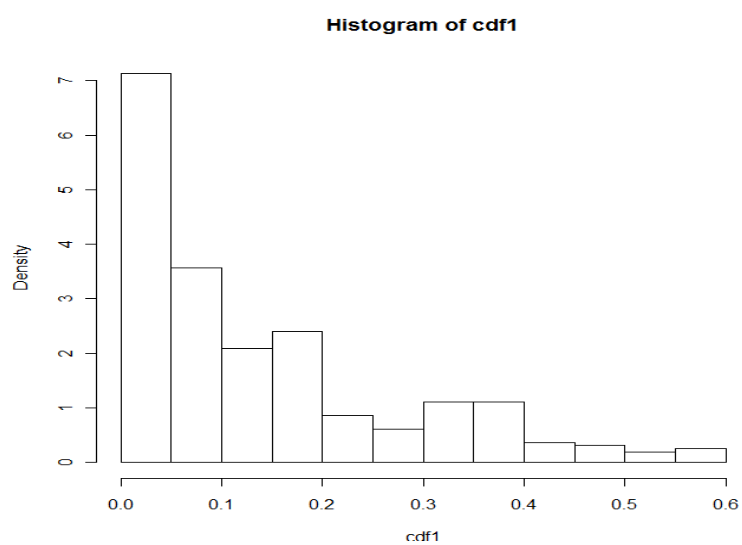

Figure 6.1 The Distribution of Project Villages before Match

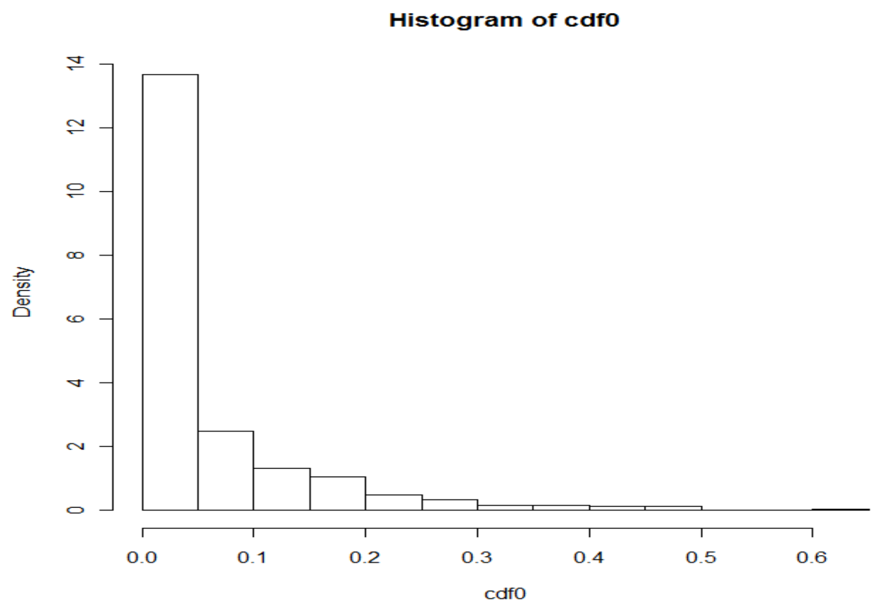

Figure 6.2 The Distribution of Non-Project Villages before Match

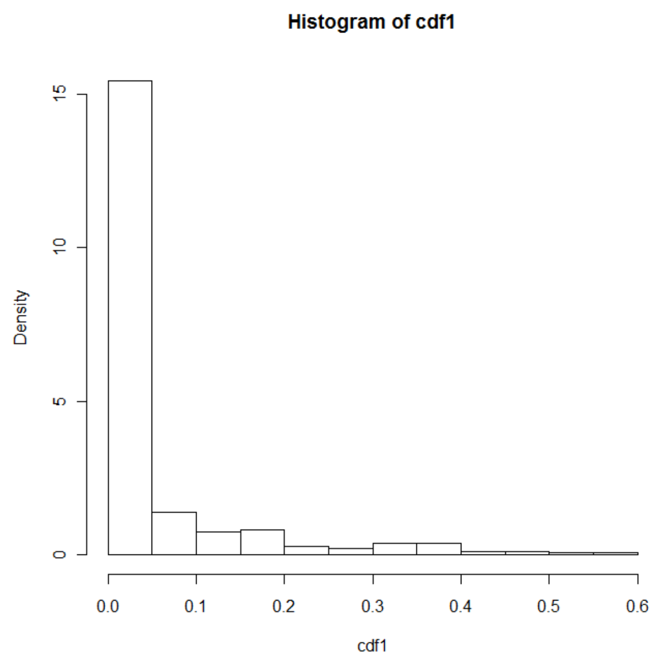

Figure 6.3 The Distribution of Project Villages after Match (M=5)

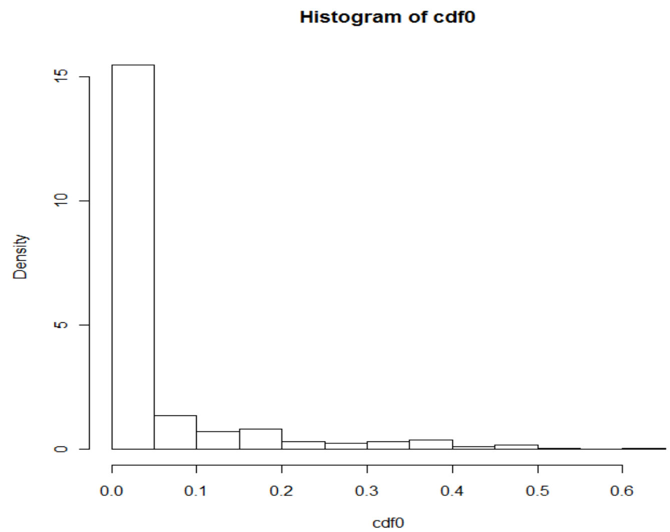

Figure 6.4 The Distribution of Non-Project Villages after Match (M=5)

Since assumption (3.26) and (3.27) are satisfied in our dataset, the average treatment effects estimated by different matching methods are similar. Larger differences are presented in the results from the control function method. This difference may be due to the incorrect specification of the linear function for some indicators. Considering the possibility of the incorrect specification of functional form, we choose to investigate the impacts of the SWPRP with the average treatment effects estimated from kernel-based matching in the next section.

6.5 The Average Treatment Effects of the SWPRP

Treatment effects are the gains from project investments. As discussed in section 6.1, the gains of the SWPRP are measured by the changes in the 21 indicators at the village level. In other words, the project investments are attributed to the changes in these indicators of the project villages. The changes are evaluated with different parameters such as average treatment effects (ATE), average treatment effects on the treated (ATT), and average treatment effects on the untreated (ATNT). Each parameter is estimated using different estimators. In our results in Table 6.1-6.15, the estimates of these treatment effects are basically consistent. However, the vairances are unstable in nearest neighbor matching and caliper matching. As pointed out by Abadie and Imbens (2006b), this might be due to invalidity of the bootstrapping method in nearest neighbir matching. Imbens and Wooldridge (2009) note that the bootstrapping method is appropriate in kernel matching. The results of kernel-based matching are very close among different approaches. However, the regression-adjusted local linear matching has a smaller variance at each bandwidth. Based on these results, we choose to evaluate the project impact mainly based on the average treatment effects estimated from the regression-adjusted local linear matching. Heckman, Ichimura, and Todd (1997) also find that this approach has better performance in their evaluation of a labor training program. Meanwhile, using the results of the regression-adjusted local linear matching allow us to make a comparison with the results of Chen, Mu, and Ravallion (2008). They evaluate the SWPRP with the same methods using the panel data aquired from household surveys. The following interpretation of our results focus on the ATTs in Table 6.14 because it provides answers to the central question of this research, what impact has been produced in the project villages. However, we are also interested in generalizing our results. The estimated results of the ATEs in Table 6.13 and the ATNTs in Table 6.15 are briefly discussed to evaluate the generalized impacts if the project is inplemented in the villages outside the project villages. The discussion is organized by categorizing the 21 indicators into five groups: wealth and income, agriculture, employment, infrastructure, and education and health services.

6.5.1 Wealth and Income

The general objective of the SWPRP is to improve living standards in the poorest villages. Improvement in living standards is usually measured by increases in income and consumption. The indicators for income and consumption are given as the first group labeled 'Wealth and Income' in Table 6.14. In the group, an important indicator that measures the distribution of wealth and income is poverty rate, which is the head count rate of the population under the poverty line of 826 Yuan ($100 equivalent at that time). A change in the poverty rate indicates both a change in the distribution and a change in wealth and income.

As shown in Table 6.14, farmers' annual net income per capita significantly increased by 22.4-25.5 Yuan, or an increase of about 3.0-3.4 percent. Further investigation reveals that the annual cash income per household significantly increased by 192.4-207.6 Yuan, accounting for about 7.6- 9.1 percent. The ATT of income in kind is statistically insignificant. Thus, the increases in income are mainly derived in cash. Since the household size is about 4.5 in our sample, the cash income per capita is about 43-46 Yuan. The cash income is gross income and should be larger than the net income. This implies that the increases in income are coincident with additional household expenditures.

However, increases in the average income do not necessarily result in poverty reduction if the project benefits the wealthier more than the poorer in the project villages. It is crucial to investigate whether or not the project reduces poverty in the project villages. As shown in Table 6.14, the ATT of the poverty rate ranges from -3.0 percent to -3.3 percent and statistically significant, meaning that the poverty rate fell by 3.0-3.3 percent in the project villages. This range of reduction in poverty agrees with the increases in net income. However, the gain in poverty reduction seems to be much smaller than that reported by Chen, Mu, and Ravallion (2008). Possible reasons that explain a smaller impact at the village level are discussed in next chapter. Although our estimate of the reduction in the poverty rate is smaller, it is statistically significant. These results are consistent with the project reducing poverty.

Considering consumption, we find that housing conditions significantly improved. Expenditure on housing is considered as consumption in this research because no market exists for the houses themselves in the poor villages. In Table 6.14, it is surprising to find that the brick-and-tile structures increased by 8.2-8.6 percent and the thatched houses decreased by 7.7-8.1 percent. Normally, households must accumulate money for a long period until they are able to construct a new house. To attribute such a large improvement in housing conditions to the income increases by the project investment is unreasonable since the increases in net income are small. Therefore, other factors must also be involved in the improvement of housing conditions in the project villages. One possible factor is the improvement of transportation. Improvement in transportation allows isolated villages to access construction materials with lower costs. This allows households in the villages to improve their housing conditions by spending their savings. When the savings are spent on housing, no money is left to purchase other large assets such as TVs. As shown in Table 6.14, the project does not significantly increase TV sets in the project villages.

6.5.2 Agriculture

As mentioned above, the project is not able to generate a significant impact on the average income in kind. As shown in Table 6.14, this result is confirmed by the ATT on the grain production, which is the major source of income in kind. The project does not lead to a significant inprovement in grain production in the project villages. These imply that the project may not change the total outcomes from agriculutral activities. This lack of impact in total agricultural outcomes is also seen in agricultural production value, which has a negative ATT that is weakly signficant at the 10 percent level. The reduction in agricultural value may be due to the out-migragtion of labor. However, evidence shows that the project does have a signficant impact on specific agricultural activities.

In crop farming, as shown in Table 6.14, the ATT is possitive 0.19-0.20 Mu for the food crops and negative 0.04-0.05 Mu of the cash crops. They are all statistically significant but have opposite signs. With the project investment, households increase the farming of food crops and decrease the farming of cash crops. The increases and decreases are not parallel. Since no evidence shows a reduction in land use for other crops, households must extend the food crop production by using poor (usually high-slope) land. However, this shift to the food crop growing does not result in an increase in grain production.

It is interesting that households increase food crop production rather than cash crop production. First, consumer preferences might play a role in the decision. Grains, especially corn, are the major food in the poor villages. Suffering from a food shortage for a long time, households give priority to increasing grain crop production with the available resources. Second, cash crops are mainly produced for markets. The markets for cash crops are underdeveloped in the poor regions. At the same time, cash crop production usually requires more inputs. The risk is higher in cash crop production because of the variation in markets and the frequent occurrence of natural disasters such as drought, flood, and strong wind. Finally, grain is also the food for animals. The excess grain can be used for animal farming. Therefore, investing in food crop production with the project aid may be the best choice because food crop production satifies the need for self-subsistence, is less risky, and is important for animal farming.

With regard to animal husbandry, as shown in Table 6.14, the households in the project villages increase pig and goat farming and reduce cattle or buffalo farming. Pig farming is one of the major sources of cash income and protein. For example, households might preserve smoked pork for year-round consumption or sell their pigs to the market. The number of pigs in a household is usually determined by the farmland and laborers on the farm. Almost every household keeps one to four pigs. Traditionally, pig farming is a method to make use of the agricultural by-products, so cost is not an important factor. However, this situation might change due to the availability of commercial fodders and off-farm employment. With the investment of the project, households may increase pig farming with commercial fodders. Thus, pig farming becomes less labor intensive and more productive. As a result, the project is able to increase the pig farming and off-farm employment simultaneously.

Goats can adapt well to the mountainous geographic environment and are the another source of cash income and protein. Goat farming is popular only in the villages of the rocky mountainous regions. Usually, the key factors that determine goat farming are the cost of the young goats and labor. The laborers staying in the villages might choose to keep goats. For cattle and buffalo, they are traditionally used for agricultural power. The demand for cattle or buffalo is determined by the amount of land and labor. Since the amount of land in a houshould does not change by the project investment, the cattle or buffalo farming is expected to remain unchanged. However, the off-farm employment does not allow some households to keep cattle or buffalo. In this case, the households share cattle or buffalo with their neighbors.

The agriculutral component of the projct was expected to improve the living standards of the poorest with about 45 percent of the SWPRP's investment. However, our findings show no gains from the investment in terms of total agricultural outcomes such as income in kind, agricultural production value, and grain production. The limitation of resources such as land is the main constraint for expansion in agricultural production in the project villages. Meanwhile, the out-migration of labor might lead to less labor inputs in agricultural activities. This does not mean that the poorest do not benefit from the project investment. Evidence in Chapter 5 indicates that villages with more land benefit more from the investment in agriculture. More importantly, households adjust agricultural activites from cash crop production to food crop production, pig farming, and goat farming so that laborers are free from farming and are available to be employed off-farm.

6.5.3 Off-Farm Employment

As shown in Table 6.14, the project is successful in helping both male and female laborers to find off-farm jobs. The ATTs are increases of 3.4-3.9 percent for male labor and 3.7-3.9 percent for female labor. These results are supported by the evidence from Chapter 5, where, in Table 5.2, the specific treatment effects on off-farm employment for both male and female labor increase in the villages with the better land resources. Before the project, the laborers in the villages with better land resources might have a higher income, so more of them are likely to work on farm. With the project, the laborers might find that the off-farm employment could bring more income and therefore shift to off-farm jobs. The laborers in the villages with poor land conditions might have already worked off farm before the project, so there is not much the project could do to promote labor mobility in such villages.

6.5.4 Rural Infrastrucutre

The project is also successful in improving the rural infrastructure such as water supply and transportation. As show in Table 6.14, the proportion of the population suffering from water shortage in the project villages is reduced by 8.7-8.8 percent. The project improved household conditions by releasing laborers from the task of obtaining water. As also shown in Table 6.14, the accessible days by vehicles to the project villages are significantly increased by about 13 days in a year. The increase of vehicle accessibility improves transportation conditions so that both agricultural products and production materials can be marketed and obtained with lower costs. Therefore, the net return to agricultural production increases. Also, as disccussed above, improvements in transportation might be the cause of the rapid improvement in the housing conditions. Meanwhile, road construction is likely to bring a positive spillover effect to the non-project villages closed to roads. The benefit from investing in infrastructure might not be limited to reducing the cost of production. The improvement in infrastructure might also create convenience for the housholds in the project villages to reach other services.

6.5.5 Education and Healthcare Services

The project seems to have been ineffective in increasing school attendance. As shown in Table 6.14, the enrollment rate of primary schooling does not significantly increase. The design of the education component is based on the assumptoin that poor education in the project villages is caused by low income, low instructing quality, and lack of education facilities such as classrooms, teaching tools, and text books. The problem of low income was addresed by the investment in farm and off-farm employment. In the education component, the project invested mainly on teacher training, new school buildings, teaching equipment, and text books. These investments might lead to an improvement in education quality rather than an increase in education networks. Education networks have been well developed in China before the project. Complete primary schools were established to teach students of 1-6 grades in each administrative village and teaching points were set up to instruct students of 1-3 grades in the larger natural villages. Therefore, lack of education services might not be the case. The major problem in education could be the low teaching quality. As discussed in Chapter 2, part-time teachers were commonly hired in poorer villages. Thus, the enrollment rate may not be an approciate indicator to measure the project's impact in education quality.

Similarly, our indicators for healthcare services fail to capture the impact of the project investment. As shown in Table 6.14, the ATT on the population-doctor ratio is positive and statistically significant, meaning that fewer doctors provided services in the project villages. This result is puzzling. In order to address the low level of healthcare in the project villages, the project established clinics, subsidized and trained village doctors. At the same time, it also invested in hospitals at the township level. Unlike education, healthcare services are market goods, and we need to examine both demand and supply. Certainly, the increase in income was likely to increase the demand for healthcare services. But this increment may be small because the increase in net income is small. On the supply side, competition increased among the village clinics and the township hospitals. The township hospitals were likely in a better position to compete. As a result, the village clinics would not have enough clients to recover their operational cost and doctors would stop their services in the project villages.

The results from the ATTs indicate that the project does produce a significant impact on the project villages. We are also interested in evaluating the possible effects if the project had been implemented in non-project villages since they are also categorized into poor villages by the local government. By investigating the ATEs and ATNTs, we find that the conclusions from ATTs generally hold if the results are extrapolated to the non-project villages. In general, the magnitudes of the ATEs and the ATNTs are larger than the ATTs. For example, the ATE on the poverty rate is between -3.3 and -4.8 in Table 6.13, implying that the project would have better result in reducing poverty rate in a randomly-selected village. In Table 6.15, the ATNT of the poverty rate ranged between -3.3 and -5.1, meaning the project would had reduced poverty rate by 3.3-5.1 percent if the project has been carried out in the non-project villages. These results seem to suggest that the project did not use resources efficiently in terms of reducing poverty. Recalling the results from Chapter 4, we find that the project selected the villages with less land resources in order to target the poorer villages. The results from Chapter 5 indicate that the project would have better results in reducing the poverty rate in the villages with better land resources. Combining these two results, we find that it is reasonable to assert that the project would have better results in reducing poverty rate in the non-project villages. The non-project villages have better land resources and therefore are wealthier. However, the project had to trade off between targeting the poorer villages and efficiency.

Differences are found among the ATTs, ATEs, and ATNTs. Income does not have a statistically significant ATE and ATNT. That is, the project did not significantly increase income in non-project villages.

In this chapter, the impacts of the SWPRP are evaluated by investigating the treatment effects on 21 indicators. The treatment effects, measured by ATTs, ATEs, and ATNTs, are estimated using different techniques of matching including nearest neighbor matching, caliper matching, kernel matching, local linear regression matching, and regression-adjusted local linear matching. The results from regression-adjusted local linear matching are stable and insensitive to bandwidth size and have small variances. We, therefore, used these results to investigate the impact of the SWPRP. From the ATTs from regression-adjusted local linear matching, we conclude that the SWPRP produced a significant overall impact in the project villages. With the project, the annual farmer net income increased by 3.0-3.4 percent and the poverty rate fell by 3.0-3.3 percent. This comprehensive impact was mainly derived from the investment in farming, off-farm employment, and infrastructure.

CHAPTER VII

CONCLUSION

Since the Southwest Poverty Reduction Project (SWPRP) was a comprehensive intervention in a complex social environment, its impacts were multiple. With a diverse package of activities, the project attempted to tackle absolute poverty in 1798 poor villages in Southwest China from 1995 to 2001. The activities were composed of various detailed investments in rural education, rural healthcare, farming, rural infrastructure, labor mobility, improving institutions, and monitoring in order to improve living standards in these villages. To ensure sizable outcomes, the total investment by the World Bank and Chinese government was to $463.55 million. The outcomes of such a large-scale and complicated project are expected to produce diverse impacts on the targeted regions. This research investigates these multiple impacts with rigorous econometric techniques using a dataset from one of three project provinces—Guangxi Zhuang Autonomous Region.

The outcomes of the project are measured by the changes, referred to as the treatment effects, in 21 different indicators constructed from a village survey dataset on 4214 poor villages in 2000. The dataset includes a sample of 327 project villages and 3887 non-project villages in Guangxi. Our original sample includes villages from both non state-defined poor countries and state-defined poor counties. As a rule in the village selection process, only the poor villages from state-defined poor counties are considered. Notice that the poor villages in state-defined poor counties are eligible, while the poor villages in non-state-defined poor counties are ineligible, to received aid from the central government prior to and during the SWPRP. To eliminate this historic bias, the villages from non-state-defined poor counties are excluded from the dataset. The new dataset includes 327 project villages and 2214 non-project villages. A probit model is established from this new dataset to estimate the probabilities of the villages to be selected as the project villages. The model is then used to examine the selection process of the project villages and the effectiveness of targeting the poorest villages. More importantly, the estimated probabilities or propensity scores play a critical role in the econometric methods employed to eliminate selection bias.

The selection bias is first reduced by trimming the outliers from the new dataset excluding the villages from non-state-defined poor counties. The outliers inside the state-defined poor counties are trimmed by comparing the distribution of the estimated propensity scores. The project villages and the non-project villages are found to overlap in a region from 0.0132 to 0.5320. The villages beyond this overlapping region are considered as the outliers and therefore are excluded from the sample. The trimmed sample includes 325 project villages and 1909 non-project villages.

The selection bias is also removed by employing the econometric methods such as the control function approach and the matching approach. In the control function approach, the correlated random coefficient model (CRCM), proposed by Heckman & Robb (1985), is established to deal with the problem of observed heterogeneity related to village characteristics. This model allows us to examine the specific treatment effects on villages with particular characteristics. The CRCM can also be used to investigate the average treatment effects. However, the precise estimation of the average treatment effects relies on the correct specification of the functional form in the CRCM, and verifying the correctness of the functional form is difficult. Therefore, matching is introduced to estimate the average treatment effects without requiring a functional form. Various techniques are used in matching such as nearest neighbor matching, caliper matching, kernel matching, local linear regression matching, and regression-adjusted local linear matching. The sensitivity of these estimators is examined by choosing different parameters. In nearest neighbor matching, the number of nearest neighbors varies from 1, 3, 5, 7, to 9; the caliper in caliper matching is chosen to be 0.00005, 0.0001, 0.0005, and 0.001; the bandwidths for the kernel function are 0.02, 0.08, 0.2, 0.4, and 0.6. With trimming and econometric methods, the selection bias is minimized or eliminated in our estimated results.

The first important result is from an investigation of the project village selection process using the probit model. As can be seen in Table 4.2, the results of the probit model indicate that the project tends to cover the villages that are composed of small natural villages and lack farmland and quality land in the mountainous regions. Because these characteristics are usually associated with poverty, the SWPRP was successful in targeting the poorer villages. However, the model also suggests that the project gave higher probabilities to the villages close to township markets and county centers and having a lower percentage of high-slope land and lower illiteracy rate. Results indicate that the selection process does not always lead to the selection of the poorest villages. This behavior can be understood as the result of operational cost minimization of the project management agents. As a result, the selected 327 project villages are not all the poorest villages in the poor counties. There are some poorer villages among the non-project villages. Such a result violates the project objective but allow us to construct a control group for the treatment effect estimation.

The specific treatment effects are investigated using the results from the correlated random coefficient model. With the model, particular attention is given to the specific treatment effects on individual villages. The results in Table 5.2 show that the treatment effects vary with the village characteristics. Land is the major factor related to the heterogeneity of the treatment effects. In the villages with more farmland, the project benefits the poorer more than the wealthier. Evidence suggests that the project promotes off-farm employment and food crop farming in such villages more effectively. The results imply that the project improves the income distribution in the villages.

The average treatment effects are estimated with the matching estimators, which do not require the specification of the functional form. The treatment effects measured by ATEs, ATTs, and ATNTs are estimated from different matching techniques and are shown in Table 6.1-6.15. By comparison, the treatment effects from regression-adjusted local linear matching method have smaller variances and are relatively insensitive to bandwidth. Therefore, its results are used to evaluate the project's impacts. According to the results, the project reduces the poverty rate in the project villages by 3.0-3.3 percent and increases net income by 22.4-25.5 Yuan, accounting for an increase of 3.0-3.4 percent. The results from the poverty rate and the net income support each other.

The impacts on income and poverty are further confirmed in the treatment effects on the other indicators, especially farming, off-farm employment, and rural infrastructure. With the project, households increase the activities of food production, pig farming, and goat farming. The project is also successful in promoting nearly 4 percent of male labor and female labor to be employed off farm. The project also increased the vehicle accessible days by 13 days in a year and reduces the population that suffers from water shortage by about 8 percent. The project's impact on the primary school enrollment is insignificant. Fewer doctors provide healthcare service in the project village after the project; this might be due the improvement of healthcare services available at the township level, which were also supported by the project. Our indicators may be not appropriate for detecting the changes generated by the project in the areas of education and healthcare services.

As expected, our findings agree with the findings by Chen, Mu, & Ravallion (2008) although the dataset and methods are different. Their dataset is a panel data of 2000 households with project and without project. The baseline data allows them to examine the impacts of the SWPRP using the method of difference-in-difference. With kernel matching technique, they reported a reduction of 11 percent in the poverty rate at the 808 Yuan poverty line and an income gain of 169 Yuan in 2000. They find that the majority of income increases are derived from animal farming. Notice that the 169 Yuan income is the gain to a typical household with the project. Taking 4.5 as the household size, the income gain per capita is 38 Yuan. Both the treatment effects on the poverty rate and the income are higher than the results from our dataset.

Two factors might contribute to smaller treatment effects in our dataset compared to the results of Chen, Mu, and Ravallion. First, their results are estimated from household data. The treatment effects in their estimation represent the impact on the households that actually participated in the project. Our dataset is at the village level and includes households that might not directly participate in the project. The treatment effects estimated from household data must be larger than that estimated from the village data. Second, Chen, et al use the difference-in-difference method with a panel data, which control for time variants. However, time-variant is impossible to be controlled in our cross-sectional dataset. As mentioned in Chapter 4, the SWPRP is considered as a part of Chinese government's 8-7 Plan that aimed to reduce poverty in the poor counties. That is, there are other poverty reduction programs going on in the non-project villages. The observations from the non-project villages might be contaminated. The counterfactuals estimated from the non-project villages are not time-invariant. Our estimates might have a downward bias.

Although a downward bias is possible, the results estimated at the village level are practically relevant. First, our results indicate that targeting the poor villages can be an effective method to target the poor. In China, the rural poor are usually geographically concentrated. Most households in poor villages are poor. To identify the poor households inside such villages is impractical. Meanwhile, investments such as public infrastructure and services affect whole villages. Therefore, it requires the efforts of the whole villages rather than individual households. Moreover, as in the SWPRP, the financial support for individual households is limited. The wealthier households may not be interested in such a small financial support and thus might be automatically eliminated from participation. Our results show that to target the whole village is a practical and effective strategy in poverty reduction.

Second, the results imply that investing in farming can result in a redistribution of income to the poorer households. The project offered a package of diverse opportunities such as off-farm employment and various farming activities to households in the poor villages. Households chose the appropriate activities to participate in. The skilled and educated laborers who find an off-farm job in urban regions are usually better-off. Those left are usually unskilled, low-educated, and poorer. The support in farming activities provides a chance to increase income from farming. More importantly, the benefits from farming are likely distributed to the poorer households rather than the wealthier.

Third, the results suggest that land and labor are the key resources in poverty reduction. As discussed above, farming is important in income redistribution in rural villages. Land and labor are therefore critical. To improve the land and the capacity of the labor is a key component in the design of a poverty reduction program.

Fourth, the results indicate households make decisions on allocating their resources based on their available resources and the development of the local markets. The phenomenon that households tend to choose to increase food crops rather than cash crops suggests that markets remain underdeveloped.

Fifth, the results demonstrate that the comprehensive approach can be an effective strategy in poverty reduction. The results of poverty are similar, but the causes of poverty are multi-dimensional. Effective approaches to solve the problem of poverty therefore should be multi-dimensional. Challenges occur practically in the effort of integrating a diverse package of activities at the appropriate targets. The effectiveness of such an integral approach is shown in the success of the SWPRP.

Finally, the results from this research show that a complete solution of the poverty problem in the project villages requires further efforts. Although the project yielded a significant reduction in poverty, the poverty rate reached as high as 47 percent in the project villages in 2000; this poverty rate is accounted using a poverty line as low as 826 Yuan (US$100, equivalent) annual income per capita. Our data does not allow us to evaluate the dynamics of poverty in the villages. However, the results of Chen et al show that the project impact disappeared in 2004. Obviously, the project villages need assistance beyond the completion of the project investment. A method for establishing a lasting impact does not currently exist. While benefiting from the project, households in the project villages remain vulnerable because the benefits are too small to have lasting impact. When the project services ended and the project capital was repaid, the sources for increasing income may also vanish. Some households may return to poverty. To extend the impact of the Southwest Poverty Reduction Project, a method that allows for continued services should be developed.

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