IRRIGATION, INCOME DISTRIBUTION, AND INDUSTRIALIZED

AGRICULTURE IN THE SOUTHEAST UNITED STATES

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IRRIGATION, INCOME DISTRIBUTION, AND INDUSTRIALIZED AGRICULTURE IN THE SOUTHEAST UNITED STATES

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A Thesis

Submitted to

the Graduate Faculty of

Auburn University

in Partial Fulfillment of the

Requirements for the

Degree of

Master of Science

Auburn, Alabama
December, 19 2008

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Date of Graduation

THESIS ABSTRACT

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Master of Science, December 19, 2008
(B.A., Liaoning University, 2004)

67 Typed Pages

Directed by Joseph J. Molnar

Improved availability of irrigation water in agriculture can stabilize crop yields and therefore incomes for adopting producers. However, because of unequal distribution of access to land and water, irrigation may have undesirable effects on income distribution and poverty status of a region other than poverty alleviation. By analyzing the extent and kind of irrigation in southeastern U.S. counties in relation to income distribution while controlling cross-county differences, this paper examines the impacts of irrigation on poverty and income inequality in the counties of nine states (Arkansas, Alabama, Mississippi, Louisiana, Georgia, South Carolina, North Carolina, Tennessee, and Florida) in the southeast United States. We examine the notion that irrigation is an aspect of industrialized agriculture that exacerbates inequality in agricultural counties.

Keywords: Inequality, irrigation, agricultural structure

ACKNOWLEDGEMENTS

I would like to express my gratitude to all those who gave me the possibility to complete this thesis. First, I would like to thank the department of Agricultural Economics and Rural Sociology where I stayed for two years, and provided me the knowledge about this thesis in the first place.

Second, I am deeply indebted to my major professor, Dr. Molnar, who cultivates my interest in statistical analyzing, and helps me in all aspects during my study here. I also want to thank my committee members Dr. Bailey and Dr. Dodekohr, who give me a lot of help in the completion of the thesis.

Finally, I want to thank my parents in China for their great support and encouragements. Also thank my friends both here and in China for their support and warm friendship.

Style manual or journal used: American Sociological Association

Computer software used: Microsoft Word 2003, Microsoft Excel, SPSS.

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CHAPTER 1

INTRODUCTION

Agriculture is an art of producing crops and livestock and it ‘closely touches almost every science’ (Brooks 1911). Agriculture is not in itself a science but it can be most intelligently and successfully carried on only by those who have some understanding of the sciences (Brooks 1911). However, gradual improvement of agricultural technology, domestication of additional plants and animals from the wide, step-by –step selection of the most optimal genotypes of crops and livestock, along with intuitive breeding, continued at a slow pace (Altman 1998) until in 1950s with the great agricultural transition.

The American agricultural structure is not a monolith, but a kaleidoscope, which changes over time although slowly. One of the most dramatic changes in the United States in the past century is the exodus of Americans from farming began in the early 1900s, and at the end of the century, the farm population stood at under 2 percent (Lobao and Meyer 2001).

However, agriculture still plays an important role in the rise or fall of any civilization, as it always did in the past. “There is no business of life which is so highly conduces to the prosperity of a nation, and to the happiness of its entire population, as that of cultivating the soil” (Buel 1840). Today, although we are able to produce much more than our counterparts in the past, agriculture is still our “nursing mother, which gives food, and growth, and wealth, and moral health and character, to our country" (Buel 1840). No one can ever imagine a world totally stands without agriculture. Value of production by agricultural sector has increased from $23.7 billion in 1970 to over $279 billion in 2004, and net farm income has increased from $14.4 billion to $28.5 over the same period (Convey et al. 2007).

Agricultural Treadmill Theory

U.S. agriculture has changed dramatically over the past few decades, specifically, from 1950 untill today, in farm numbers, size, technology, and other aspects. There were around 5.4 million farms in 1950, and decreasing to 2 million in the 1990s. Average farm size grew from 215 to 473 acres during the same period[1].

During the past half century, farm profits remained low although farm size grew significantly and at the same time more and more new technology was adopted. In order to explain this phenomenon, Cochrane (1958) introduced a notion that "farmers are on a treadmill which, in spite of their constant adoption of new technologies, wears away any profits which might result".

According to agricultural treadmill theory, no one of the small farms which produce the same products can affect the commodity's price; hence the farmers who adopt new technology and thus increase productivity are able to gain significant benefits. However, after some time, others follow and increase supply. The commodity's price tends to fall with increased supply. Then, the increased efficiency in agricultural production can drive down the prices. The downward pressure on crop price directly has two results: (1) Those who have not yet adopted the new technology must now do so lest

[1] DATA from The University of Georgia College of Agricultural & Environmental Science Cooperative Extension Service

they lose income (price squeeze) and (2) those who are too old, sick, poor or indebted to innovate eventually have to leave the scene. Their resources are absorbed by those who make the windfall profits ("scale enlargement") (Hashimi et al. 2004). In effect, the latter results in redistribution of natural resources and rural income and further exacerbates inequality.

Agricultural Production and Irrigation

From ancient times, population concentrated in areas which had abundant and readily available water supply. Only with the advert of irrigation techniques, civilization began to cultivate crops in arid regions where agriculture is impracticable or impossible. For other regions such as semi-arid regions or even humid regions, appropriate irrigation still has positive effects on agricultural production. Irrigation is the artificial application of water to soil to assist the production of crops *(*Snyder and Melo-Abreu 2005).

One crucial aspect of the agricultural transition is the change in irrigation. Irrigated agriculture has expanded enormously over the past five decades. Irrigated agricultural land has increased nearly six times during the past century worldwide, much of which occurred after the 1950s with the development of industrialized agriculture process (FAO 2000b). Most of the expansion in irrigated area during the period has taken place in developing countries. At the global scale 2.8 million sq km (689 million acres) of agricultural land was equipped with irrigation infrastructure around the year 2000. About 68 % of the area equipped for irrigation is located in Asia, 17 % in America, 9 % in Europe, 5 % in Africa and 1 % in Oceania (Siebert et al. 2007).

Irrigated agriculture is one of the most important components of the world food production, and a major human use of land and water resources. Estimates of water use in the United States indicate that about 408 billion gallons per day (Bgal/d) were withdrawn for all uses during 2000 (Hutson et al. 2004). In the United States, irrigation remained the largest use of fresh water since the 1950s.

A sustainable industry including agriculture should be economically viable and socially acceptable (Crossen 1992). It is widely accepted that irrigation is important to the health of the agricultural industry, and has played a critical role in past and current well-beings of human society. It is estimated that 17 percent of global farmland under irrigation contributes about 40 percent of production of cereal crops (WCD 2000). Intensification of irrigation and the concomitant expansion of related agribusiness have brought and will continue to bring various benefits to the human world. The direct benefits of irrigation centrally include an increase in crop yields due to the steady of availability of water to meet crop need. Irrigation also makes possible the production of a broader range of crops, many of which are considered specialty crops, (crops that are generally not viable under dry land agriculture). Finally, because crop yields are more stable and reliable under irrigation, insurance and other related costs are significantly reduced.

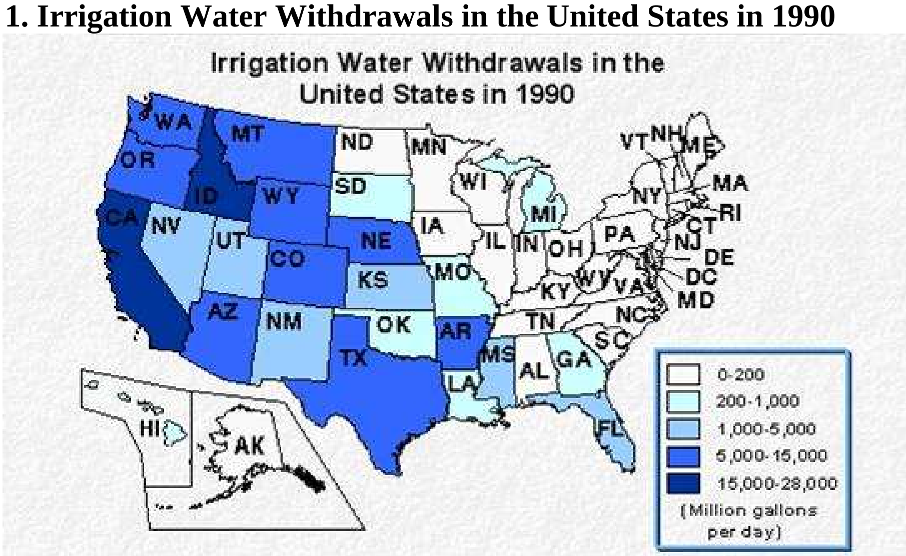
Despite the significant contribution of irrigated agriculture to increasing food production and to overall socio-economic development, irrigation has come under increasing criticism over the past decade—for concerns such as socio-economic inequity, social disruptions and environmental changes that are attributed to irrigation development and reservoir construction (Hussain 2002).

Irrigation in the Southeastern U.S.

The study area includes 9 Southeastern U.S. States: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee. We focus on these 756 counties because they are relatively homogenous in size and encompass a distinct macroclimatic and cultural area of the United States.

Water use data has been collected by the USGS Water Resources Division starting in 1950 and has continued at five-year intervals since. Since 1950, irrigation is the greatest in all human use of fresh water resources, and has increased greatly over time. Compared to Western states such like California, the Southeastern states use very little water for irrigation. Alabama, for example, it is estimated that Alabama has lost close to 10 million acres of farming — a loss due in large part to the competitive advantage enjoyed by federally-subsidized farm irrigation in Western states, and lags far even behind neighboring states (Langcuster 2004). The most irrigation intensive of the 9 states is Arkansas, which currently ranks ranks fourth in the United States in irrigated acreage, with more than four million irrigated acres (Robinson et al. 2002).

Figure 1. Irrigation Water Withdrawals in the United States in 1990



Statement of Problem

Appropriate irrigation technology increases agricultural production growth and therefore income for adopting producers, and hence should have positive impacts in poverty alleviation. However, because of unequal distribution of access to land and water, irrigation may play an undesirable role on income distribution, and hence worsen the problem of inequality in rural areas.

Some argued that irrigation development in various regions tends to convert marginal and poor farmers into landless laborers (Chambers 1988), but relatively little theoretical or empirical efforts have been made to study the effects of irrigation on inequality. The absence of research might be a result of the complicated nature of the linkages between irrigation and inequality (Huang et al. 2005) which involves the fact that irrigation often is often associated with rural households that reside in relatively favorable areas (David and Otsuka 1994). Even for the researchers who made such efforts, most of the studies used household-level (Huang et al. 2005) and state-level (Sampath 1992) data to examine the association between irrigation and inequality, but very few studies use smaller geographic units, such as metropolitan areas, counties, or census tracts.

In order to understand why irrigation, if possible, may have undesirable effects on income distribution and poverty status of a certain region, a set of questions should be clarified before the whole research begins:

1. Some scholars argued that although industrialized agriculture is one of the 20 greatest engineering achievements of the 20th century (National Academy of Engineering, 2006). It may exacerbate inequality in rural income distribution rather than alleviate it. So

the question is, whether irrigation, as one of the most important aspects of agricultural technology and engineering in arid areas and on large-scale farms, should be considered as a representative of modern industrialized agriculture and whether it should be responsible for income inequality in rural regions.

2. The second question has to do with the data sources. Readily available and widely used data include Census of Agriculture and U.S. Geological Survey (USGS). The Census of Agriculture is the primary data source for statistics related to agricultural activities in the United States. After 1950, the Census of Agriculture was completely separate from the Decennial Census, and is now published every five years, in years ending in "2" and "7." The United States Geological Survey was established on March 3, 1879. As stated in their mission statement, the USGS “serves the Nation by providing reliable scientific information to describe and understand the Earth”. Now USGS has become a leader in the national sciences. However, because of differences in data collection and scientific focuses, their data are somewhat inconsistent with the USDA irrigation during the same period of times. I will take a closer look to these differences in the following chapters.

3. One of the most important components of research is to choose the right unit of analysis. Since farms are generally run on the basis of family labor, and household is the one that fulfils an import role to provide livelihood for its members, further, income is usually analyzed using the unit of family, many studies use household as their unit of analysis to explore the relations between irrigation and income. However, household level data are highly inconsistent and hence hard to rule out all other explanations of the issue. On the other hand, other studies prefer to use bigger geographic aggregates such as

state and country level data, such as the study of Equity Imapcts of Irrigation Development by Sampath (1992). But very few studies use smaller geographic units, such as metropolitan areas, counties, and census tracts. As mentioned above, county is our aggregate unit of analysis. We use county-level data not use because such data are most readily available, but also because counties provide comprehensive coverage, spanning both metropolitan and nonmetropolitan places (Lobao et al. 1999). Further, because counties are smaller than nation and state level units, they are less heterogeneous in general, and less likely to obscure the true association between irrigation and income inequality.

But care should be taken with using county-level data because it contains inherent pitfalls: the data in broader level of analysis may not be useful to make inferences to lower level of analysis (communities and households). In this study, we readily acknowledge that these data are not useful to make conclusions within specific communities or households. Rather, the study presents a broader picture of the effects of irrigation on inequality in the Southeastern United State which focuses on the term of "on average".

Significance of Study

This study contributes to the understanding how irrigation influence a region's poverty status and income distribution in Southeastern U.S. agricultural counties. Contrasted with those desert-irrigated agriculture in western U.S. states such as California, the counties under study use relative little water in irrigation despite of their readily available suffice fresh water resources. Alabama, for example, ranks near the bottom in the amount of land being irrigated (Birmingham Business Journal, 2006). On the other hand, western irrigated agriculture, utilizing the subsidized water projects primarily in California and over-pumping of ground water in the High Plains, avoided crop losses due to drought. This increased efficiency drove down agricultural prices so that in a slow painful decline, farmers in the East were driven out of business because they couldn't compete with the sustained yields produced in the West (McNider et al. 2003).

Agriculture is a pervasive problem, especially in eastern states which under-utilize their land and water resources but at the same time suffer great economic and social losses due to abnormal dry weather. Scholars in the east believe that it is the time for eastern states to fully and seriously consider irrigation as an effective assistant for traditional rain-fed agriculture, and determine the feasibility of large-scale irrigation in the states under study. Therefore, any information that could aid in full understanding of effects of increased irrigation on economic and social aspects should be readily applicable.

Objectives

This study focuses on the irrigation intensity, agricultural status, poverty and income inequality in 756 counties in the Southeast United States. The overall objective of the study is to analyze the potential effects of irrigation on rural income and equality and the social feasibility of large-scale irrigation in the Southeast U.S. counties. Irrigation intensity is measured both in acres of irrigated farmland and estimated ground and surface water withdraws. Poverty is measured on the county basis and inequality is determined by the Gini coefficient. Educational difference and population structure are also included to consider the non-spurious relationship between irrigation intensity and income inequality and to rule out other explanations.

The fundamental task and method is to determine the effects of irrigation intensity on rural income distribution using regression model. Several basic steps are used to accomplish this goal:

First, descriptive statistics are used to find an overall pattern of both irrigation intensity and income distribution, to test outliers, and to deal with missing data. Descriptive statistics provide a general understanding of what our data are like and provides simple summaries about the sample and measures. In my study, I choose three of the most commonly used descriptive statistics: the mean, the standard deviation, and the range. The mean, as a very informative measure of the "central tendency" of the variables under study, is simply the arithmetic average of the values in the set. Standard deviation is the square root of the variance, which is the sum of squared differences between the values and the mean. We use standard deviation to measure the “spread” of the variables, to see how far the data points are from the mean. The range is another commonly used statistic to measure variations of the data, and it simply indicates the difference between the largest number and the smallest one in the data set.

Second, a factor analysis is necessary not only because it can make the analysis process more straightforward but also provide a better understanding of the correlation between irrigation and inequality. In order to provide a ‘complete’ measure of irrigation we introduced more than ten variables from both USGS and NASS irrigation data sets. However, perhaps the only flaw of this measure lies in its comprehensiveness: too many variables increase the complexity of data deduction and analysis; further, the individual variables which cannot explain much of the variance in key independent variables may increase the risk of establishing a spurious relationship that we are interested. Factor analysis is used to study the pattern of the many explanatory variables and the factor scores are saved as variables the main independent variables for further analysis.

Third, it comes to the analysis of the correlation between irrigation and poverty rate. Here we use these factor scores (they are saved as variables during the factor analysis process) instead of the original variables to do the regression analysis. Before the whole regression analysis started, a test of Multicollinearity is performed between the explanatory variables. In the presence of multicollinearity, the estimate of one variable's impact on the dependent variable while controlling for the others tends to be less precise than if predictors were uncorrelated with one another (Van den Poel Dirk 2004). In some cases, if different explanatory variables tend to measure the same issue, or some variables are highly correlated with each other, they are redundant, and then multicollinearity occurs. In order to provide a more precise understanding about the true relationship of interest, the problem of multicollinearity should be resolved before we move on.

Fourth, control variables are introduced into the analysis and two-model regression analysis is used to rule out all other explanations and to find the non-spurious relationship between irrigation intensity and income inequality. It is well accepted that population structure such as race or age and especially educational status of a specific area has significant impacts on the region’s poverty status and income distribution. Hence, we introduce those variables and other cross-county difference as our control variables in order to rule out their potential effects on testing the hypothesis we are interested.

The next chapter develops a conceptual framework that anticipates a set of hypotheses linking irrigation intensity to rural poverty and income inequality.

CHAPTER 2

CONCEPTUAL FRAMEWORK

This chapter addresses the history and development of irrigation, how it is measured, the theories and measurements of poverty and inequality and how they are related to irrigation scales and intensity. The social impacts of large-scale irrigation are examined in the context of industrialized agriculture in western developed countries. This chapter also addresses the adoption of technology in irrigation development, its market infrastructure, the great agriculture transition in U.S. beginning in the 1950s, and the hypothesized relationship between industrialized agriculture and rural income distribution. Further, since irrigation is not the only determinant of rural poverty and income inequality, reasons that leads to our hypothesized outcome beyond irrigation are also introduced and examined.

Perspectives on Irrigation Development

Water Supply and Market Infrastructure

Water is a critical component for the survival of both human and ecological systems, and takes an important role in economic and recreational activities. Neither plants nor animals can survive long without it, and water is used in virtually everything we make and do (Frederick 2004). Hence, freshwater supply is a crucial issue for any civilization. In the following paragraphs I discuss irrigation water supply and infrastructure in the United States.

Because of the United States' large size and wide range of geographic features, nearly every type of climate is represented. The climate is relatively humid in the east, semiarid in the Great Plains, desert in the Southwest, and arid in the Great Basin (the World Fact book, 2001). The United States' average daily precipitation equals 4.2 trillion gallons (Reshkin, 1998), but there are still water shortages because of unequally distributed precipitation in the States and increasing water demand. Further, uncertainty of water supply due to timing, location and reliability, increasing costs to develop additional water supply system, the vulnerability of the resources and the problems of restoring and protecting valued surface and groundwater resources, the importance of reliable supplies of high-quality water for human and environmental health and economic development are vital concerns. The shortcomings of our institutions for allocating scarce supplies in response to changing supply and demand conditions has made water supply issue a critical one to the country's development (Frederick 2004).

Meeting the increasing demand by traditional structural supply augmentation is dogged by increasing environmental and fiscal costs (Howitt and Hansen 2005). The coincidence of high water demand is largely met by conservation and reallocation of existing supplies. Water trading, which includes both sale and lease water rights clearly plays an indispensable role in stimulating conservation and reallocating supplies. However, because of its special physical characteristics, trading of water is not the same as other goods or services. Uncertainty of both demand and supply is a fundamental factor that determines whether and how water market develops. There is tremendous variation of rainfall across space and time, and on the other hand, demand and supply peaks do not always coincide within the water year (Howitt and Hansen 2005). To solve the uncertainty, water transportation and storage projects are constructed to convey water largely at public expenses, so water markets are more developed in areas where federal and state have invested resources to create facilities, such as the western states in U.S. It is unrealistic to expect the water users to repay all the development costs of irrigation projects in many cases (Hargreaves et al. 1998), so in the Southeastern nine states of interest where lack federal or state investment in irrigation, water projects are not as developed because water transfers require significant costs, in term of both institutional and transporting costs. Federal water projects in the Southeast tend to focus in transportation and relocation, not supply.

Even irrigators are not expected to pay all the development costs, in most water projects at least part of operation and maintenance costs are paid through water user fees, and “the maturity of an irrigation project is reflected by the proportion of operational and maintenance costs that is borne by the irrigators themselves” (Hargreaves et al. 1998).

Adoption of Technology

Some expected that the world population to exceed 10 billion people by the year 2050 (Brown et al. 1997). Expanding population will cause severe stress on water resources, the environment, and on the ability of agriculture to provide sufficient food. Such capacity, since the latter part of the 20^{th} century, has expanded “due to the development and adoption of new technologies, rather than the expansion of cultivated land” (IPCC. 1996). It is realistic to anticipate that irrigation technology will continue to play a crucial role in agricultural activities in the future.

Various types of irrigation techniques are adopted to provide the right amount of water each plant needs. They differ in how the water obtained from the sources and how it is distributed. Surface irrigation, including furrow, borderstrip or basin irrigation, is the process to move water over and across the land by simple gravity flow in order to wet it and to infiltrate into the soil (Britannica 1994). Drip irrigation (also known as trickle irrigation), is a system that water is delivered only close to the root zone of plants, and drop by drop. This irrigation method is highly efficient since both evaporation and runoff are minimized (Britannica 1994). In sprinkler or overhead irrigation, water is piped to one or more central locations within the field and distributed by overhead high-pressure sprinklers or guns. Center pivot irrigation is a form of sprinkler irrigation consisting of several segments of pipe (usually galvanized steel or aluminum) joined together and supported by trusses, mounted on wheeled towers with sprinklers positioned along its length (Britannica 1994). Lateral move (side roll, wheel line) irrigation is a system that a series of pipes, each with a wheel of about 1.5 m diameter permanently affixed to its midpoint and sprinklers along its length, are coupled together at one edge of a field. Water is supplied at one end using a large hose (Britannica 1994).

Improved irrigation technology, especially drip irrigation, is able to make the plant use a greater proportion of the total amount of water applied, and conserve water with less loss than traditional gravity irrigation. Moreover, with the reduced water use, irrigation-related energy costs are significantly reduced, too (Negri and Brooks 1990).

The United States has approximate 20 million irrigated hectares, of which about 60% is irrigated by gravity or surface methods (furrows, basins, and borders), and around 30% is sprinkler (Hargreaves et al. 1998).

Industrialized Agriculture

It is estimated that 80% of the world's food is provided by industrialized agriculture and 20% by subsistence agriculture (Miller 2005). Industrialized agriculture system used in the United States and in other nations are relatively new compared to traditional agriculture, coming after World War II. Industrialized agriculture, (or high-input agriculture), as the contrast to traditional agriculture (or low-input agriculture), means an agricultural method using large amount of fossil fuel energy, water, commercial fertilizers, and pesticides to produce single crops (monocultures) or livestock animals (Miller 2005). The purpose of production is for commercial sale other than individual consumption. The vast majority of labor in this agricultural system is provided by machines to replace human workers. On the other hand, large-scale storage facilities and refrigeration allow some crops to be stores for years and so mitigate fluctuations in productivity due to drought or other calamity. A complex transportation and trade system allows there crops to be moved around the world with little difficulty (Sutton and Anderson 2004).

Industrialized agriculture is well known for its high productivity; however, it has a lot of undesirable impacts on the environment such as water pollution and soil degradation. Chemical fertilizers, pesticides, and herbicides applied to increase productivity pollutes water and soil and may kill a lot of other plants and animals, and hence results in the loss of biodiversity. In turn, industrialized agricultural systems may produce animal welfare problems, environmental problems such as management of waste, groundwater overdraft, and contamination, and concerns about the safety of food (Rollin 1995).

Concerns about the social impacts of industrialized agriculture have emerged in recent years, too. It is well acknowledged that this system has led to the demise of small farmers, since they are not able to effectively compete with large commercial farmers. Small farmers who do not have enough resources to adopt new technology may have to leave farming. Other social impacts of industrialized agriculture include "the loss of jobs, the further disadvantaging of women economically if they do not have access to the use and benefits of the new technology, the increasing specialization of livelihoods, the growing gap between the well-off and the poor, and the cooption of village institutions by the state" (Pretty 1995)

Model of Irrigation Impact and Inequality

Irrigation Adoption

In common parlance, irrigation maybe defined as "the application of water to land by artificial means for the rising of crops and other products of the soil" (Long 1916). This definition emphasize the watering of land by "artificial means", not by rainfall, although "possibly the cultivation of land by means of water naturally moistening and rendering it productive by natural overflow may amount to a valid appropriation of such water" (Long 1916). In most cases, irrigation is not a matter of necessity, since there are some crops can be grown by the aid of rainfall alone even in arid regions. However, even if irrigation is not a necessity, it is "everywhere of value, because it's magic brings into full fruition all of the attractions with which the State is so generally endowed" (Mead 1901).

Irrigation projects and technologies have been developed to effectively manage water resources to help increase crop productivity. The performance of the technologies generally depends on crop requirements, soil and weather conditions, etc. But decisions whether and how to irrigate, on the other hand, is a human factor. In the analysis of adoption of agricultural production in Central Nebraska River Basins, the Mississippi Embayment, the Snake River Basin, the South Georgia Coastal Plain, and the Southern High Plains, Margriet Casell and her colleagues (2001) pointed out that producer characteristics are very important determinants of irrigation adoption level. Farmers with at least some college education are more likely to adopt irrigation practice. Moreover, years of farming experience and land ownership are also positively and significantly related to the use of irrigation (Casell et al. 2001). Whether or not a producer had crop insurance did not have impacts on irrigation adoption, and the effects of farm size on irrigation adoption differed greatly by reason (Casell et al. 2001). Other producer factors that may influence irrigation adoption in her study included: crop rotations (positively related except in the Central Nebraska and Snake River Basins), and participation in a federal commodity program (positively related).

Besides human factors, Casell and her colleagues also studied the effects of natural resources endowments of the field may have on irrigation adoption. Their research results in the above mentioned regions showed that soil productivity and soil erosion due to rainfall had no influence in irrigation decision, but most other natural factors under analysis played significant role on irrigation adoption decision. It is not surprised the most important natural factors in determining the use of irrigation under their study was climate variables. Generally, producers in regions with low average rainfall and high average temperatures were most likely to irrigate. The slope of the field, on the other hand, has negative effects on irrigation adoption. It means that the greater the slop of the field, the less likely a producer would irrigate. However, in regions where irrigation was mostly sprinkler systems, the slope of the field seemed have no effects on irrigation adoption (Cussell et al. 2001).

Rural Poverty

Poverty is a difficult question from both a methodological and a theoretical point of view (Mingione 1996). It is not confined to less developed countries, and it affects both individuals and collective groups. Generally, Poverty means “deprivation, a denial of access to those things which a person believes necessary for their life to be worth living: not only food, shelter and safe drinking water, but also education, and the opportunity to engage with other human beings from a position of dignity” (The World Bank 2007).

Rural poverty is a highly complex term in the context of relatively affluent countries such as Britain and the United States (Milbourne 2004). Rural places face increasing economic adversity since the early 1990s and rural people face declining opportunities (Duncan 1992). Rural poverty is a persistent problem in both developed and developing countries and scholars have been worked on this issue for decades. In “Empowerment and Rural Poverty”, Steve Suitts explores the potential for developing strategies that empower the rural poor by increasing their direct control over economic and political institutions. In “Policies to Alleviate Rural Poverty”, Greenstein and Shapiro take a pragmatic look at national policies about working, two-parent, elderly rural families. What they recommend is a policy that could raise income in working poor families without diminishing work incentive (Duncan 1992).

Although there is no known pinpoint to what actually causes poverty, it is well established that age, race, education and other individual or social factors all have impacts on poverty. In 1960s researchers pointed out a pattern of growth in female-headed households among this population that was lined to poverty and to indicators of social disorganizations (Moynihan 1965; Clark 1965). Zinn and Wilson (1987), on the other hand, focused on general social patterns such as economic conditions when try to explain poverty and marginalization. Most researches tend to use household as their unit of analysis when study poverty, social exclusion or anti-poverty program. Household surveys are a flexible instrument for gauging financial welfare, as they allow us to assign a household and a group of dependents to each individual (McGinnity 2004). However, there is a continuing controversy in environmental and social justice literature regarding unit of analysis (Lester et al. 2001). Some argue that small units are preferable (Anderton 1996; Bowen et al. 1995). Others argue that it is preferable to create area units that preserve intra-area homogeneity for the variables of interest (Haining 1990).

Rural poverty is usually measured in terms of the proportion and the absolute number of rural populations living in deprivation or below the poverty threshold or poverty line. The poverty threshold is the minimum level of income deemed necessary to achieve an adequate standard of living (Ray 1998). However, we have to keep in mind that the use of a single poverty line for a region under study as a whole conceals: (1). The degree of inequality in the distribution of income / consumption among the poor; (2). The occupational categories of the poor as hired agricultural workers, share croppers, very small holders of land or livestock, nomads, artisan fisherman, forestry workers, female heads of household, etc; and (3) the age and sex composition of the members of poor households (Ghonemy 1990).

Inequality

The problem of distribution is one of the most central issues in both economic and social affaires in each civilization, and it has been widely studied in recent literatures. Economic inequality refers to disparities in the distribution of economic assets and income (Bourguignon 1998). An essential preliminary to any inequality study is "clarification of the nature of the distribution to be analyzed to ensure that it represents the appropriate concept of economic power and does so for each constituent unit" (Osberg 1991).

There is no single cause of inequality within the society. Actually the reasons of unequal distribution of income are multiplier, complex, and often inter-related. Well established factors that may have impacts on inequality include: race, gender, culture, labor market, development patterns and individual preferences such as enjoying more income or leisure, willingness to take risks and so on (Lambert 2002).

Commonly used statistical or summary measures of economic inequality include: the range, the relative mean deviation, the variance, the coefficient of variation, the standard deviation of the logarithms, and the Gini coefficient (Temkin 1993). These measures have been adequately discussed and evaluated in economic literatures, and they all have well-known difficulties in explaining inequality in some cases. For example, the range measured by the result of maximum minus the minimum divided by society's average level of welfare completely ignores the pattern of distribution, and Gini coefficient is criticized to be implausible for comparing situations whose average levels differ greatly (Sen 1973; Temkin 1993). Actually, every measure may loose plausibility when applied to a particular situation.

Impacts of Irrigation Development on Income and Poverty

In the United States, more than 400 billion gallons of water are withdrawn per day from ground and surface waters, and agriculture is the largest water user due to irrigation that accounts for 137 billion gallons out of the 400 total (Hurson 2004). Agricultural water management contributes to the production of agricultural outputs, which in turn contribute to livelihoods through food and nutrition, health, income, and employment (Molden 2007). The impacts of irrigation on both economic and social impacts have been widely studied. Since irrigation development forges inter-sectoral and inter-regional linkages through output growth and income flow, its employment and income impacts have powerful multiplier effects (World Bank 1991). Irrigation has multiplier benefits on economy through increased agricultural productivity, including poverty alleviation, increased productivity, promotion of local agro-enterprises, and stimulation of the agriculture sector as a whole (Molden 2007; Litchfield and Faures 2003; Huang et al. 2006).

Irrigation has historically had a large positive impact on poverty reduction (Hussain 2005; Lipton et al. 2003). Irrigation enables people to improve crop productivity, grow high-value crops, generate higher income and produce employment opportunities at a higher implicit wage rate (World Bank 2006). The poor populations who are affected by irrigation development include the irrigated producers themselves, poor rural laborers, poor net feed purchasers in rural areas, and the urban poor (Lipton et al. 2005). Besides immediate economic benefits, irrigation development also has long-term effects on the poor population through a multiplier effect that will drive an increase in nonfarm rural output and employment as the level of rural spending rises (Word Bank 2006).

However, in Molden's studies, he pointed out that while "agriculture water management and development play an important part in poverty reduction, they cannot banish poverty alone. Also needed are complementary investments in education, health, rural infrastructure, capacity building, and supportive institutions, together with pro-poor, pro-gender research on low-cost and gender-suited technologies, crop research advances, and improved agronomic and water management practices and related dimensions of social exclusion, equity, and empowerment."

Impacts of Irrigation on Economic Inequality

As a major part of technological transformation in agriculture, irrigation saved millions from starvation in human history. However, many studies today criticize that irrigation may have some side effects in society besides the well-established environmental problems (Oosterbaan 1988). One of the most critical social issues is inequality, since the benefits of irrigation projects are not shared equitably. Such debate focused on tow distributional issues: the first is the disparity of benefits for farmers within the command area and those outside of it; the second is the distribution of water access for farmers within the command area (Ascher and Healy 1990). It is not realistic to expect that irrigation projects are able to bring precisely the same amount of water or product benefits to all farmers, so even some mechanisms and policies are designed to help to reduce inequality, some degrees of inequality still remain.

Irrigation generally increases agricultural productivity, which often brings more abundant, less expensive food. So at least some of the poor population live within or close to the command area will be better off since they are able to afford more food or other goods and services related to the agricultural production. According to Engel's law, the poor usually spend a higher proportion of their dispensable income on food than the rich, hence poor people gain more benefits from irrigation development. However, development of irrigation projects may increase the competitiveness of some farmers while reduce that of others, so the small farmers who are unable to compete with large commercial farmers may be forced to leave the scene.

On the other hand, structure of asset ownership in rural areas has impacts on agricultural water management too (Cuffaro 2001). A very unequal distribution in land ownership, for instance, may influence the collective action in irrigation. Inequality in land ownership implies: large landowners who will gain a large share of irrigation benefits have a strong incentive to contribute to collective action; small farmers' incentive may be tiny, encouraging free-riding (Cuffaro 2001). In general, inequality reduces the probability of success action in irrigation (Bardhan 1993; Bardhan and Ghatak 1999). Moreover, construction of irrigation projects may increase access to water for upstream users at the expense of downstream users (Birdsall et al. 2001).

CHAPTER 3

METHODS

This chapter outlines the methods in this research. There are three main parts in this chapter, the first part consists of sample and data collection, the second section is the explanations of dependent and independent variables in my study, and the last part has to do with the analysis strategy in this study. Generally academic research on the impacts of irrigation falls into two categories, using either “time-series” or “cross-sectional” data. Time-series data deal with one particular area such as a city, county, state, over many year; cross-sectional data look across many different geographic areas within the same year. This study uses cross-county data to address the relationship between irrigation and poverty rate and income inequality.

Data and Unit of Analysis

As mentioned above, county is our aggregate unit of analysis. This study uses data from secondary sources including United States Department of Agriculture (USDA) and United States Geological Survey (USGS), focusing on 9 states including Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee, comprising 756 counties in the Southeast United States. We focus on the estimated irrigation data for the year 2000. The USDA National Agricultural Statistics Service (NASS) conduct the Census of Agriculture every five years. Here, we examine the 2002 and 1997 data which are reported in Table 10 of the 2002 Agricultural Census.

We focus on these 756 counties because they are relatively homogenous in size and encompass a distinct asroclimatic and cultural area of the United States. We use county-level data not use because they are most readily available, but also because counties provide comprehensive coverage, spanning both metropolitan and nonmetropolitan places (Lobao et al. 1999). Further, because counties are smaller than nation and state level units, they are less heterogeneous in general, and less likely to obscure the true association between irrigation and income inequality.

But care should be taken with using county-level data because it contains inherent pitfalls: the data in broader level of analysis may not be useful to make inferences to lower level of analysis (communities and households). In this study, we readily acknowledge that these data are not useful to make conclusions within specific communities or households; rather, the study presents a big picture on the effects of irrigation on inequality in the Southeastern United State which focuses on the term of "on average".

Dependent and Explanatory Variables

In this section, we describe the dependent and explanatory variables used in this study. I use the same explanatory variables to address their effects on the two dependent variables. The explanatory variables consist of two main independent variables: irrigation intensity and irrigation scale, which are drawn from two different datasets.

Dependent Variable: Poverty Rate and Income Inequality

The main focus of my study is to understand the potential impacts of irrigation development on rural poverty and income distribution in the southeast United States.

Consequently, my dependent variables consist of two aspects: poverty rate and income inequality at the cross-county level.

The poverty rate in the Southeast United States is a little higher than other parts of the United States. Approximately 12.7% of the total population was below the official poverty thresholds in the same year (Wikipedia 2007). Generally speaking, population under age 18 constitutes a group with higher poverty rate than other age groups. The average poverty rate of people under age 18 of these selected counties 24.0% with a standard deviation of 6.78%, while the poverty rate for children under age 18 nationwide in 2004 is only 17.8% (wikipedia 2007).

Every country or region has a national or regional income, which is divided among those individuals who actually earned a share of it. In a perfectly equal society, each percentage of the population earns exactly the same portion of the national or regional income. In an unequal society, some of its population earns more income than others. Commonly used methods to measure income inequality include: the Gini Coefficient, Theil-Bourguignon Index, Theil Entropy Index and Wolfson Index. Here we choose the Gini Coefficient as the measure of income inequality. Gini coefficient ranges from 0, which means no inequality, to 1, which represents perfect inequality. The advantages of using this indicator are several: First, it is a measure of inequality by means of a ratio analysis, rather than a variable unrepresentative of most of the population, such as per capita income or gross domestic product (Wikipedia 2007). Second, the Gini coefficient is more sensitive to the middle of distribution and performs well in tapping contemporary inequality (Allison 1978).

Income inequality has increased since 1960s (Dennis 2002), while income increased among all demographics (Bartles 2004), the upper-most earners saw substantially larger increases (Johnston 2005). It is estimated that income increased by 9% in 2005, with the mean for the top 1% increased by 14% and that for the bottom 90% dropping slightly by 0.6 (Johnston 2007). According to Gini coefficient data, income inequality in the United States, already among the highest in the post-industrial world (CIA 2007), has risen considerably between 1967 and 2005 among households and individuals (US Census Bureau 2006). The Gini index rose by 20.3% from 34.0 in 1967 to 40.9 in 2005 (US Census Bureau 2006).

Independent Variables: County-level Irrigation Data

To assess the impacts of irrigation on income distribution, we use various county-level measurements to delineate the variance in irrigation: number of farms under irrigation, acres of farmland under irrigation, and most important, the percentage of farmland that is irrigated. We use principle component factor analysis to identify dimensions of variability based on NASS farm data and USGS water use data.

The National Agricultural Statistics Service (NASS) provides the most complete count of U.S. farms and ranches and the people who operate them, and the Census of Agriculture is taken every five years. The irrigation datasets I use to address the social impacts of irrigation development on rural communities are prepared under the direction of the U.S. Department of Agriculture (USDA) and National Agricultural Statistics Service (NASS) (Joseph 2004). The irrigation data (NASS county-level data Table 10) collected detailed data for on-farm irrigation practices, and include farm numbers, farm sizes, acres irrigated by categories of land uses such as harvested cropland, pastureland etc., and acres irrigated and non-irrigated farmlands for each county in the United States.

The United States Geological Survey (USGS) is a scientific agency of the United States Government (Eliperin 2006) which focuses on the landscape of the United States and its natural resources. The use of water in the United States has been estimated by USGS at 5-year intervals since 1950 (Huston 2005). The data we use in this analysis mainly focus on water-use categories such as ground-water withdrawal and surface water withdrawal, public supply and self-supplied, and industrial and agricultural purpose related withdrawal. The information is provided using a county-based national model, although study chiefs in each State have the option of producing independent county estimates of water withdrawals for these categories (Huston 2005).

Control Variables

In order to effectively assess the impacts of irrigation, as an aspect of industrialized agriculture, on income inequality in counties, we control several sets of other variables including cross-county farm difference. It is widely accepted that race and education has significant effects on poverty and all types of inequality, hence here we introduce racial and educational structure variables as our control variables when test the relationship between irrigation and poverty.

Analysis Strategy

To address the social impacts of irrigation at county level, the basic model is a regression analysis between irrigation variables and poverty, and income inequality. However, because our data come from two different data sources, a preliminary descriptive analysis is necessary to acquire some basic understandings of the difference in irrigation variables between the two datasets, and main dependent variables. Then it follows a factor analysis to simplify and signify the analysis, and the factors are stored as new independent variables to do the regression analysis.

Simple Descriptive Analysis

To measure irrigation development in the nine states in our study, we use county-level data obtained from both NASS irrigation data and USGS water withdrawals. The 756 counties in Southeast United States formed a selected sample because they are relatively homogenous in size and encompass a distinct asroclimatic and cultural area of the United States. According to a preliminary descriptive analysis of the NASS irrigation data, of the 756 counties, 92 counties (12.2% of the sample size) have irrigated land less than 100 acres; approximately 50 percent of these counties have irrigated land less than 1000 acres; only 8 percent have irrigated land more than 50 thousand acres. The average size of irrigated land in these counties is 14.55 thousand, with a standard deviation of 43.76 thousand.

The results mentioned above are slightly inconsistent with 2000 USGS irrigation data, which we will explore in great detail in the following sections. According to this dataset, the average size of irrigated land of the 756 counties is 13.52 thousand, with a standard deviation of 40.36 thousand acres. This inconsistence may due to the irrigation difference of time periods (USGS irrigation data 2000, NASS irrigation data 2002), may also have to do with the instruments and measures the two national surveys used, and other observational and experimental errors.

Another critical variable that reflects the irrigation characteristics in the Southeast United States is irrigation related water withdraw. In 10.5% of the 756 counties, the amount of irrigation water withdraw is close to zero Mgal/d; 50 percent of the sample have irrigation water withdraw less than 1 Mgal/d; only 20 percent have irrigation water withdraw more than 10 Mal/d. The average amount of irrigation water withdraw is 21.73 Mgal/d, with a standard deviation of 83.14 Mgal/d.

It is widely accepted that appropriate irrigation can increase crop yield and thus household income, hence act effectively as poverty alleviation. Southeast United States have relatively less intensive irrigation than western United States (desert-irrigated agriculture), although we cannot draw a definite conclusion of the relationship between irrigation and poverty rate before adequate data collection and analysis, the poverty rate in the Southeast United States is a little higher than other parts of the United States. The mean poverty rate of the 756 counties is 17.07% in 2004, with a standard deviation of 4.95%, while approximately 12.7% of the total population was below the official poverty thresholds in the same year (Wikipedia 2007). Generally speaking, population under age 18 constitutes a group with higher poverty rate than other age groups. The average poverty rate of people under age 18 of these selected counties 24.0% with a standard deviation of 6.78%, while the poverty rate for children under age 18 nationwide in 2004 is only 17.8% (wikipedia 2007).

Factor Analysis

In order to provide a ‘complete’ measure of irrigation we introduced more than ten variables from both USGS and NASS irrigation data sets. However, perhaps the only flaw of this measure lies in its inclusiveness: too many variables increase the complexity of data deduction and analysis; further, the individual variables which cannot explain much of the variance in key independent variables may increase the risk of establishing a spurious relationship that we are interested. Hence, a factor analysis is necessary not only because it can make the analysis process more straightforward but also provide a better understanding of the correlation between irrigation and inequality.

According to Thurstone (1947), the purpose of factor analysis methods is to "identify the principle dimensions or categories" of the variables under study. More specifically, factor analysis is recognized as aiming to summarize interrelationships among variables in a concise manner as an aid in conceptualization (Gorsuch 1974). It is a statistical method used to explain variability among observed random variables in terms of fewer unobserved random variables called factors (Sheppard 1996). The advantages of using factor analysis is the reduction of number of variables, by combining two or more variables into a single factor, and the identification of groups of inter-related variables to see how they are related to each other (Tucker 1993).

Regression Model

Then it comes to the analysis of the correlation between irrigation and poverty rate. Regression analysis is a statistical tool to analyze the relationships between variables, and especially, to investigate whether there is a causal correlation between the variables of interest. Further, regression analysis provides a way to access the "statistical significance" of the estimated relationships, that is, the degree of confidence that the true relationship is close to the estimated relationship (Sykes 2001). Here we use these factor scores (they are saved as variables during the factor analysis process) instead of the original variables to do the regression analysis.

Since our main independent variables come from two different data sets, which are slightly inconsistent, in order not to confuse the correlations, we will use regression model to do the analysis separately. For each analysis, we have two models, the first one is called "simply regression analysis", which only includes the main independent variables and dependent variables (called Model One); the second analysis is a multivariate analysis, which include control variables that are well known for their effects on rural poverty and income inequality (Model Two). The equation for the second model is: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_p X_p + \varepsilon$ where β_0 stands for the intersect of the hypothesized line, X_1 means the main independent variable, ε means the error which is not dependent on the selected sample. Because the Model Two takes control variables into consideration, hence here the β_1 to β_6 are not zero (one main independent variable and five control variables that may have significant impacts on poverty rate). Then we perform a linear regression analysis to address our hypothesis about whether or not irrigation has statistically significant impacts on poverty rate in the selected 756 counties under study.

The reason why we introduce control variables is based on a painful fact for investigators: the dependent variables are usually affected by a variety of factors in addition to the ones we are interested. A multiple regression allows additional factors to enter the analysis, and to estimate the effects of each variable on the dependent variable under study. By introducing control variable in to regression analysis, we are able to reduce the errors may occur, and able to understand more accurately which variable is dominate in affecting the dependent variable, and whether irrigation has statistically significant impacts on poverty rate and income inequality.

However, introducing the control variables increase the risks of inducing "multicollinearity" in the population, that is, the introduced control variables may correlated with some of the independent variables to some extent (Wooldridge 2004), and makes the analysis of effects of the independent variables more difficult. By definition, if two or more independent variables have a high degree of correlation (either positive or negative), the issue of multicollinearity arises. To solve the problem, have to do regression diogoze to examine the multicollinearity among the independent variables before we finally decide which variables should be involved to do the regression model.

CHAPTER 4

RESULTS AND FINDINGS

In this chapter hypotheses are tested and results are discussed. First, descriptive analyses are used to provide a general understanding of all the variables of interest. Second, irrigation intensity and scale are summarized by factor loadings analysis, and the factor scores are saved as the main independent variables. Then multicollinearity among explanatory variables is examined by cross-tabulations of all the main independent variables and control variables. In the last section we perform two regression models to test our hypothesized relationships between irrigation and poverty rate and income inequality.

Descriptive Analysis

Table 1 provides a snapshot of not only the key dependent and independent variables, but also illustrates other variables that may have impacts on poverty rate and inequality and should be controlled. It is widely accepted that race and education has significant effects on poverty and all types of inequality, hence here we introduce racial and educational structure variables as our control variables when test the relationship between irrigation and poverty. From table 1, we can see that the average percentage of white population of the 756 counties is 0.72, with a standard deviation of 0.19. The average percent of persons with less than high school in 2000 is 28.96, with a standard deviation of 7.34. In order to understand poverty more clearly, we introduced a standard measure: median household income because it is not highly influenced by extreme incomes compared with mean household income. The average median household income is 34,113 dollars, with a standard deviation of 7,753 dollars.

Table 1. Descriptive Statistics for Irrigation Variables for 756 Southeast U.S. Counties, USGS 2000 and Census of Agriculture 2002 And 1997

Variable	Mean	Standard Deviation	Range
USGS Variables			
Irrigation, acres, sprinkler in thousands	4.85	10.55	78.45
Irrigation acres micro irrigation in thousands	1.05	6.65	80.56
Irrigation acres surface flood in thousands	8.65	36.71	404.22
Irrigation total acres in thousands	14.55	43.76	446.85
Irrigation groundwater withdraws in mgal/d	15.54	57.40	616.45
Irrigation surface fresh water withdraws in mgal/d	6.19	43.01	957.00
Irrigation total withdraws in mgal/d	21.73	83.14	1124.54
NASS Variables			
Farms number, 2002	58	118	1,680
Farms numbers 1997	56	124	1,587
Land in irrigated farms acres, 2002	32,335	66,015	506,470
Land in irrigated farms acres, 1997	32,718	69,598	546,803
Irrigated landacres, 2002	13,521	40,345	418,452
Irrigated land1997	13405.37	39,943	417,803
Control Variables			
percent of white population	0.72	0.19	0.86
percent of black population	0.25	0.19	0.86
Percent of persons with less than high school, 2000	28.96	7.34	39.10
Percent of persons with a college degree (at least a 4 year degree), 2000	14.07	6.78	46.10
Unemployment Rate 2000	4.81	1.50	11.30
Unemployment Rate 2004	6.16	1.85	11.10
Dependent Variables			
Median Family Income (2004)	34,113	7,753	60,010
Poverty Percent All Ages	17.07	4.95	30.7
Gini Cofficient	0.40	0.04	0.28

Factor Analysis

The results of principle component analysis of seven irrigation variables show that only one factor has an eigenvalue greater than 1, so only one factor is extracted from the analysis. Table 2 provides factor loadings for USGS irrigation and water withdrawal data of the selected counties in southeastern U.S. counties in 2000. Similarly, only one factor is extracted from the factor analysis of the NASS irrigation data, and Table 3 provides factor loadings for NASS irrigated farm acres, southeastern U.S. counties, 1997-2002.

Table 2. Factor Loadings for USGS Water Withdrawal Data, Southeastern U.S. Counties 2000

	Component
	1
Irrigation total acres in thousands	0.987
Irrigation total withdraws in mgal/d	0.976
Irrigation acres surface flood in thousands	0.956
Irrigation groundwater withdraws in mgal/d	0.897
Irrigation surface fresh water withdraws in mgal/d	0.690
Irrigation, acres, sprinkler in thousands	0.634
Eigenvalue	4.523
Explained variance	75.383
Extraction Method: Principal Component Analysis.	

a. 1 components extracted.

Table 3. Factor Loadings for NASS Irrigated Farm Acres, Southeastern U.S. Counties, 1997-2002

	Component
	1
Land in irrigated farms acres, 1997	0.985
Irrigated land acres, 2002	0.983
Irrigated land acres, 1997	0.981
Land in irrigated farms acres, 2002	0.973
Variance explained	96.137
Eignevalue	3.845
Extraction Method: Principal Component Analysis.	

a. 1 components extracted.

Test for Multicollinearity

Multicollinearity refers to a statistical phenomenon that two or more independent variables in a multiple regression model are highly correlated (Motulsky 2002). In this situation the coefficient estimates and significance tests for each independent variables involved may be underestimated (Dirk and Bart 2004). In general, if we want to predict the effects of various X variables on Y, multicollinearity is not a problem since the overall R^2 (or adjusted R^2) quantifies how well the model predicts the Y values (Motulsky 2002), however, in this paper our interest is to test the impacts of only one of the various X variables (irrigation factor scores saved in the data sets when we do factor analysis) on our dependent variables, we have to minimized the effects of multicollinearity.

SPSS has a Collinearity Diagnostics option that allows investigators to assess whether they have a problem with collinearity in the data. Using this option, we examine this issue among all our predictor variables for both USGS and NASS data sets.

Table 4 and 5 provide the collinearity diagnostics for the independent variables from both USGS and NASS irrigation data sets. A tolerance score ranges from 0 to 1. If it is close to 1, it means little multicollinearity, whereas a value close to 0 suggests that multicollinearity may be problem. VIF (Variance Inflation Factor) is the reciprocal of the tolerance. The larger VIF suggests a greater multicollinearity. When VIF is great than 10, the variables should be reconsidered.

Table 4. Collinearity Diagnostics for USGS Water Withdrawal Data, Southeastern U.S. Counties 2000

Coefficients

Model		Collinearity Statistics	
		Tolerance	VIF
1	(Constant)		
	USGS REGR factor score for analysis	1	1
2	(Constant)		
	USGS REGR factor score for analysis	0.72	1.40
	total population of county in thousands	0.67	1.50
	Farms number, 2002	0.05	19.76
	Farms numbers 1997	0.05	20.41
	Percent of white population	0.03	38.29
	Percent of black population	0.03	39.50
	Percent of persons less than high school, 2000	0.23	4.28
	Percent of persons college degree , 2000	0.31	3.19
	UR2000	0.34	2.98
	UR2004	0.37	2.72
	Median Family Income (2004)	0.33	3.04

a Dependent Variable: Poverty Percent All Ages

Table 5. Collinearity Diagnostics for NASS Irrigation Acres Data, Southeastern U.S. Counties 2000

Coefficients

		Collinearity Statistics	
Model		Tolerance	VIF
1	(Constant)		
	NASS REGR factor score for analysis	1	1
2	(Constant)		
	NASS REGR factor score for analysis	0.62	1.62
	total population of county in thousands	0.68	1.46
	Farms number, 2002	0.05	19.35
	Farms numbers 1997	0.05	20.42
	Percent of white population	0.03	33.91
	Ppercent of black population	0.03	34.85
	Percent of persons with less than high school, 2000	0.22	4.52
	Percent of persons with a college degree , 2000	0.30	3.29
	UR2000	0.34	2.93
	UR2004	0.38	2.60
	Median Family Income (2004)	0.33	3.05

a Dependent Variable: Poverty Percent All Ages

From the table 4 and 5 above, we can see that the VIF of four variables are great than 10, they are: farm number 2002, farm number 1997, percent of white population, and percent of black population. Variables farm number 2002 and farm number1997 is highly correlated, and they measures exact the same thing in our regression analysis, so we only retain farm number 2002 as one of our control variables. Similarly, percent of white population and percent of black population measure exactly the same thing, so we discard one of these two, and retain only percent of black population. Notice that percent of people with less than high school degree and percent of people with college degree are not highly correlated, so we should retain both for further analysis.

Regression Analysis

Then it comes to the analysis of the correlation between irrigation and poverty rate. Here we use these factor scores (they are saved as variables during the factor analysis process) instead of the original variables to do the regression analysis. We will do two separate regression models for both USGS and NASS irrigation data sets. For each analysis, we have two models; the first model has only one independent variable, while in the second one, a set of control variables is introduced. Then we perform a linear regression analysis to address our hypothesis about whether or not irrigation has statistically significant impacts on poverty rate in the selected 756 counties under study.

Table 6 provides the results using NASS irrigation acreage factor loadings as our main independent variable, while table 7 shows the findings using USGS irrigation water withdraw as our independent variable of interest. The reason why we perform two regression analyses respectively instead of mixing the two independent variables together as two main predictors to do the analysis is that the two datasets are somewhat inconsistent, and hence may distort our whole study.

Table 6. Regression Analysis of Poverty Rate on REGR Factor Score of Selected USGS Irrigation Variables 2000

Model		Unstandardized Coefficients		Standardized Coefficients	t
		B	Std. Error	Beta	
1	(Constant)	17.14	0.2		87.26
	REGR factor score USGS for analysis	1.12	0.3	0.14**	3.7
2	(Constant)	15.19	1.02		14.92
	REGR factor score USGS for analysis	0.17	0.12	0.02	1.44
	Total population of county in thousands	0	0	-0.01	-0.47
	Farms number, 2002	0	0	-0.03*	-1.93
	Percent of black population	8.66	0.45	0.33**	19.44
	Percent of persons less than high school	0.17	0.02	0.25**	9.45
	Percent of persons with a college degree	0.17	0.02	0.23**	9.98
	UR2000	0.72	0.07	0.22**	9.85
	UR2004	-0.04	0.06	-0.01	-0.61
	Median Family Income (2004)	0	0	-0.49**	-21.67
	R^2	0.80			
	F-ratio	589.80			

a Dependent Variable: Poverty Percent All Ages

Table 7. Regression Analysis of Poverty Rate on REGR Factor Score of Selected NASS Irrigation Variables 1997

Coefficients

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t
1	(Constant)	17.02	0.22		77.12
	REGR factor score NASS for analysis	1.53	0.29	0.22**	5.19
2	(Constant)	13.92	1.13		12.29
	REGR factor score NASS for analysis	0.14	0.12	0.02	1.18
	total population of county in thousands	0.00	0.00	-0.01	-0.64
	Farms number, 2002	0.00	0.00	-0.04**	-2.35
	percent of black population	8.87	0.51	0.32**	17.38
	Percent of persons with less than high school	0.19	0.02	0.27**	9.17
	Percent of persons with a college degree	0.18	0.02	0.25**	10.04
	UR2000	0.79	0.08	0.23	9.47
	UR2004	-0.02	0.06	-0.01	-0.29
	Median Family Income (2004)	0.00	0.00	-0.48**	-19.70
	R2	0.89			
	F-ratio	504.10			

a Dependent Variable: Poverty Percent All Ages

From table 6 above, we can see that without consideration of other factors that may have effects on poverty rate, irrigation intensity makes a statistically significant difference on the dependent variable, because the p-value is much smaller than the commonly used $\alpha=0.05$ level. When introduced the control variables including race structure, education and unemployment rate, our linear model is:

$Y = 15.19+0.02X_1-0.01X_2+0.33X_3+0.25X_5+0.23X_6+0.22X_7-0.01X_8-0.49X_9+ \varepsilon$ where X_1 to X_6 stand for all the predictors respectively.

Similarly, from table 7, we can see that USGS water withdraw factor loadings has a statistically significant impact on poverty rate too and when control variables are considered, the linear model is:

$$Y = 13.92+0.02X_1-0.01X_2+0.04X_3+0.32X_4+0.27X_5+0.25X_6+0.23X_7-0.01X_8-0.48X_9+\varepsilon$$

The two models provide a general understanding on how irrigation intensity and water withdraw may affect current poverty rate in a specific region, however, the most serious problem involved in the two linear models is that we find when considered the control variables, the correlation between irrigation and poverty rate is not statistically significant anymore (both p-values of the two models are much greater than 0.05).

Notice those irrigation factors scores seem to be positively related to poverty, however, the factor scores are actually negative. Hence, we can see that irrigation plays a desirable role on poverty alleviation from both USGS and NASS date sets. However, when control variables are introduced, the relationship is no longer significant. Hence irrigation is not a single factor that can predict rural poverty in agricultural counties in Southeast United States.

Impacts on Income Inequality

In addition to evaluation of the correlation between irrigation and poverty rate in the southeast US counties, we should further try to address the relationship between irrigation and income inequality. Commonly used methods to measure income inequality include: the Gini Coefficient, Theil-Bourguignon Index, Theil Entropy Index and Wolfson Index. Here we choose the Gini Coefficient as the measure of income inequality. The advantages of using this indicator are several: First, it is a measure of inequality by means of a ratio analysis, rather than a variable unrepresentative of most of the population, such as per capita income or gross domestic product (Cowell, 1999) Second, the Gini coefficient is more sensitive to the middle of distribution and performs well in tapping contemporary inequality (Allison 1978).

A low Gini coefficient indicates more equal income or wealth distribution, while a high Gini coefficient indicates more unequal distribution. 0 corresponds to perfect equality (everyone having exactly the same income) and 1 corresponds to perfect inequality (where one person has all the income, while everyone else has zero income). Figure 2 is a map of household income inequality in the United States in 2000. From the map we can see that the nine states under study are approximately the most unequal in income distribution in the United States.

In the following sections we will use a regression based approach to analyze the correlation between irrigation and Gini coefficient. In this approach, the estimated income flows contributed by characteristics, such as, area of irrigated land, level of education and age, are taken into consideration when we construct the linear regression model. However, since irrigation scale and intensity are more related to the on-farm income in rural areas than value-added off-farm income and incomes from other sources, we have to decompose the income inequality by sources of income in rural counties. We will decompose the Gini Coefficient for total household income as a weighted sum of the inequality levels of incomes from different sources, with the weights being functions of the importance of each component followed Qiuqiong Huang and his colleagues' study in rural China in 2005. "For example, if the income contributed by irrigated land accounts for a large share of total income and is itself highly unequally distributed, it is likely to increase the total income inequality. However, if income from a component is negatively correlated with total income (i.e., this component is more concentrated in the hands of poor farmers), then larger shares of that factor might help equalize total income" (Huang et al. 2005).

Figure 2. Household Income Inequality in the United States in 2000

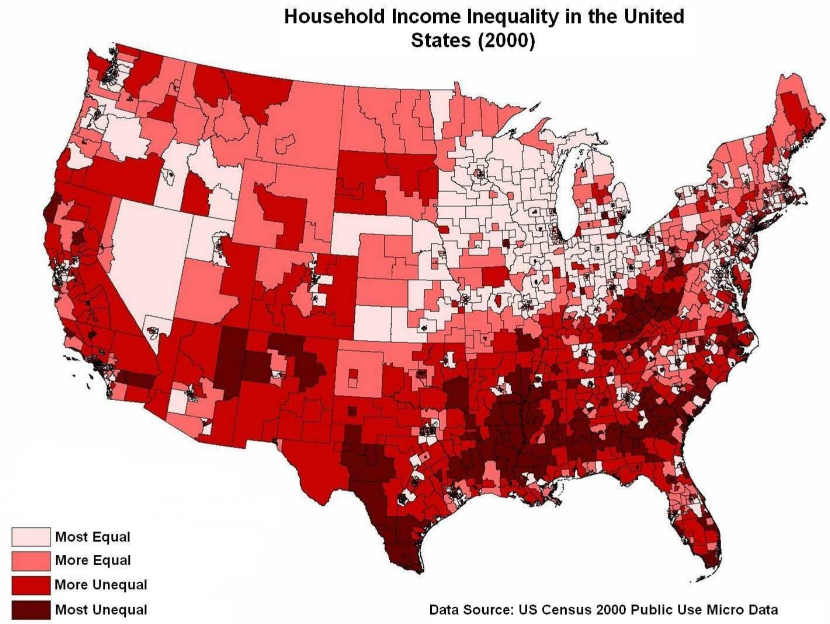


Table 8. Regression Analysis of Income Inequality on REGR Factor Score of Selected USGS Irrigation Variables 2000

	Unstandardized Coefficients		Standardized Coefficients	t
	B	Std. Error	Beta	
(Constant)	0.40	0.00		282.48
REGR factor score USGS for analysis	0.01	0.00	0.26**	6.85
(Constant)	0.37	0.01		25.76
REGR factor score USGS for analysis	0.01	0.00	0.12**	4.18
total population of county in thousands	0.00	0.00	0.03**	1.08
Farms number, 2002	0.00	0.00	0.00	-0.09
percent of black population	0.06	0.01	0.32	10.16
Percent of persons less than high school	0.00	0.00	0.26**	5.29
Percent of persons a college degree	0.00	0.00	0.41**	9.56
Unemployment Rate 2000	0.01	0.00	0.29**	6.85
Unemployment Rate 2004	0.00	0.00	-0.18**	-4.46
Median Family Income (2004)	0.00	0.00	-0.39**	-9.09
R2	0.60			
F-ratio	112.87			

Dependent Variable: gini coefficients

Table 9. Regression Analysis of Income Inequality on REGR Factor Score of Selected NASS Irrigation Variables 2000

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t
		B	Std. Error	Beta	
1	(Constant)	0.40	0.00		254.89
	REGR factor score NASS for analysis	0.02	0.00	0.31**	7.50
2	(Constant)	0.36	0.02		22.84
	REGR factor score NASS for analysis	0.01	0.00	0.11**	3.33
	total population of county in thousands	0.00	0.00	0.06*	1.88
	Farms number, 2002	0.00	0.00	-0.02	-0.50
	percent of black population	0.06	0.01	0.32**	9.09
	Percent of persons with less than high school	0.00	0.00	0.27**	4.88
	Percent of persons with a college degree	0.00	0.00	0.41**	8.44
	UR2000	0.01	0.00	0.33**	7.27
	UR2004	0.00	0.00	-0.20**	-4.58
	Median Family Income (2004)	0.00	0.00	-0.37**	-7.90
	R2	0.62			
	F-ratio	97.64			

a Dependent Variable: real gini coefficients

From table 8 and table 9 above, we can see irrigation actually reduced gini coefficient (factor scores are negative, so irrigation and income inequality are negatively correlated). The relationship is statistically significant at 0.01 level, but not very strong for both variables from two different data sets. It is still significant when a set of control variables are involved. Gini coefficient is a single statistic to measure how equal income is distributed to households (or individuals) within a specific area. Our cross-county data suggests that intensive use of irrigation is able to reduce income inequality in rural counties to some extend, which is contradictory to our hypothesis.

CHAPTER 5

CONCLUSION

This study is contribution to the larger project of Mitigating Local and Regional Agricultural Droughts by Increased Irrigation using Cool Season Run-off in Alabama that includes evaluation of available water resources, land suitable for irrigation, environmental issues related with increased irrigation, technical feasibility, potential economic benefits and risks, social impacts, funding, and farm policy changes. This part of the project focuses on the potential social impacts of increased irrigation intensity and scale.

We seek to understand the consequence of irrigation adoption for rural communities and farming in general. This chapter will tie together the information from all data sets to understand the key relationships in our study and discuss further research possibilities.

Major Findings

The purpose of the first part in our study is to provide a basic understanding about irrigation and rural poverty status quo. A descriptive analysis summarizes the average, standard error and range statistics of all variables of interest. Irrigation is less developed in our study area than in western states, but with higher poverty rates and income inequality than the average State's level. Further, in order to understand the relationships underlying the statistics, we use a factor analysis method to simplify the analysis. Factor scores and saved as a variable in the data sets during the process for further analysis. Factor scores can be both positive and negative. A negative score does not mean that the variable has a negative value; rather, the negative values result from the fact that factor loadings can be negative (Burgard andKuznicki 1990). Saved factor scores then are used as our main independent variables to study the relationships between irrigation and poverty, and income inequality. Collinearity diagnostic is performed before regression analysis to minimize the inflation of the variances of parameter estimates. Multicollinearity may result in lack of statistical significance of individual independent variables and may also result in incorrect regression coefficient estimates, and consequently in incorrect conclusions about relationships between predictors and dependent variables (Snee and Marquardt 1984). In our analysis, we removed some variables that measure exactly the same issue as other variables to reduce multicollinearity, and provide better understandings about the correlations of our interest. Finally, two regression models are used to study the relationships between irrigation and poverty rate, irrigation and income inequality for both data sets.

The findings in our study suggest that although irrigation plays a positive role on poverty alleviation, however, it is not the single factor to determine poverty status in a rural region. Rural poverty is jointly affected by a various factors other than irrigation and productivity, such as race structure, education, etc. However, irrigation plays a statistically significant, however moderate, role on income inequality.

Future Study

This research mainly focuses on cross-county data and SPSS programming. The primary purpose is to provide a general understanding about the relationship between irrigation development and poverty and income inequality, however, why and how they are related have not been fully accessed. Further study on these issues may shed light on how actual programs should be implemented. County level data are limited in that they are not able to provide full understandings about how smaller units are affected, such as groups, households or individuals, hence this study is unable to determine whether large-scale irrigation can meet all groups' needs or only the county as a whole.

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