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Electric Power for Rural Growth

How Electricity Affects Rural Life in Developing Countries

Douglas F. Barnes

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Electric Power for Rural Growth

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Westview Press / Boulder and London

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Rural Studies Series, Sponsored by the Rural Sociological Society

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Published in 1988 in the United States of America by Westview Press, Inc.; Frederick A. Praeger, Publisher; 5500 Central Avenue, Boulder, Colorado 80301

Library of Congress Cataloging-in-Publication Data
Barnes, Douglas F.
Electric power for rural growth: how electricity affects rural life in developing countries / by Douglas F. Barnes.
p. cm.—(Rural studies series)
ISBN 0-8133-7568-1
1. Rural electrification—Developing countries. 2. Rural electrification—Social aspects—Developing countries. 3. Developing countries—Rural conditions. I. Title. II. Series: Rural studies series of the Rural Sociological Society.
HD9688.D44B37 1988
333.79'32'091724—dc19 87-34544
CIP

Printed and bound in the United States of America

The paper used in this publication meets the requirements of the American National Standard for Permanence of Paper for Printed Library Materials Z39.48-1984.

6 5 4 3 2 1

This book is dedicated to the memory of

Frederick C. Fliegel

who recently passed away on an overseas assignment furthering international education and advancing our knowledge of international development. As an outstanding scholar at the top of his profession, he was self-assured but never self-righteous, he had strong opinions but was always open to new ideas. As a teacher he excelled as an adviser by giving thoughtful recommendations and gentle guidance rather than making self-serving demands, by being quick to praise and slow to criticize. With his students he was empathetic, pensive, insightful, wasted few words, and always available and willing to listen. He had an infectious laugh that made everyone who knew him feel relaxed and at ease. His good works live on through the unselfish help, goodwill and knowledge given to his countless students and colleagues, an influence that reaches all over the world.

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Preface

The belief that rural electrification is a catalyst for socioeconomic change in developing countries has come under fire during the last ten years. The research on which this book is based came about as a reaction to the public policy debate over rural electrification for development. In the context of the polemics for and against rural electrification at the time this work began, most analysts agreed that there was a great need to understand exactly how rural electrification affects the lives of those in rural areas. As a consequence, this study was designed to go beyond a review of the issues in the debate over rural electrification to include detailed empirical analyses of the socioeconomic impact of rural electrification. It was felt that adding new information to the public policy debate was more important than recapitulating the competing positions. The study was begun in 1980 with funding from the Office of Energy of the United States Agency for International Development (USAID) and was completed with assistance from Resources for the Future (RFF) and the World Bank. The views expressed in this book are those of the author and do not necessarily reflect those of the organizations that supported the study.

The manuscript contains many tables and statistics which have been compiled from empirical surveys. The research has been reported in such a manner, however, that even someone unfamiliar with advanced statistical techniques should be able to understand the analysis. Although the findings are presented in terms of general relationships identified in the study, the statistical analysis backing up the findings is more advanced than any of the past empirical work on rural electrification. Control variables such as income and education have been included in the analysis, which has usually not been done in earlier studies. Past research on rural electrification has been used by both the advocates and the critics of rural electrification. It is hoped that the findings from this study will add to the knowledge of the way electricity actually affects life in rural areas, and will therefore contribute to a dialogue based on a better understanding of the development process.

The project proved challenging because it cuts across the boundaries of several disciplines, including economics, sociology, and population research. It also encompasses a broad range of analyses of economic development, including social impact, equity, quality of life, migration, and benefit-cost analysis. In the process of writing this book, I have expanded my own knowledge from sociology into economics and other fields. There have been situations in which I was at the very limits of my knowledge of the disciplines involved in the analysis. As a consequence, I was not hesitant to seek advice from researchers at the World Bank and Resources for the Future who unselfishly contributed their valuable time to improve the final version of the manuscript.

I would like to thank Joy Dunkerley and Bill Ramsay for their continual support throughout the project and Lincoln Gordon for guidance early in the project. Without their efforts and support this work would never have been completed. Lalit Sen gave advice and support for all phases of the work. Joel Darmstadter, Henry Peskin, and Pierre Crosson provided comments on draft versions of various chapters in the manuscript. The original funding for the project was provided by USAID Cooperative Agreement AID/DSAN-CA-0179 (ARDEN Project), and I wish to thank Alan Jacobs and Pamela Baldwin in the Office of Energy for their support and coordination of the project. Bob Ichord also demonstrated a continuing interest throughout this project, and I thank him for his many suggestions both early and late in the project. Finally, the World Bank provided crucial support for the final phase of the project, and I wish to thank Karl Jechoutek and Jim Fish for their generous support, encouragement, and comments.

The comparative nature of the research was made possible by the reports from and on India, Colombia, and Indonesia prepared under the ARDEN Project. B. B. Samanta and A. K. Sundaram prepared an excellent report on "The Socioeconomic Impact of Rural Electrification in India." A benefit-cost report was ably completed in India by R. Venketesan along with S. K. Pachauri, K. Ravi Shankar, and S. Bassi. Eduardo Velez and Janice Brodman each contributed valuable reports on the socioeconomic impact of rural electrification in Colombia and Indonesia, respectively. Phil Costas, of the National Rural Electrification Cooperative Association, was generous with his valuable time throughout the project. Reeve Vanneman and Frederick Fliegel provided excellent comments

on an earlier draft version, and their insights have been extremely useful in my revisions. Fred Buttel, the editor of the Rural Studies Series, along with two anonymous reviewers provided excellent comments for preparing the final version of the manuscript.

I also wish to thank Linda Walker for her time and effort in helping edit and organize all facets of the work on the research project and the book. The final editing was ably done by Lucy Cunnings. Angela Blake typed most of the first draft of the book. My thanks also go to Mike Coda, who provided excellent research assistance for the project. Mike Coda and John Jankowski also offered editorial suggestions. I also appreciate the help of Caroline Bouhdili and Marshall Klaus, who were extremely thorough in checking every reference and every number in the book. Finally, I wish to thank my wife, Mary Ann, for support and encouragement without which the project could not have been completed.

Douglas F. Barnes

1
Introduction

Whether rural electrification is an appropriate strategy or even a catalyst for rural growth has been a matter of public policy debate for the last ten years. The debate between the advocates and the critics of rural electrification centers on the best means to achieve socioeconomic development. There is no question that electricity is a future necessity for rural areas in developing countries. The debate centers on whether it is too soon to introduce electricity to rural areas in many countries, whether programs should have a residential or a productive emphasis, and whether electricity introduces great inequalities into rural areas, since typically it first goes to the most wealthy households.

Some fundamental issues being debated involve disagreements over the actual socioeconomic consequences of rural electrification and whether the high capital investments in electricity distribution are justified. It might be imagined that many of the differences of opinion could easily be resolved; simply quantify the benefits, assign monetary value to them, and weigh these against the cost. Unfortunately, resolution of the outstanding issues in the debate is not so simple. Many of the socioeconomic consequences of rural electrification are hard to quantify, especially in monetary terms. For example, higher quality of lighting or changes in quality of life are benefits that are hard to measure. Also, assessing the costs of rural electrification is complicated by electricity growth rates, load factors, and many other considerations which vary from country to country.

The purposes of this book are to delineate the issues in the public policy debate, to advance empirical knowledge about the major issues, and to reach conclusions on the efficacy of rural electrification for development. It was recognized very early in the research that rural electrification

varies substantially between countries. As a result, the research is comparative in order to avoid the pitfalls of assuming that country-specific characteristics are general consequences of rural electrification. Rural electrification evaluations were completed in three countries: India, Indonesia, and Colombia. These countries have different histories of rural electrification, and distinct industrial structures. For example, the focus of the rural electrification program in India has been on agricultural productivity, while in Colombia and Indonesia the emphasis has been on rural households. Although the most comprehensive data from the empirical studies are from India, the country comparisons provide very interesting contrasts on the impact of public policy on the outcome of rural electrification programs.

Rural electrification projects affect regions, communities, and households. A unique feature of this research is the use of three units of analysis: rural industries, communities, and households. This allows the research to examine macro-level changes. Most previous studies have focused exclusively on households, which can be inappropriate for examining changes in literacy, migration, or interregional equity. The expansion of empirical knowledge concerning the impact of rural electrification on macrochanges in the structure of rural villages is one of the important contributions of this research.

An examination of all the policy issues surrounding rural energy and rural electrification is beyond the scope of this book. Nevertheless, the question of rural electrification and its impact on long-term socioeconomic development, equity, and rural quality of life are thoroughly analyzed, as are the actual costs and subsidies involved in rural electrification. The next section describes the questions that were deemed the most important in the rural electrification debate. The following section briefly describes the regions in which the three surveys were conducted. The final section in this chapter details the organization of the book.

RESEARCH OBJECTIVES

What Is Rural Electrification?

Defining rural electrification would appear to be an easy task. Obviously there is rural electrification when rural households or communities have electricity for use in houses, in businesses, and on farms. However, electricity may be distributed to only one house, to a community, or to a region. If four households from a community of thirty households have electricity, does this mean that the community has rural electrification? Is a village classified as having electricity if it has service at night, but not during the day, as is very common for communities with isolated diesel generation electrical service? And electricity can be generated from different sources. A large central grid may use coal, oil, or hydropower, but electricity can also be generated from small decentralized sources such as mini- and micro-hydropower plants, diesel plants, biogas generation units, photovoltaic cells, and wind.

Most rural electrification programs in developing countries involve some form of connection with a central grid. For densely populated countries with emerging grid networks, this may be the best way to plan rural electrification schemes. However, there are some important exceptions. In China it is estimated that micro-hydro supplies a large portion of the electricity for rural areas, although these electricity sources are increasingly being connected to the central grid. In some of the South Pacific islands, local generation of electricity is about the only form of electrification, since the islands are so spread out that any grid-based system would be virtually impossible. The issues of electricity generation and the most efficient means of distribution are extremely important for determining electricity cost, a subject addressed in chapter 7.

For assessing the impact of rural electrification, the generation source does not really matter unless cost or technical considerations place constraints on the extent of service and the time that electricity can be consumed. The benefits of household lighting undoubtedly will be the same no matter whether the electricity is generated at a coal-fired plant a

hundred kilometers from a house or from a photovoltaic cell placed on the rooftop. However, the extent to which electricity is used in a community is extremely important for evaluating its impact, and this may be limited by the technology used to produce electricity. A village in which four households have had electricity for one year would be different from a similar sized village in which fifty households have had electricity for ten years. Although electricity is basically the same no matter what the generation source, its present and future development can be affected by limitations on service.

In this book, rural electrification is defined as the availability of electricity for use in rural communities, regardless of the form of generation. The impact of rural electrification can vary according to the number of years that a community or household has had electricity, the extent to which electricity has been adopted in the community for various activities, and the quality and extent of the electric service (see chapter 7). The source of generation does involve issues of cost and quality of service, but given the same extent and quality of service, the source of generation has very few consequences for the impact of electricity on people in rural areas. Rural electrification for most of the communities and households surveyed for this book means the extension of the central grid to rural areas. Nevertheless, similar impacts could be achieved if similar levels of electricity were generated from isolated, decentralized sources.

Research Questions

A general set of questions and objectives were formulated at the inception of the research to guide and coordinate the empirical investigations. These research objectives were developed after a thorough review of the literature (see Cecelski, 1982) and after extensive interviews with donor agencies instrumental in funding rural electrification. The questions and issues in the following list are part of the original research objectives of the study. They also to some extent reflect the organization of the chapters in this book.

1. Does rural electrification generate additional productivity, higher income, greater employment, and struc-

tural change in rural areas? Does it contribute to greater regional equity and reduce excessive migration to urban areas?

2. How does rural electrification fit into a broader strategy of rural development? What complementary conditions or inputs make for success or failure? Can one rank the complementary conditions and inputs in order of importance and evaluate their relative importance to rural electrification itself?

3. What are the effects of rural electrification on "equity" in development-for example, in providing benefits to different income classes or in widening opportunities for small farmers, landless agricultural workers, and artisans? How does rural electrification affect the roles of women and children?

4. What are the benefit-cost ratios of rural electrification (a) in financial terms and (b) in social terms?

5. What are the most effective types of rural electrification policies and strategies to maximize the overall benefit-cost ratios (including priorities in selection of project areas, subsidies, and tariff structures)?

6. How does central grid electrical service for rural areas compare to decentralized forms of electricity/energy production, including biogas, wind, and other forms of energy?

7. How do different rural electrification policies affect the impact and implementation of rural electrification in various countries?

Needless to say, not all of these questions can be answered definitively. But most of the above questions have been explicitly analyzed, either through quantitative analysis or more qualitative methods. The unifying themes behind these research objectives are economic development, rural quality of life, and the costs of rural electrification. This book is organized according to these topics.

DESCRIPTION OF THE SAMPLE AREAS

The rural electrification study is based on surveys in India, Colombia, and Indonesia. Within these countries, communities and households were selected based on their level of development and the number of years with electricity. For both India and Colombia the states or regions in the sample are

quite diverse, while the sample for Indonesia is from one relatively homogeneous region. In India the four sample states are located in geographically as well as culturally distinct regions, and the same is true for Colombia. The regions selected in India range from the highly developed, groundwater-irrigated Punjab to the dry farming, pulse-growing plains of Maharashtra. In Colombia the mountain coffee-growing regions contrast sharply with the traditional, small farmer central areas. The following is a general description of the characteristics of the study regions. A detailed description of the research design for the countries is presented in the Appendix.

The sample areas in India are located in the four major regions of the country (see figure 1.1). Andhra Pradesh is a state in South India bordered on the east by the Bay of Bengal. Many parts of the state are heavily canal-irrigated and are very productive rice-growing regions. These regions produce two and in some cases three crops or harvests in the same year. The primary crops are grown during the monsoon season, but in some of the irrigated regions a second crop is grown on the moisture left after the first harvest. The drier regions in Andhra Pradesh, which grow coarse grains and pulses, are poor, contrasting with the rice areas, which are among the most productive in the country. Irrigation is a necessity for growing more than one crop per year.

Maharashtra is a neighboring state in West India, extending all the way to the Arabian Sea. Except along the coast, the state has somewhat less rainfall than Andhra Pradesh, but canal irrigation is not as well developed there, and most farmers rely on small pumpsets to irrigate. Pumpsets need either diesel engines or electric motors linked to an irrigation pump. As a consequence, crops are grown during the monsoon and again during the winter season when no rain falls. Maharashtra has a somewhat lower agricultural income per person than Andhra Pradesh.

The other states in the India survey, Punjab and West Bengal, both have very high agricultural yields. However, during the last 15 years agriculture has advanced tremendously in the Punjab, while it has stagnated in West Bengal. In fact, these two states sometimes are compared to draw lessons for agricultural development, with Punjab cited as the model to follow. Punjab is agriculturally the most advanced state in India and now exports both rice and wheat to other states. Land in Punjab is irrigated from private tubewells, and crops

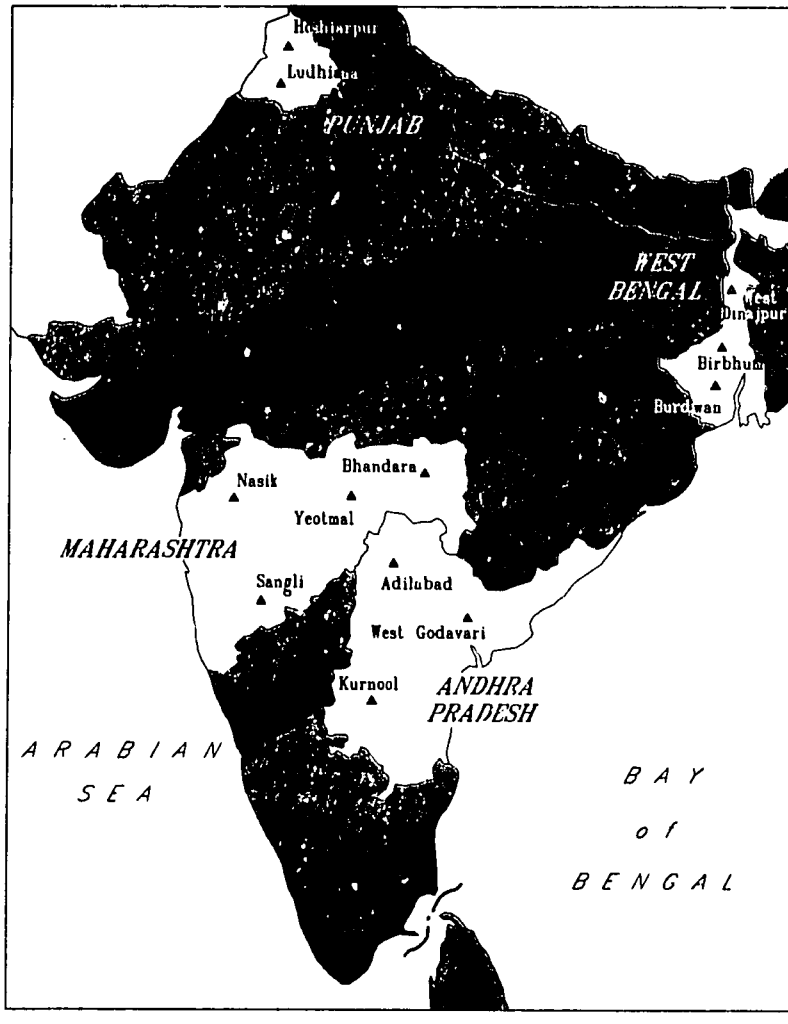


Figure 1.1 Location of Sample States and Districts in India.

are grown during two and sometimes three seasons. Although the major crop in Punjab is wheat, the production of winter rice has been expanding significantly. By contrast, although West Bengal is historically one of the most productive states in India, yields there have not kept pace with yields in the rest of the nation. West Bengal has very rich soil and high annual levels of rainfall but few private wells. Consequently, double cropping in the state is quite low. Paddy rice grown during the monsoon season is its staple crop. The high yields per acre in West Bengal are offset by its high population density; the agricultural income of 63 dollars per person compares unfavorably with 144 dollars for Punjab. Thus, the four states in the India survey are clearly quite diverse and represent regional differences in that country.

Three regions in Colombia were selected because of their regional diversity (see figure 1-2): the North Coast, typified by large cattle farms; the Central Region, with small traditional farms; and the coffee-growing area. The North Coast region is sparsely populated and has large and in many instances modern farms. However, the region has extremes in socioeconomic levels of living. The coffee-growing region, which has both large and and small plantations, is more densely populated. Since coffee is Colombia's main export crop and a major source of foreign exchange, the coffee region has the highest standard of living in the country. One unique feature of the region is that the National Federation of Coffee Growers has made significant investments in education, health, and other "basic needs" programs. Thus, the area ranks high for most social indicators. Although the Central Region contains the city of Bogota, the rural areas are very mountainous, with traditional agriculture dominated by small farms. Compared to the North Coast, there is a more even distribution of income in the coffee region, and the standard of living is comparable to the national average.

The Indonesian sample area is different from the India and Colombia samples. The district selected for the study was the Klaten district, which in 1977 became a pilot area for a rural electrification project (see figure 1.3). Klaten is a relatively advanced region with a very productive agricultural base. Its agriculture is dominated by rice produced on land endowed with year-round gravity-fed irrigation. Klaten is somewhat atypical of Indonesia because there is vigorous household enterprise sector, along with small-scale industries and

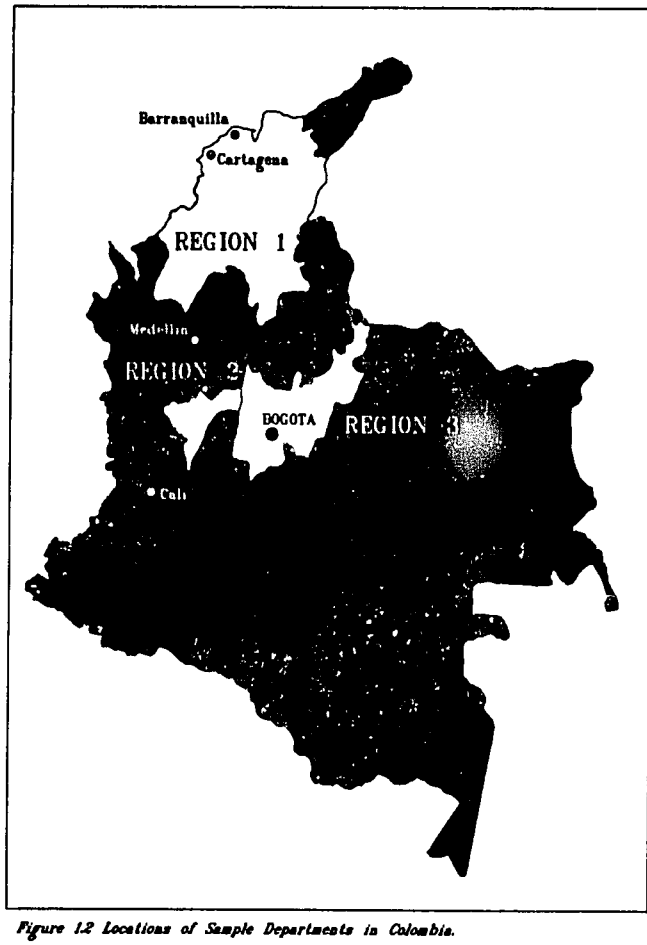


Figure 1.2 Locations of Sample Departments in Colombia.

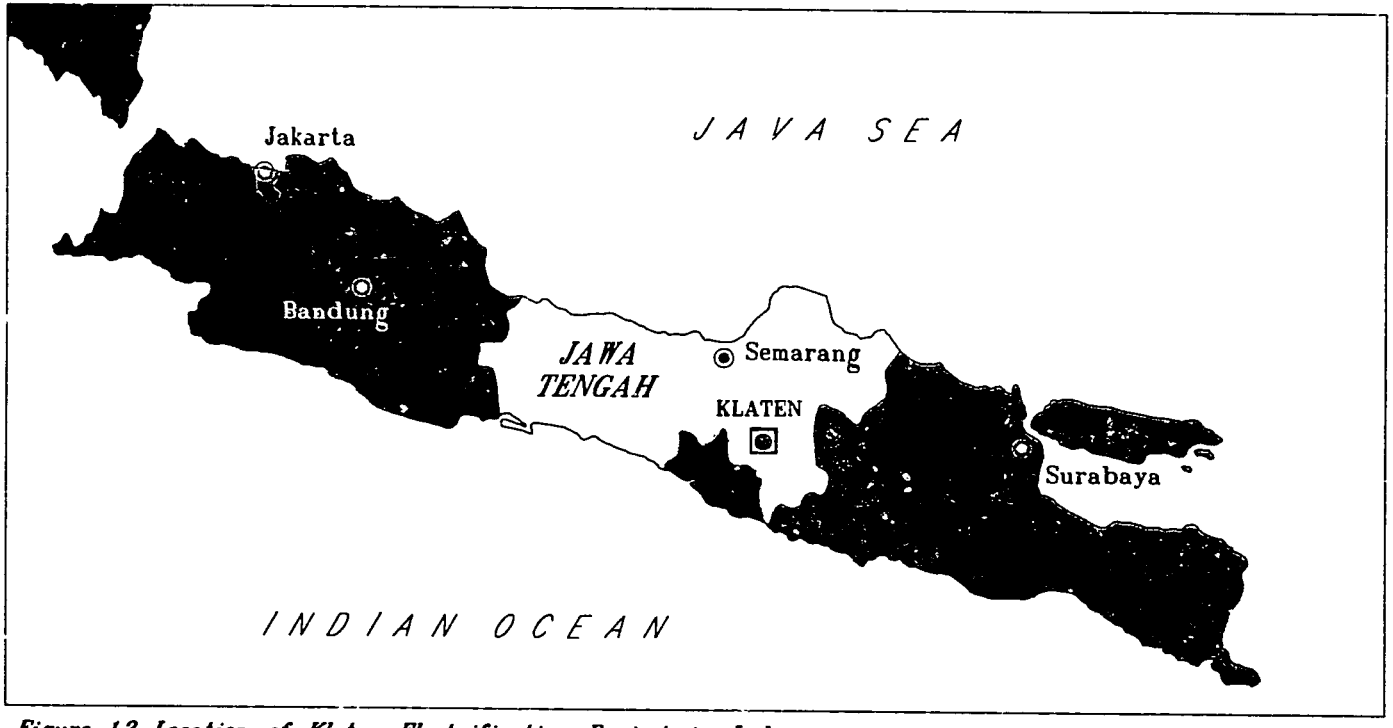


Figure 1.3 Location of Klaten Electrification Project in Indonesia.

businesses. The area of investigation is only 60 kilometers away from the district capital, which is a moderate-sized rural town serving as a marketing center for the surrounding agricultural community. Like the rest of the district, the villages in the study are in one of the most densely populated agricultural areas in the world. The eight villages in the study are both more wealthy and more industrial than the national average. Therefore the findings from the Indonesia study must be qualified by the highly developed nature of the region, along with the fact that the region only recently received electricity.

ORGANIZATION OF THE RESEARCH

The rural electrification public policy debate presents a dilemma for administrators. There is growing evidence that the beneficial impact of rural electrification in the United States may not be duplicated in developing countries, especially in those with low per capita income. However, there are still many unresolved questions. Which of the critics' charges are mere accusations? Should rural electrification projects be dropped completely, cut back, or altered to have greater socioeconomic impact? The issues in the public policy debate are presented in chapter 2.

The resolution of the controversy depends on an evaluation of the socioeconomic benefits along with the cost of rural electrification as examined in this research. The productive consequences of rural electrification must be evaluated over the long term. Many evaluation studies of rural electrification have been conducted only a few years after villages or communities have received electrical service, thus only measuring short-term consequences.

Even allowing for the social benefits accruing with rural electrification, it is clear that its productive use and the long-term consequences in many cases must provide a principal justification. The major contribution that rural electrification can make to rural economies may be the gains in productivity and income and the creation of jobs, both for agriculture and for industry. Even when only a minority of rural households connect to the electric grid, the projects may be worthwhile if the consequences include jobs and higher incomes for the rural

poor. While electrification of households might directly benefit only a village elite, there may be evidence that it also helps to expand irrigation, which ultimately stimulates employment as well as raises productivity. The research examines in what ways and in what context rural electrification has the greatest impact on rural productivity, incomes, and employment. Also discussed is whether the changes in rural productivity, if any, justify the high costs and large subsidies that are incurred by rural electrification.

Agriculture and Industry

In most developing societies, agriculture employs as much as 80 or 90 percent of the rural population. The primary benefit of rural electrification in agriculture is the expansion of irrigation capacity. Rural electrification may indirectly stimulate an increase in rural employment through the expansion of cultivated land, through double and triple cropping of land, and as a consequence of working the land already under cultivation more intensely. Most reports from areas which have participated in the so-called Green Revolution have reported subsequent increases in rural employment, at least in the initial stages. Electric-powered machines may even substitute for labor in bottleneck periods such as harvest time. Small-scale threshers might facilitate harvesting, so that new crops can be planted for the second growing season. On the other hand, the benefits attributed to rural electrification for irrigation may also be achieved by diesel engines. Chapter 3 examines the impact of rural electrification on agricultural development.

The impact of electrification on rural industries may be less pronounced than in the agricultural sector. In the past, agro-industries have relied on diesel engines or animate power, so the most noticeable consequence of rural electrification may be the substitution of electric motors for diesel engines. Many crafts and household industries currently do not need electricity directly in production, although electric lights might increase their productivity by allowing work to continue after dark. Most medium and major industries have already chosen to locate in cities, towns, or growth centers because of the availability of electricity, transportation, and communication

facilities An evaluation of agro-processing industries (flour mills, etc.) and other industrial growth is presented in chapter 4.

Social Effects

Rural electrification can have an impact both on the structure of rural communities and within rural households. Too often past studies have exclusively examined rural households, and only for direct impacts of rural electrification. However, rural-urban migration, population growth, education, and literacy are all structural characteristics of communities which can be affected by rural electrification. There has been little research on the relationship between rural electrification and migration. Public meeting places, warehousing, night schools, and street lighting are community services which might be initiated or improved with rural electrification. Although these are not direct productive consequences, they nevertheless may have considerable effect on community life and indirectly may have an impact on rural productivity. Likewise, rural electrification may have adverse effects on rural communities. The changes in rural communities brought about by rural electrification are examined in chapter 5.

At the household level electricity can change rural living and energy use patterns, but questions have been raised as to whether electricity benefits only the more wealthy households. For instance, rural electrification in households can provide clean, high quality light, since with the introduction of electricity households typically switch from kerosene to electricity for lighting. Often the purchase of other household appliances may follow the installation of lighting, thus altering the work and living patterns in rural households. But if electricity is only used in the high income households, then these benefits of rural electrification programs may go only to the most wealthy people in a community. The equity question is examined in chapter 6.

Benefits, Costs, and Rate Structure

Cultural factors and traditional practices are apparently not a major constraint for rural electrification. The major stumbling block to future growth is financial viability. The limited use of electricity in rural areas and thinly spread consumer demand mean that rural electrification typically must be subsidized by developing country governments. Political resistance is likely to develop against indefinite budgetary subsidies to electric utilities, and it is still not known whether rural electrification can be self-supporting in some countries, even in the distant future. One major problem, therefore, concerns the subsidy policies and the structure of tariffs to keep the industry viable. The organization, rate structure, and subsidization questions relate essentially to the electric industry but have broad ramifications for development strategy. These issues are examined in chapter 7.

The cost of alternative power generation schemes needs to be compared with the costs of central grid generation. Judith Tendler (1977, pp. 44-49) has made a strong case for diesel autogeneration systems for residential service. The advantage of local autogeneration is that the maintenance problems are manageable at the local level, the capital investment does not necessarily have to take place in a relatively short period of time, and the systems do not have to run for 24 hours, thus substantially reducing costs. However, even Tendler recognizes that in the long run autogeneration is more expensive than central grid electricity. Other potential decentralized sources of power generation include diesel engines adapted to run on biogas fuel, wind power, photovoltaics, minihydro, and some others. Comparisons of the costs of alternatives with the central grid are also reported for India in chapter 7 in order to evaluate the comparative cost advantage of central grid versus decentralized generation for providing electrical service.

CONCLUSION

The rural electrification debate is part of the changing

views on energy strategies for developing nations. The consequence of the debate has been that staunch advocates have reduced their claims that rural electrification is the key to development, but they continue to be committed to rural electrification as a necessary condition. The severest critics have shunned rural electrification as ineffective for development and have advocated an energy policy based on new and renewable technologies. In between these extreme positions is a wide range of opinions including emphasis on rural productivity, decentralized generation of electricity, and postponing rural electrification programs in nations with extremely low levels of Gross National Product.

Partly as a consequence of the paucity of rigorous empirical studies on rural electrification, arguments for and against it have been marked by a lack of consensus on key socioeconomic issues. Many complex and sometimes controversial questions surrounding rural electrification are addressed in this research. Some of the items of the debate involve ideological beliefs about the nature of development, and others are intertwined in the complex development process and are difficult to untangle. But even on topics for which obtaining information was difficult or data sources were less than ideal, judgments have been made from the most recent evidence. New insights have been gained from the India, Colombia, and Indonesia studies, and in many instances the comparisons among the different countries are as interesting as the findings from the individual countries. The issues in the public policy debate are reviewed in detail in the next chapter.

2
The Public Policy Controversy over Rural Electrification

The blind faith placed in rural electrification during the 1960s and early 1970s as being a key to energy development policy has been questioned in recent years. As recently as a decade ago, rural electrification was perceived almost as a magical force which would transform poor areas into highly productive regions. Advancing power lines into poor rural areas was synonymous with providing the necessary infrastructure for quickly bringing them into the twentieth century. Communication, lighting, productivity increases, reduction in birth rates, the elimination of traditional customs blocking modernization, and many other benefits would flow from a reliable supply of electricity to the rural areas. Electricity obviously plays an indispensable role in modern society and modern life; that a society could progress without a substantial commitment to rural electrification seemed almost incomprehensible to the early planners, as it does even today. Certainly electricity is a prerequisite for attaining the level of productivity and quality of life experienced in developed countries.

If this is true, then what is the controversy over rural electrification? Why are there questions regarding the priority rural electrification should have in development?

The early optimism has been clouded by more recent reports from a number of developing countries indicating that the anticipated development effect of rural electrification has been very slow in materializing and prospective customers in electrified villages and communities are not adopting electricity at the rate envisioned. When fewer people in rural communities take advantage of available electrical service, there is less chance that electrification programs can have an impact on rural productivity and quality of life. And since most rural electrification projects in developing countries are subsi-

dized, lagging demand for electricity may be a substantial financial strain on the utilities, whether public or private. Concerns also have been raised regarding the equity of rural electrification investments and subsidies. Since only the better-off villagers may be able to afford to adopt electrification, rural electrification may worsen the gap between the rich and the poor.

CONTEXT OF THE RURAL ELECTRIFICATION DEBATE

Energy policy for developing nations before 1974 basically was rural electrification policy. The U.S. Agency for International Development (USAID) was the first donor agency with major involvement in rural electrification. Before the early 1970s interest in rural electrification for developing nations had been stimulated by the tremendously successful programs in the United States. In the United States the creation of the Rural Electrification Administration (REA) in the mid-1930s had led to a tremendous growth of rural electrification, a burst of new rural productivity, and a dramatic improvement in the quality of rural life. For the most part, rural electrification was administered through a separate government agency providing subsidized loans to rural cooperatives. These cooperatives constructed the distribution system and administered the consumer billing and collection activities, but very few cooperatives were involved in the actual generation of electricity. The cooperatives generally were consumer-oriented companies with the political ideal that electrical energy should be available to consumers at reasonable and subsidized rates.

The rural electric cooperatives and the commercial power companies in many cases were in conflict with one another. In the early literature published by the REA, there are many accounts of the public power companies "skimming the cream." That is, the commercial companies would attempt to connect the most densely populated rural communities, leaving the expensive scattered consumers to the cooperatives. The advantage of establishing rural electric cooperatives was that they were very consumer oriented, so they promoted not only the connection of rural consumers, but all of the appli-

ances that were available in the urban areas as well. The cooperatives had an institutional interest in connecting all rural consumers rather than just those most profitable to them.

Through the cooperatives, the REA was very successful in extending electricity to rural areas, but many problems encountered by the rural electrification programs have now been forgotten. For instance, Frederick Muller in 1944 assessed the state of rural electrification in the United States as follows:

> Generally speaking, three factors influence the rural use of energy. There is little of the high industrial load and none of the dense residential load which have made utility operation profitable in urban areas. Second, farmers and other rural residents are new, naturally conservative consumers. The purchase of electric energy becomes for most of them a considered alternative to other possible uses of their income. Rural consumers generally are still in the stage of exploring the economy and convenience of electric light and power, and they still hesitate to use these facilities in large quantities. Rural communities have not come to the realization of the advantages of electrification with respect to local industries. The third factor is the economic status of most rural residents. They have not found it easy to pay for wiring, equipment, or energy. In 1935, . . . 42.1 percent of the country's farms were operated by tenants; 34.5 percent were mortgaged, rendering it somewhat difficult for operators to make extensive improvements. Finally, of course, a fairly high percentage of farms are submarginal and not profitable even if electrified. These factors have worked together to keep rural loads and consumption per consumer low. (Text has been slightly reworded).

These same issues have been raised concerning rural electrification in developing countries today. Farmers in most developing countries do not have even the income or purchasing power of farmers in the United States in the 1930s and 1940s, yet the expectation for developing countries has in many instances been framed on the experience of the United States. The early projects in countries such as Colombia, Ecuador, and the Philippines were expected to promote development like that which had occurred in the United States in the 1940s and 1950s. However, these early expectations were not realized.

Also, the oil crisis in 1974, followed by sharp increases in the price of commercial energy, led to an increase in energy research and a movement to examine alternative forms of energy. The unrealistic expectations for rural electrification along with increased emphasis on alternative forms of energy led to a debate over rural electrification policy.

The reports on rural electrification generally can be classified into three time periods. In the early 1970s there were several reports favorable to rural electrification, reporting optimistic assessments of the socioeconomic impacts. In the middle 1970s there was a stream of reports that criticized the then current rural electrification policy. As mentioned above, these reports were in response to the growing concern over energy and dissatisfaction with rural electrification as the major energy policy for developing nations. As a consequence of the criticism, in the early 1980s there have been a series of new examinations of rural electrification to determine the actual benefits for developing nations (see Smith et al., 1983; USAID, 1981; Inter-American Development Bank, 1979).

Early Favorable Studies

The early studies of rural electrification supported it as having favorable consequences for socioeconomic development (Ross, 1972; Madigan et al., 1976). A study in Colombia (Ross, 1972) indicated that rural electrification could act as a catalyst in the development process. The study found that household consumption of electricity is related to high household income and educational levels, it improves product quality in service industries, and it enhances the feeling of security in rural communities. For economic development, electricity was found to be important for crop production and food processing industries, and it apparently did not substitute for existing labor. The study from the Philippines (Madigan et al., 1976) was equally positive. For the most part, its findings were very similar to those of the Colombia study; electricity use was found to be associated with higher incomes and education. In general, these early Colombia and Philippine studies are glowing accounts of the benefits of rural electrification.

Despite the positive findings of the early studies, ques-

tions could be raised concerning whether the associations were a cause or an effect of rural electrification. Higher income households will have higher levels of education, and they also have the purchasing power to adopt electricity. Consequently, it is difficult to determine whether rural electrification or income was the main reason for the significant associations. As a consequence of the early studies' methodological drawbacks on the issue of causality, rural electrification was wide open to charges by critics who advocated a change in rural energy policy.

Debate and Evaluation within Donor Agencies

At about the same time as energy in general was coming under closer scrutiny because of the necessity to make adjustments in light of rising oil prices, criticism of rural electrification for development became a serious public policy issue, and the pendulum began to swing away from rural electrification. The shift began in earnest with two reports critical of rural electrification. In 1977, Development Alternatives completed a critical report on program performance of the National Rural Electrification Cooperative Association (NRECA), a trade association group which had planned and implemented many rural electrification projects for USAID. Robert Nathan Associates in 1979 completed a report indicating that the documentation of USAID rural electrification projects was not of sufficient quality to determine whether rural electrification had achieved its anticipated social impacts. McCawley (1979) reviewed the evidence for and against a rural electrification program in Indonesia and concluded that electrification was a "doubtful priority" for rural development and there would be very little chance that the goals of rural electrification projects could be attained. Similarly, Judith Tendler (1979) recommended that the rural electrification policy of emphasizing the extension of electricity to rural households should be altered to include a greater focus on rural productivity. Finally, Douglas Smith (1980) adopted the position that rural electrification programs basically were uneconomical and unproductive, and alternative energy programs should be adopted instead of rural electrification.

In the space of almost ten years, the pendulum swung from an almost unquestioning acceptance of rural electrification as a necessary development input to a questioning of whether it has any worthwhile socioeconomic impact. But now, because of the recent decline in the price of oil, investments in alternative energy technologies are coming into question, which may once again result in a shift toward rural electrification policy. In the next sections, the views for and against rural electrification are reviewed.

THE ADVOCATES: RURAL ELECTRIFICATION AS A POWERFUL AGENT OF CHANGE

As noted, the early justifications of rural electrification were viewed almost as self-evident truths. Rural electrification was thought to be a necessary condition for future development. At least among the agencies promoting rural electrification, a firm belief prevailed that development could not proceed without electrification. Before the recent controversy, in a 1974 report to the World Bank, Gilbert Moon (1974, p. 138) of NRECA stated the case for rural electrification thus:

> Once areas have been selected, it appears . . . that the need for pilot [rural electrification] projects as a basis for experimentation and evaluation is not in keeping with twentieth century expertise. Surely enough is known about the effects of electrification for it to stand on its own merits. Comparative analyses of electrified areas vs. nonelectrified areas may be a boon for statistical researchers, but in the viewpoint of those of us who have spent thirty years in the development of rural electrification, it is a tremendous waste of human resources. Select an area and electrify it on the basis that, if nothing else, it may provide an improved social climate. If the older rural residents make no productive use of electricity, then place your faith in the next generation or the next.

However, one should not be too critical of a statement made before the more recent controversy over rural electrification as a priority for development.[1] The past five years have witnessed a growing awareness of the need for evaluations by all

those involved in the controversy, not only to determine the efficacy of rural electrification, but also to determine when, where, and with what complementary conditions rural electrification has the most impact. In this section the position of advocates of rural electrification is presented.

Electricity as a More Efficient and Less Expensive Energy Form

Efficiency and cost effectiveness are the two most commonly cited justifications for rural electrification. Rural households can benefit from electricity through better quality lighting and labor-saving small appliances, all at very reasonable costs. Small-scale agro-industries can improve productivity through the use of efficient driveshaft power for grain mills and other machines. In agriculture, irrigation using electric pumpsets can expand food production by enabling farmers to increase yields and to have two and even three crops per year.

Because of economies of scale, central grid power might well be cheaper than available alternatives. In a project appraisal document, NRECA (1976, pp. 33-34) calculated that for equivalent household lighting, kerosene for lanterns would cost about twice as much per month as electric lights. The quality of electric light would also be superior to the equivalent light from a kerosene lantern. Household labor-saving devices such as electric irons, along with items such as electric fans, would substantially improve the quality of rural life in ways that are very hard to measure in quantitative terms. Nevertheless, the cost competitiveness of electricity versus the alternatives would depend on a host of regional characteristics, including length of electricity lines and cost of operation.

Advocates point out that in the households that can afford appliances women and children are the main beneficiaries of rural electrification. Although cooking with electricity is well beyond the means of many rural people, income-producing activities such as handicrafts can be continued well after dark in households with electricity, as can recreational activities (like reading and playing games) that require a high quality of light. Several studies have found that villagers have a greater feeling of safety when there is public lighting in the small towns and villages (Operations Research Group, 1977, p.

62; National Electrification Administration, 1978, p. 27). According to advocates, comparisons between the light that is provided by electricity and that from kerosene favor electricity both on the basis of cost and on that of quality of light.

Electrification's advocates claim that irrigation using electric pumpsets is both more efficient and usually less expensive per unit of water output than irrigation by means of Persian wheels or other traditional systems such as hauling leather water-filled bags from a well by driving a team of bullocks. Also, since the timing of irrigation is extremely important, wind power has the drawback that it may not be sufficient to provide the water at the right time. Diesel engines come very close to the efficiency and - depending on oil prices - cost effectiveness of electricity, but they are less suitable than the electric submersible pumps for deep wells. In addition, diesel fuel is often a foreign exchange drain for many developing countries.

According to the advocates of electrification, electricity as a source of driveshaft power and lighting for rural industries is ideal for small rural industries in developing countries. Agricultural processing industries-the main industry in the rural areas of most developing countries - can utilize electricity to grind food grains, press oil seeds, and perform a variety of other tasks. Beyond food processing, available electrical service may lead to a variety of new industries, including small machine shops for repairing implements and cottage industries using electric powered tools. As in irrigation pumping, diesel engines are an alternative to electric motors, but they require more maintenance, often are more expensive to operate, and may involve foreign exchange problems for purchasing diesel fuel.

Rural electrification advocates stress that once a region is provided with electrical service, the number and diversity of rural industries will expand and the quality of products from existing industries will be improved. Rural electrification is perceived as a necessary condition for future diversified economic growth. While the effects may not be felt immediately, they say, over the long run the availability of reliable electrical service will lead to a growth of rural industries.

The Urban Bias in Development

Rural electrification is proposed by its advocates as a means of balancing development investments between urban and rural areas. As of 1971, while about 70 percent of the population in developing countries was rural, only 12 percent of that rural population had access to electricity (see table 2.1), compared to over 80 percent for urban populations. For 1971, the World Bank (1975, p. 17) estimated that only about 10 percent of the cumulative investment in the power sector was for rural electrification. Electrification's advocates point out that this bias is compounded by the fact that food pricing policies in many developing countries hold down the cost of food for urban populations. Thus, the rural areas in many instances, subsidize urban regions by providing less expensive food. In addition, a large percentage of development programs are capital-intensive projects in urban areas. For instance, although lending for rural development has been increasing substantially at the World Bank, only 20 percent of total loans for the 1968-1974 period were for agriculture or rural development (World Bank, 1975, pp. 86-87). Its advocates see rural electrification as a convenient way to redress some of the urban-rural inequities in development programs. Since it costs less to provide service to high density urban regions than to the sparsely populated rural areas, the revenues from the more profitable urban electrification typically subsidize rural electrification in developing countries.

On the question of equity, advocates assert that rural electrification can directly and indirectly benefit the rural poor in addition to redressing regional inequities. The direct impact would include improvements in the quality of life for the rural poor who adopt electrical service. Although the rural poor are not as likely to connect to the central grid, most analysts have been surprised at the extent to which low-income families will sacrifice a substantial percentage of their earnings to obtain the benefits of electrification. A recent survey by the U.S. Bureau of the Census (1980, p. 18) reports that 15 percent of the poorest rural households in the Philippines have electricity - a surprising number, given their low level of income available for basic needs.

Table 2.1 Extent of Rural Electrification by Region, 1971

Region	Total population, 1971[a] (millions)	Rural population, 1971 (millions)	Percent of total population urban, 1971[b] (percent)	Population of rural areas served by electricity, 1971[b,c] (millions)	Percent of persons in rural areas with access to electricity, 1971[b,c] (percent)
Latin America	282	140	50	32	23
Asia	934	700	75	105	15
Africa	182	165	91	7	4
Other[d]	143	87	61	45	15
Total	1,541	1,092	71	189	12

Source: World Bank, "Rural Electrification," A World Bank Paper (Washington, D.C., World Bank, October 1975), p. 17.

[a]Population figures refer to the whole region, minus the counties listed in other category (see footnote d).

[b]The definitions of "village" and "rural" vary between countries. Generally, villages are conglomerations of 5,000 to 10,000 inhabitants or less; rural refers to low-density population outside the villages, often living in clusters close to large farms.

[c]Electrification data are not available for each country; the percentages should be taken as typical levels of countries in the region, about which there may be considerable variance.

[d]Algeria, Cyprus, Egypt (Arab Republic of), Iran, Morocco, Saudi Arabia, Tunisia, and Turkey. Electrification data have been compiled from miscellaneous documents and correspondence with countries, and are not official statistics. Population data are from United Nations documents.

Advocates also emphasize that electrification indirectly leads to increases in employment and spurs various other income-producing activities. For instance, with electricity land can be farmed several times during the same year, substantially increasing the amount of required labor. Capital improvements that increase productivity do not displace labor, as was earlier feared, but actually create an additional demand for labor (see Day and Singh, 1977). While agriculture is still the main source of economic activity in rural areas, new jobs can also be created through small-scale industries. Thus, while most of the rural poor probably do not benefit directly from rural electrification, according to advocates the employment of the rural poor in industry and agricultural jobs is a significant indirect benefit of electricity.

In short, its advocates claim that investments in rural electrification are infrastructure improvements that will enhance the quality of rural life and lead to long-term increases in rural productivity and employment, with the result that rural areas will be more desirable places to live. Improvement in the quality of rural life may have innumerable spillover effects, such as a reduction in the extent of rural-urban migration, and qualified professionals such as doctors and agricultural extension workers may be more willing to serve in rural areas having conveniences such as electricity.

THE CRITICS OF RURAL ELECTRIFICATION

The belief that rural electrification is an appropriate development strategy for almost all developing countries has been shaken during the last eight years. Critics assert that it is too expensive, does not benefit all social classes equally, and has no direct impact on agricultural or industrial development. As a consequence of this all-encompassing criticism, in some instances funding for rural electrification in recent years has been curtailed.[2] The basic criticism centers on the place of rural electrification in energy strategies for socioeconomic development. Rural electrification by itself obviously will not irrigate fields, apply fertilizer, or produce industrial goods. Critics point out that rural electrification must be placed in the context of integrated rural development programs to have a substantial impact in the countryside.

The questions raised concerning rural electrification center around the socioeconomic impact and cost effectiveness of investments. The five central issues raised by critics are: (1) the appropriate time for implementing rural electrification projects in the development cycle, (2) whether rural electrification schemes should have a household or rural productivity emphasis, (3) whether the rural poor benefit, (4) the capital-intensive nature of investments, and (5) the place of rural electrification in more general energy strategies for economic development.

Is It Too Soon?

As indicated, the success of rural electrification in the United States during the 1930s has provided the model for extending electrification to developing countries. The question still remains whether this experience is relevant to poor rural areas in developing countries. The growth rates in household connections in the United States probably cannot be duplicated in developing countries because of the substantially lower levels of household incomes and rural employment. Projections of load demands by utilities in some countries have been very disappointing (see Sen Gupta, 1977; Sambrini et al., 1974). After a thorough review of projects in Indonesia, McCawley (1979, p. 68) criticizes rural electrification as doing little to achieve the various objectives originally anticipated as project benefits. The poor in rural areas cannot afford electricity; the tariffs are generally set so high that only the wealthy can afford it. The fact that low incomes constrain participation by the poor in the benefits of rural electrification programs causes a lower than anticipated growth in connections, which puts undue financial strain on the utilities. McCawley's conclusion is that other developmental priorities should come before rural electrification.

That countries with relatively high per capita incomes have more extensive rural electrification programs is substantiated by an examination of countries at different levels of socioeconomic development (see table 2.2). The countries in table 2.2 have been arranged by gross national product. Access to electrical services generally is lower in poor countries such as Burma, Chad, and Ethiopia, while the reverse is true in higher-income developing countries such as Costa Rica, Chile, and Mexico. Very few African countries have extensive rural electrification programs.

The percentage of rural populations that adopt electricity when it becomes available also is higher in wealthier countries (see table 2.3). In a wealthy region in Argentina, a rural electrification cooperative was able to connect over 90 percent of the rural households, even though some of the households were widely scattered on farms and ranches (personal communication from Inter-American Development Bank, 1980). The mean per capita income for Argentina in 1978 was $1,910 per person, well above the average for most developing countries.

Table 2.2 Access to Electricity in Developing Nations, 1980

Country	GNP, 1978 (dollars per capita)	Percent with access to electricity			Percent rural of total Population
		Rural	Urban	Total	
Suriname	2110	44	88	61	60
Barbados	1940	50	100	90	20
Argentina	1910	5	99	80	20
Uruguay	1610	65	95	80	19
Brazil	1570	5	95	62	40
Costa Rica	1540	52	95	70	55
Chile	1410	30	99	85	20
Mexico	1290	50	99	80	37
Panama	1290	30	77	90	30
Korea	1160	90	99	95	51
Jamaica	1110	15	60	35	60
Malaysia	1090	n.a.	n.a.	52	70
Dominican Republic	910	n.a.	n.a.	35	54
Ecuador	910	30	72	38	58
Colombia	870	19	86	62	36
Ivory Coast	840	20	90	45	65
Nicaragua	840	20	64	41	52
Peru	740	n.a.	n.a.	35	45
El Salvador	600	12	75	36	61
Nicaragua	560	n.a.	n.a.	20	74
Guyana	550	5	60	50	40
Bolivia	510	10	78	33	66
Philippines	510	n.a.	n.a.	31	70
Thailand	490	18	70	27	83
Honduras	480	n.a.	n.a.	21	68
Cameroon	460	0	28	6	n.a.
Liberia	460	2	85	25	72
Kenya	320	n.a.	n.a.	6	87
Sudan	320	n.a.	n.a.	8	87
Haiti	260	0	23	5	77
Madagascar	250	n.a.	n.a.	18	85
Pakistan	230	n.a.	n.a.	22	74
Tanzania	230	n.a.	n.a.	7	93
Guinea	210	n.a.	n.a.	5	n.a.
Sri Lanka	190	0.5	23	6	76
India	170	n.a.	n.a.	14	79
Burma	150	n.a.	n.a.	7	78
Chad	140	6	70	10	86
Ethiopia	120	0	33	4	89
Nepal	120	n.a.	n.a.	5	95
Bangladesh	90	0	19	2	91

Source: World Bank, "1981 Power/Energy Data Sheets for 100 Developing Countries," (Washington, D.C., World Bank, 1984).

Note: n.a. means not available.

Table 2.3 Gross National Product, 1978, and Households Connected to Central Grid as Percentage of Total Potential Households

Country	GNP, 1978 (dollars per capita)	Percentage of total potential households actually adopting electricity
Argentina	1910	over 90
Costa Rica	1540	70-80
Ecuador	910	35-64
Colombia	870	50-68[a]
Philippines	510	42[b]
Philippines	510	20-51[c]
Bolivia	510	12-22[d]
India	180	26

Sources: Kessler et al., 1981; Goddard et al., 1981; Butler et al., 1980; Mandel et al., 1981; National Council of Applied Economic Research, 1981; U.S. Bureau of the Census, 1981; (Argentina, Personal Communication): World Bank, 1980.

[a]Figure from Sanders et al., 1978, pp. 100-101. All of the households were in line of sight of major roads.

[b]Figure from U.S. Bureau of the Census Survey, 1981.

[c]Figure from report by Mandel et al., 1980.

[d]The figure from Butler et al., 1981 is for those in electrified regions. The percent rises to 60 percent for those in reach of electricity lines.

In the Philippines, which had a $510 per capita income, the adoption rate for customers is about 42 percent of potential customers (U.S. Bureau of the Census, 1981). A survey in Colombia (Saunders et al., 1978) found that only 12 percent of the potential customers in the lowest level-of-living category took advantage of electrical service, compared to 68 percent

for the total sample of households in the survey. The mean per capita GNP for Colombia in 1978 was $870, again above average for developing countries. Such evidence spurs critics to suggest that for most developing countries it is too soon for rural electrification, and other development programs should be commenced prior to rural electrification in order to raise income levels. In this view, rural electrification is a luxury that should be implemented at a later stage of development.

Residential Versus Productive Use of Electricity

The early emphasis on residential electrification has become a point of sharp and sometimes great contention.[3] Critics argue that since the more wealthy households can easily afford to connect to the rural electrification grid, rural electrification programs with a household emphasis are really a subsidy for the wealthy in the rural areas. The rural poor can have no way of benefiting from the electrification of more wealthy households. Judith Tendler (1979, p. 21) has expressed the concern that rural electrification based on promotion of residential rather than productive uses is contrary to the New Directions programs for USAID.

> The New-Directions impact of rural electrification projects may lie elsewhere than with the benefits to rural households. Concerns with providing equity to household users - or distributing equity properly among household users - may result in a fairly limited impact on the rural poor. The focus of equity concerns on the household consumer is somewhat misplaced outside the context of U.S. rural history, where rural unemployment was not a major problem the way it is in the Third World today. . . . Instead, a good part of the gains from electrification for the poorest may occur through electricity using production activities that increase employment. In addition, the impact on the poor of public uses of electricity - like village hospitals and village lighting - may be much greater than availability of electricity for individual household use.

Tendler concludes that the focus of rural electrification should not be to subsidize the rich, but to stimulate economic devel-

opment and rural employment. If rural electrification can cause significant growth in jobs, then perhaps the rural poor can benefit from the electricity program.

But can a country demonstrably alter the impacts of rural electrification by changing the focus of the program from household to rural productivity? The answer really depends on many conditions, including the level of development of the country and the extent of the commitment to allocate funds to improve rural productivity. The two contrasting cases of India and the Philippines are instructive. As indicated, in the Philippines the utilities have promoted residential household electrification. While the Philippines has to some extent recently modified this approach, in 1975 ten rural electrification cooperatives there sold about 48 percent of their kilowatt hours to residential customers (see Denton, 1979, pp. 138-143; and table 2.4). Only 4 percent of the sales were for agriculture, and industrial sales were estimated to be approximately 10 to 15 percent. The 1982 figures for rural electric cooperatives in the Philippines indicate the situation is changing. There has been a rise in the share of kWh consumption for industry to 27 percent and a decline in the share for households to 37 percent, but agriculture's share remains quite low.

The household emphasis in the Philippines contrasts sharply with the situation in India, where agricultural connections are heavily subsidized and residential users must pay the same rates as their urban counterparts. In electrified villages in India very few residential households have electricity. Irrigation pumping accounts for over four-fifths of the total generated load (Sen, 1980, p. 28); just over one-tenth goes for domestic lighting, and the rest is for rural industry and commerce. These figures are consistent with the electricity consumption data for specific projects presented in table 2.4. At least for these two countries, it appears that a household or productivity policy emphasis does have an impact on which sector has the greatest connected load, although over time these differences eventually may diminish.

But critics also indicate that the benefits of electrification for agriculture and small-scale industries also go largely to individuals in upper income classes. Small farmers must be able to afford the capital investment in pumpsets or other complementary inputs. Rural artisans need to be able to purchase the electrical equipment that will improve their produc-

Table 2.4 Electricity Consumption by Sector in Some Rural Areas (percent of kWh consumed)

	Residential (1)	Commercial (2)	Industrial (3)	Irrigation (4)	All Productive uses (2)+(3)+(4)	Other[a]	Total
Colombia (1971)	55	27	3	-	30	15	100
Costa Rica (1973)	28	-	-	-	-	72	100
El Salvador (1972)	36	24	34[c]	2	60	4	100
Nicaragua (1976)							
COERAM	30	-	2[e]	60	62	8	100
CODERSE	26	4[d]	55[e]	4	63	11	100
CAEER	54	6[d]	18[e]	2	26	20	100
India							
Telangana, P.P. (1975-76)	21	12	17	48	77	2	100
Suryapet, A.P. (1971)[b]	6	1	4	88	93	1	100
Una, Gujarat (1973)	13	-	7	79	86	1	100
Bayad-Modasa, Gujarat (1973)	18	-	23	54	-	5	100
Indonesia (1974-75)	69	-	3	-	3	28	100
Philippines							
Camarines Sur I (1975)	60	29	-	1	31	10	100
Albay Coop. (1975)	64[f]	21	4	-	25	11	100
Misamis Oriental (1975)	44[g]	16	23[h]	2	41	15	100
Av. for 7 Cooperatives (1982)	37	16	27	1	44	8	100
Thailand, PEA (1972)	30	34[i]	34[j]	-	68	2	100

Source: Table adopted from Cecelski, 1982, p. 10. Sources for tables include Ross, 1972; Sanders et al., 1978; McCawley, 1979; Development Alternatives, Inc., 1977; Madigan et al., 1976; Turvey and Anderson, 1977; National Council of Applied Economic Research, 1978; Sen and Misra, 1974; Sambrani et al., 1974; and National Rural Electrification Cooperative Association, 1982.

[a]Includes street lights, government offices, public buildings, water pumps and systems, and own use by plant.

[b]Percent connected load.

[c]LV 14 and HV motive power 20.

[d]Small business and industry.

[e]Large business and industry.

[f]Poblacions 31.5, barrios 32.5.

[g]Poblacions 21, rural 23.

[h]Small 18.0, medium 3.3.

[i]Small business 16, general business 12, medium business 6.

[j]Large business and mining.

tivity. The expected result is that people in the upper strata of rural communities would be able to take advantage of the benefits of subsidized electricity. By contrast, the poor must continue to rely on traditional and noncommercial sources of energy (see Sen, 1980, p. 20).

Community and Regional Inequality

Rural electrification might also cause regional imbalances in socioeconomic development. Not only does it disproportionately benefit the more wealthy rural households; critics indicate that rural electrification may primarily benefit the more wealthy regions within a country. The reasoning is that capital and complementary inputs are necessary before rural electrification can have a significant impact on socioeconomic development, and therefore many productivity- and employment-generating benefits of rural electrification would be limited to more prosperous regions. One conclusion from a recent USAID study in the Philippines (Mandel et al., 1980, pp. 13-14) is that "the contribution of electricity to the development process depends on the level of development of the area, the availability of capital and other financial and human resources as well as the implementation of programs which stimulate the use of power." In a study of a backward region in India it was found that productive use of electricity lagged behind expectations because of lack of capital, inability to obtain bank loans, insecurity of markets for products, and unreliable supplies of electricity (Centre for Studies in Decentralised Industries, 1980). This has led critics to assert that electrification has more of a socioeconomic impact and has a higher rate of load growth in the more prosperous regions of developing countries, thus exacerbating regional inequalities.

Too Expensive and Little Productive Impact

Rural electrification programs are very capital intensive. Construction of generating capacity and extension of

lines into rural areas almost always are subsidized by governments in developing countries. Concessional loans from donor agencies and multilateral banks for rural electrification schemes generally range from 20 to 40 million dollars per project, depending on the size and nature of the projects. Such large investments can be justified only from the long-term stream of revenues and the social and economic benefits produced by the project.

Despite the large capital expenditures, critics argue that rural electrification projects may have very little impact on rural productivity in agriculture or small-scale industry or on regional levels of socioeconomic development. In an article advocating decentralized energy for rural communities in developing countries, Smith (1980) asserted that rural electrification has no productive benefits and generates no additional regional development. Many evaluation studies favorable to rural electrification cite the number of electrified industries that have been started since villages were electrified (see, for instance, Small Industry Extension Training Institute, 1976). Smith observes that most of the industries that started after regions or villages were electrified may have done so for independent reasons, and moreover they could have been powered by another energy source. The conclusion of the critics' line of reasoning is that the economic benefits of rural electrification for establishing rural industries are insignificant, especially when compared to the costs involved in extending the central grid. The same argument could be made concerning the effects of rural electrification for irrigation. Individual diesel engine pumpsets can perform the same function as electric motors, without the substantial investments necessary for constructing generating capacity and expensive distribution systems.

Critics assert that there is not much credible evidence which specifically supports a direct connection between rural electrification and social benefits. Investments in rural electrification are investments forgone for other community services or energy programs (see Soft Energy Paths, 1980). For instance, investments in schools, water supply, health services, and roads all may have substantially more direct impacts on literacy, population growth, rural-urban migration, and the other social benefits. The critics feel the opportunity costs of rural electrification far outweigh the small and insubstantial social benefits. Money spent on other rural development or on

alternative energy programs can more equitably and effectively improve rural productivity and quality of life.

Alternative Energy Strategies

Rural electrification is blamed by critics for preventing a more balanced energy development strategy, which would include traditional fuels such as fuelwood and charcoal along with alternative technologies such as biogas and wind energy. Rural electrification advocates are accused of recommending their technology for anyone and for every location, regardless of the energy resources available in the villages (see Development Alternatives, 1977). Before the energy crisis of 1973-74, electrification was the only significant rural energy development strategy. Now that rural energy needs have been more critically examined, expensive rural electrification programs have been easy targets for criticism.

Decentralized or "soft paths" of energy development typically involve matching the energy end use with the energy source (see Lovins, 1977; Pendse, 1980a and 1980b; Smith, 1980). For example, many critics of rural electrification are in favor of alternative technologies suitable for specific locations and end uses, including wood or biogas for cooking or hydropower for irrigation. The type of technology would depend on the resources available in a specific village; obviously a village on a semiarid plain could not adopt hydropower as a power source. Many alternatives to central grid - some still in the experimental stages - are being evaluated within the context of diversified energy policies for developing countries.

CONCLUSION

By definition, the main goal of all development strategies is social and economic development. The rural electrification controversy revolves around choosing a strategy for reaching this goal. The advocates of rural electrification strongly feel that it is a necessary condition for development, and that

it is a catalyst that will lead to improved rural productivity and a better rural quality of life. Its critics argue that many other projects should receive priority over rural electrification in developing countries, especially in those countries at a very low level of economic development.

The arguments against rural electrification are that the current scale of projects is too large; that the extension of the grid to isolated rural areas is too costly, given the weak demand; and that the predominant focus in some countries on electrifying rural households rather than productive activities is inappropriate. But from a policy standpoint, rural electrification certainly can complement other technologies. In addition, all of these arguments depend on key uncertain factors. One of these factors is the price of oil, and therefore the cost of pumping with diesel pumpsets. The recent decline in oil prices complicates the picture for both central grid and decentralized alternatives. Another is that newer types of alternative energy schemes, such as biogas, wind, and direct solar alternatives, must be practical and cost effective. Finally there is the question of the actual socioeconomic impact of rural electrification. In order to sort out the claims and counterclaims by advocates and critics, the next chapter begins a substantive analysis of the actual impact of rural electrification in the development process.

NOTES

1. In fact, during a talk to the Society for International Development (1982), Samuel Bunker of NRECA indicated that NRECA has benefited from the controversy because it has led to more critical evaluation of current and past policies in the organization.

2. Rural electrification funding is somewhat hard to detail (see Niblock, 1982, for the most extensive review of rural electrification funding). Over the past twenty years, USAID has been the dominant agency funding rural electrification projects, but presently it is completing just two projects, one in Bangladesh and one in Pakistan. The World Bank has been steadily funding rural electrification for the last ten years, and there seems to be no curtailment of its lending activity. The Inter-American Development Bank (IDB) is the third major donor agency involved in funding rural electrification projects. For the IDB, lending increased from $200 million during the 1965-1970 period and $318 million during 1970-1978, to $219 million during the four years 1975-1979. However, this may be partly a consequence of the ebb and flow of new projects. For most other donor agencies, funding for rural electrification is sporadic, so no over-time trends are discernible.

3. NRECA, which has developed, designed, and promoted a large number of rural electrification projects in developing countries, has recommended both household emphasis and administration of programs by rural electrification cooperatives projects. The NRECA philosophy is to keep electricity rates low so that the rural poor can afford electrical service, to support extensive coverage of rural households, and to promote participation in rural electric cooperatives. This emphasis has led to high household connection rates for countries like the Philippines and Costa Rica. Thus, the rural electrification schemes which have been designed for extensive household coverage in most cases appear to have reached their goal.

3
Electricity for Agricultural Development: Case Study of India

The controversy about the role rural electrification should play in development is confusing because in some developing countries it apparently has had very little impact on agricultural development (see Saunders et al., 1978, Butler et al., 1980; Mandel et al., 1980; Goddard et al., 1981; Madigan et al., 1976) while in other countries the impact has been substantial (Samanta and Varma, 1980). The questions that need to be answered include whether rural electrification stimulates agricultural development and, if it does, whether an alternative energy program could achieve the same ends at less cost.[1] The question of cost will be addressed in a later chapter; this chapter focuses on the impact of rural electrification.

Improvements in rural infrastructure often are cited as preconditions for agricultural development. Usually a distinction is made between programs for the development of physical and institutional infrastructure, with physical infrastructure referring to roads, rural electrification, large-scale irrigation, and other similar projects, and with institutional infrastructure referring to programs involving agricultural extension, disease and pest control, and educational and research facilities. However, in this chapter rural electrification will be considered as part of the total rural infrastructure, and its impact on agricultural development will be examined in conjunction with other infrastructural inputs such as credit, agricultural extension, rural markets, and diesel engine pumpsets.

Basically, rural electrification can affect agricultural production in three different but related ways:

1. Electric powered machinery can be utilized directly in the process of agricultural production. Water pumps, fodder choppers, and threshers are examples of farm machinery

that can be driven by electric motors.

2. Electricity may have more diffuse effects on agricultural modernization not directly captured in specific on-farm activities. Some of these diffuse uses of electricity might be cooling milk in collection centers, listening to radios or watching television, or reading by means of better lighting. With radios or televisions, agriculturally relevant materials can be easily transmitted to remote audiences.

3. Electricity can be used for lighting and in on-farm operations such as crop processing and poultry and dairy operations.

The impact of rural electrification in the three countries in the study may be affected by the type of agriculture, the extent of commitment to rural development, and the available technologies. In India the impact of rural electrification was indirect through changes in irrigation patterns and agricultural innovations. In Colombia and Indonesia rural electrification had very little impact on agricultural development. Most of the rest of this chapter, therefore, focuses on the India case study. The details of the methodology used to collect the data are presented in Appendix A.

THE RURAL ELECTRIFICATION AND DEVELOPMENT MODEL

The rural electrification agricultural development model is based upon the assumption that it is part of a land intensification program that includes irrigation (see Hayami and Ruttan, 1971, pp. 282-283), so the model applies mainly to countries at very high levels of cultivation intensity and population density. The introduction of electricity into a region makes it possible for farmers (1) to switch from traditional, and in many cases gravity-fed, irrigation sources; (2) to change from diesel engine pumpsets, or (3) to irrigate farmland for the first time. With deep tubewells, submersible electric pumpsets may be the only practical means by which water can efficiently be brought to the surface. However, if the water table is relatively high, farmers are able to choose between electric pumps, diesel engines, or traditional methods of irrigation, such as the Persian wheel or leather bags drawn from a well.

Increasing the percentage of land under irrigation generally can affect agricultural practices by encouraging farm innovations. With irrigation of rainfed farmland, both double cropping and changes in cropping patterns become possible. During the Indian monsoon season, for example, most agricultural production is rainfed, with irrigation pumping being used only in areas where rainfall has been below normal or sporadic. The benefits of irrigation typically are conditioned by level of rainfall, the length of the growing season, and the availability of ground water. During the winter season that follows the monsoons, the water table generally is high enough so that irrigation makes possible the growing and harvesting of a second crop. Just as important, more renumerative crops can be grown in place of the traditional unirrigated varieties. Superior cereals (rice and wheat) and cash crops (sugar cane and tobacco) can replace the inferior cereals (millet and barley) that are grown in most unirrigated, dry areas. Thus, irrigation makes possible two or even three crops during the same year, producing significantly greater incomes for farmers.

The story of the Green Revolution is a well-known chapter in the history of development. In India, packages of fertilizers, hybrid seeds, and pesticides were introduced to farmers in pilot programs during the 1960s. At the same time, the agricultural extension staffs in the regions were expanded to help disseminate information and advise farmers about the program. While substantial increases in agricultural productivity were realized, the pilot programs were unrepresentative in the sense that they were limited to the most progressive districts.[2] Although at the time there was some concern that the benefits would accrue only in the most advanced districts, the program quickly spread to surrounding districts, and now virtually all regions in India have access to hybrid seeds and other inputs (see Brown, 1971, for a detailed analysis). The initially successful programs were those for wheat during the late 1960s, but hybrid rice varieties, mostly of the nonpaddy variety, along with varieties of inferior cereal grains such as sorghum and millet, became widespread during the 1970s. However, the productivity of the hybrid seeds depends to a large extent on an assured and well-timed supply of water during certain critical periods of plant growth.

High agricultural yields depend directly on farming practices. Rural electrification can indirectly cause changes in farm practices, such as increasing the percentage of the village

cropland under irrigation or stimulating agricultural innovation. Thus, the proposed model for rural electrification and agricultural development can be diagramed as follows:

Availability and access to agricultural inputs including electrification --->	Change in farm practices ----->	Change in agricultural production

It is necessary to analyze explicitly all of the complementary inputs and their relationship to rural electrification and changes in farm practices in order to evaluate the role of rural electrification in the development process. Although this complicates the analysis, the issues raised by critics necessitate controlling for such variables as access to electricity, agricultural extension, roads, and others.

CHANGES IN THE INDIAN VILLAGES, 1966-1980

India has actively pursued a policy of promoting electric irrigation pumps since 1966. The dramatic growth in electrical energy for irrigation resulted from an explicit national commitment to improve agricultural productivity through rural electrification and to substitute Indian coal for imported oil. The all-India data in table 3.1 and figure 3.1 illustrate that the number of villages receiving electricity and the extent of irrigation through electric pumpsets increased dramatically in the late 1960s and early 1970s. The number of pumpsets increased from approximately 2 per 1,000 hectares in 1966 to more than 36 by 1977. During the same period the percentage of villages with electric pumps increased from about 12 percent to more than 40 percent.

The villages in the India survey reflect this national commitment to rural electrification and to expansion of irrigation. During the early 1960s there were very few pumpsets in the sample villages. Most of the irrigation was by traditional methods, which included gravity-fed, animal, and even human powered forms of irrigation. The small average area covered by traditional well irrigation sources (on average less than one acre per irrigation source, and for animal driven irrigation less than two acres per irrigation source) indicates that the water

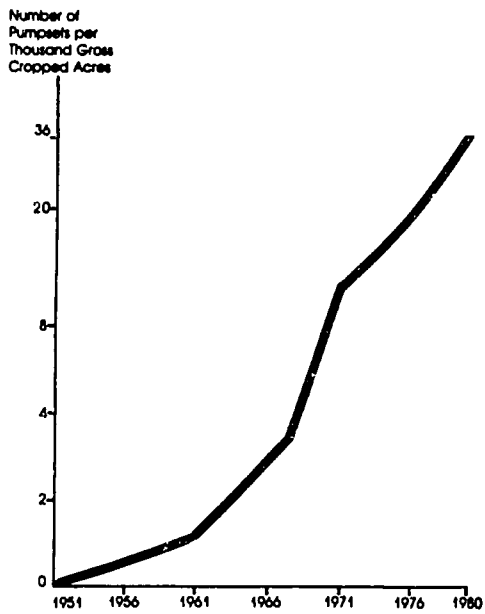
Table 3.1 Increase in Electrified Pumpsets in India, 1951-1979

	Number of villages with electricity at the end of plan period	Percent of villages with electricity at the end of plan period	Number of pumpsets at the end of plan period	Number of additional villages electrified	Number of additional pumpsets energized	Average number of pumpsets per electrified village
1951	3,061	.53				
1951-1956	7,296	n.a.	56,056	4,233	35,056	7.7
1956-1961	21,750	3.78	198,984	14,456	142,848	9.1
1961-1966	45,144	n.a.	512,756	23,394	313,852	11.4
1966-1969	73,732	12.81	1,088,824	28,588	576,048	14.8
1969-1974	156,729	27.22	2,426,133	82,997	1,337,329	15.5
1974-1979	232,042	43.44	3,599,328	76,313	1,173,195	15.5

Source: Rural Electrification Panel-Committee on Power, September, 1979; Planning Commission, Government of India, "Sixth 5-Year Plan 1980-85: A Framework" (New Delhi, Government of India, 1980).

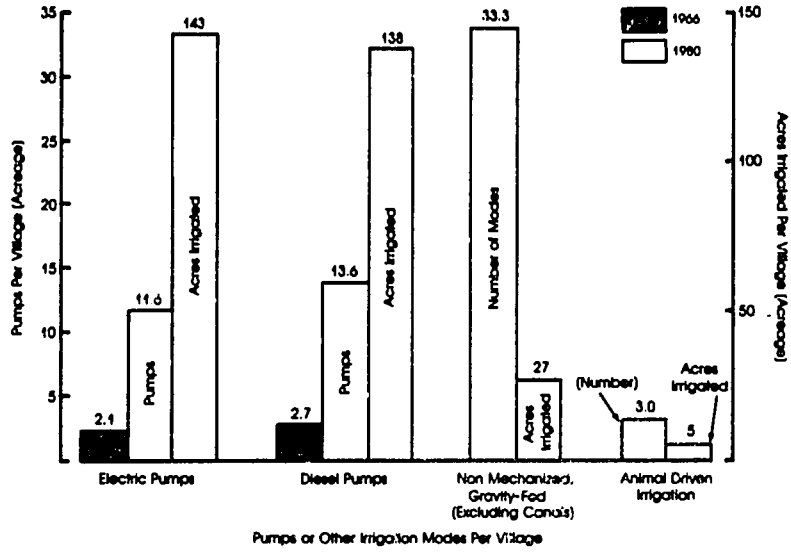
Note: n.a. means not available.

Figure 3.1 Growth of Rural Electrification in India: Electric Pumpsets per 1,000 Hectares Gross Cropped Area.



Source: "Basic Statistics on Indian Economy," Commerce Research Bureau, Bombay (January 1980).

Figure 3.2 In Increased Importance of Electric and Diesel Pumps for Irrigation Compared to Traditional Methods, India, 1966, 1980.



Source: India Survey, 1980.

Note: All Figures are Means for Total Sample. In addition There Were Canal Irrigation Systems For the Villages. For the 1966 Sample There Were 108 Villages and for 1980 There Were 132 Villages.

output per source is far lower than for diesel and electric pumpsets. Between 1966 and 1980, farmers bought both diesel and electric pumps to intensify cultivation. As can be seen from figure 3.2, the average number of diesel and electric pumps per village in the survey increased from about two to over eleven. Because these pumps are more efficient than traditional methods, there was a significant increase in well-irrigated land, which no doubt led to a change in cropping patterns. The amount of land under irrigation by pumps is now many fold greater than that using traditional irrigation sources (excluding canals). India's commitment to encourage farmers to irrigate their land through the use of private wells with diesel and electrically powered pumps was extremely successful.

There were other important changes in the use of agricultural innovations in the Indian sample villages during the 1966-1980 period (see table 3.2). For instance, the average per-

Table 3.2 Agricultural Innovations in India, 1966 and 1980 (Percent of Village Leaders)

Item/Index	1966 Mean	1966 Standard deviation	1980 Mean	1980 Standard deviation
Leaders using agricultural inputs1				
Percent of leaders using fertilizers	73	24	96	13
Percent of leaders using green manure	47	28	44	29
Percent of leaders using new implements	35	27	48	36
Percent of leaders using improved seeds	54	25	90	16
Perceived utility of agricultural inputs for increasing production2				
Contribution of fertilizers	4.0	0.1	4.3	0.3
Contribution of green manure	2.8	1.4	3.4	1.5
Contribution of new implements	2.0	1.4	3.1	1.8
Contribution of compost pits	3.9	1.2	4.2	0.3
Contribution of improved seeds	3.3	1.0	4.5	0.3

Source: India Survey, 1980.

1All items coded 0 or 1, with 1 representing most use.

2Each item coded on a scale of 1 to 5, with 5 equivalent to greatest contribution.

centage of village leaders using fertilizers increased from 78 percent to more than 96 percent, indicating that fertilizer use is well established in almost all the villages sampled. Likewise, leaders using improved seeds increased from 54 percent to 90 percent, a dramtic increase. The change for new implements was much more modest, rising from 35 to 48 percent. The village leaders were also asked questions regarding the utility of individual agricultural innovations, and those responding that the innovations had "some" or "much" utility were coded as having favorable perceptions. All of the variables presented in table 3.2 were used to construct the village agricultural innovation index.[3]

The villages now have much greater access to agricultural inputs, including hybrid seeds, fertilizers, and pesticides, than they did 14 years ago. This is the result of improved production and distribution systems, both private and public, that have eliminated many of the bottlenecks that existed in the 1960s. To measure access to agricultural inputs, the village leaders were asked: "Given the willingness to pay, how much difficulty have farmers had in acquiring key agricultural inputs?" The average percentage of leaders reporting difficulty in obtaining fertilizers decreased from 59 to 38 percent between 1966 and 1980, and difficulty in obtaining improved implements declined from 56 to 42 percent.

The changes in rural infrastructure in India may be a contributing factor to agricultural development in India (see table 3.3). During the 14-year time period between the surveys it is quite evident that infrastructure improved. Schools, transportation, mass media, and banks all became more abundant in the countryside. The only exceptions were agricultural extension and rural markets. The market decline probably is a consequence of market consolidation typical of agricultural commercialization. Because of improved transportation, local markets may begin to concentrate in central rather than dispersed locations. Such a process is typical of the development of growth centers and market towns (see Wanmali, 1983).

The decline in the availability of agricultural extension services over the 14-year period is more puzzling, since one would expect that agricultural services should improve. This trend requires some explanation. The sample contains 36 villages which were part of the Intensive Agricultural District Programme (IADP) which began in the early 1960s. These dis-

Table 3.3 Agricultural Practices, Infrastructure Proximity, and Village Leader Changes in India, 1966-1980 (108 Villages)

	1966		1980		1966-1980 Changes	
	Mean	Coefficients of variation	Mean	Coefficients of variation	Mean	Coefficients of variation
Dependent variables						
Percent irrigated area of net cultivated area	20.33	157.61	22.81	140.98	2.10	12.25
Percent well irrigation of net cultivated area	.70	268.28	8.59	138.02	8.10	11.99
Percent multiple cropped area	16.47	148.75	28.26	110.63	11.00	29.96
Agricultural innovation index (0-4)	2.18	35.75	2.69	20.64	0.51	0.75
Village grain mills	0.76	176.67	1.81	176.37	1.05	2.65
Village characteristics and programs						
Village population	1,654.82	85.94	2,071.05	84.79	2.61*	3.34
Proximity to bank (0-4)	0.60	120.58	1.48	62.86	0.088	1.04
Proximity to middle and secondary schools (0-8)	4.17	46.07	4.56	41.48	0.39	1.80
Proximity to transportation (0-12)	5.49	42.10	6.93	32.18	1.44	2.20
Proximity to mass media (0-16)	5.37	57.20	7.38	41.85	2.01	2.56
Proximity to wholesale and retail markets (0-8)	3.48	46.50	2.33	65.05	-1.16	1.93
Years since village electrification	1.33	195.84	8.12	95.80	7.10	6.25
Times talked to agricultural extension (0-24)	9.13	48.55	10.30	49.48	1.18	6.02
Percent literacy	19.25	49.32	25.89	57.48	6.64	11.45
Electric pumps	1.23	283.12	7.36	184.16	6.14	11.47
Diesel pumps	1.33	176.49	6.04	149.11	4.71	8.79

Source: Douglas Barnes and Hans Binswanger, "The Impact of Rural Electrification and Infrastructure on Agricultural Changes in India, 1966-80," Economic and Political Weekly, Vol. 21, No. 1, January 4, 1986.

Note: The numbers in parentheses represent the scale for the 1966 and 1980 measures of the variables. The 1966-1980 change is the difference between 1980 and 1966 for all cases. The literacy measures are for 1961 and 1971. The percent irrigated area for 1966 is from the 1971 District Census Handbooks. The population measures are the compound annual growth rate between 1971 and 1981.

*Compound annual growth rate 1971-1981.

tricts were singled out as being advanced and a good environment for inducing agricultural change through spurring the adoption of new agricultural technologies. As a consequence, these districts received more agricultural services than the surrounding districts. This program was ended in the early 1970s. The program could have inflated the number of extension agents in the villages for the 1966 period, while they returned to more normal levels by 1980.

The villages in the survey represent a broad range of rural electrification. Some villages had electricity for over 15 years, while others did not yet have electricity. Electric service was extended to 57 percent of the villages in the sample during the 14 years following 1966. In 1966, only 33 percent of the villages in the sample had electricity. By 1980, the number had increased to 71 percent. This is reflected in the number of years that the villages had electricity. In 1966, the average number of years with electricity was just over 1 year, as most of the villages had not yet been connected to the central grid. By 1980, the average number of years with electricity for the sample villages was over 8 years.

Credit appears to be a very important input for agricultural development. The percentage of leaders indicating farmers had some difficulty in obtaining credit increased slightly between 1966 and 1980, but this might be because more farmers were trying to obtain credit in 1980 than in 1966. An average of about two banks per village were available for providing input loans, so credit was generally available in these villages. In fact, the leaders estimated that 78 percent of the farmers who applied for credit had received it, but there was a wide variation in results among the villages.

The variable of access to mass media measures the degree to which a village is connected to the larger society through the communications network (proximity to cinema, post office, telegraph, library, and telephone). Between 1966 and 1980, mass media access improved for all items except proximity to a library. A "proximity to school" item measured village distance from middle and high schools. Primary schools were excluded because virtually all of the villages in the sample have primary schools. As might be expected, there were high schools in only 15 percent of the villages sampled, but there were middle schools in 33 percent.

IMPACT OF INFRASTRUCTURE ON FARMING PRACTICES

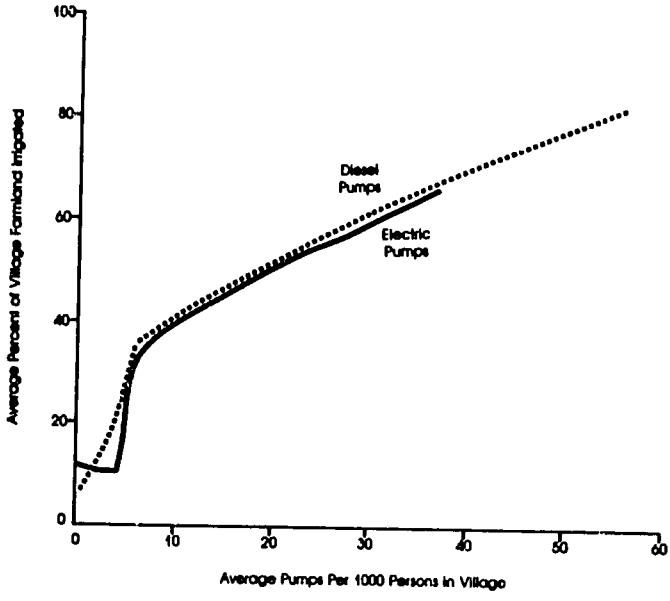
Availability of agricultural inputs must be translated into actual changes in farming practices to have an impact on crop yield. By themselves, rural electrification, agricultural extension, and credit programs can only have an indirect impact on crop production. As indicated above, during the last 20 years in India there has been a shift from "traditional" to more "modern" agricultural practices. Even the decision to irrigate is closely linked with the decision to modernize with other agricultural practices, such as use of hybrid seeds. For agricultural modernization the important farming practices are irrigation, multiple cropping, and agricultural innovations. each of which will be examined below.

Irrigation and Multiple Cropping

The percentage of land under irrigation in villages is a direct consequence of the extent and type of irrigation. In India there are four main modes of irrigation, i.e., wells, tanks, rivers, and canals. The sources of motive power for irrigation are electric or diesel pumps and a variety of traditional irrigation methods such as gravity-fed or human- or animal-driven devices. The measures of irrigation used in this study are percent of land irrigated and percent of land multiple cropped.[4] Generally, land that is irrigated is more valuable than land that is not irrigated; likewise, multiple-cropped land in many cases is more valuable than land which is irrigated for only one season.

Although canals are important for some regions, diesel and electric pumps are both more efficient and more convenient than the traditional methods of well irrigation and have become increasingly important in India. Farmers are abandoning the unwieldy traditional animal-drawn leather bags and Persian wheels for pumps. Thus, the extent of irrigation pumping and the percentage of land under irrigation are closely related. As is shown in figure 3.3, the increase in electric pumpsets per capita is associated with a substantial growth in the percentage of irrigated land, ranging from 16 to 66 percent

Figure 3.3 Diesel and Electric Pumps Are Positively Related to Percent of Village Farmland Irrigated, India, 1980.



Source: India Survey, 1980.

Note: Each Line is Based on 6 Points Calculated From Breakdowns of Categories With an Approximately Equal Number of Villages.

of total cropped area. The results are similar for diesel engine pumpsets, with percent of area irrigated increasing from 7 to 57 percent.[5] Thus, diesel and electricity have become very important energy sources for irrigation.

Pumps may not be the only inputs that affect irrigation. As a consequence, an analysis was made to determine the impact of rural electrification while controlling for other inputs and infrastructure on the percentage of area irrigated. The results are presented in table 3.4. As expected, diesel and electric pump variables are closely associated with percentage of area irrigated, while most other complementary inputs are not significant. Only nonmechanized irrigation is positively related to percentage of area irrigated after controlling for diesel and electric pumps. The absence of any other asso-

Table 3.4 Regression of Village Characteristics with Levels of Irrigation and Cropping Intensity India, 1980

	Percent of land irrigated			Percent of land multiple cropped		
	OLS regressions		Pearson's correlations	OLS regressions		Pearson's correlations
	1	2	3	4	5	6
Years since village electrification	--	0.22* (2.88)	0.30	--	0.01 (0.07)	0.15
Electric pumps per capita	0.29* (3.91)	--	0.54	0.07 (0.70)	--	0.20
Diesel pumps per capita	0.43* (6.00)	0.52* (7.36)	0.64	0.22* (2.34)	0.24* (2.79)	0.33
Traditional irrigation per capita	0.11 (1.80)	0.15* (2.23)	0.12	0.00 (0.04)	0.00 (0.00)	0.01
Percentage of leaders describing credit as adequate	0.10 (1.54)	0.11 (1.65)	0.24	0.28* (3.23)	0.28* (3.22)	0.38
Proximity to markets	0.08 (1.32)	0.11 (1.56)	0.14	0.12 (1.32)	0.13 (1.43)	0.22
Proximity to schools	0.02 (0.37)	-0.01 (0.06)	0.16	-0.09 (-0.99)	-0.09 (0.95)	0.10
Proximity to cities and transport services schools	0.10 (1.50)	0.09 (1.19)	0.24	0.08 0.93)	0.09 (0.97)	0.22
Proximity to means of communication	-0.03 (-0.38)	-0.17 (2.11)	-0.01	0.04 (0.33)	0.01 (0.09)	0.18
Number of newspapers and periodicals read	0.04 (0.51)	0.07 (0.80)	0.11	0.15 (0.16)	0.16 (1.41)	0.24
Index of farmers having trouble getting inputs	0.05 (0.78)	0.07 (1.04)	-0.05	0.05 (0.55)	0.05 (0.58)	-0.09
Index of leader's contact with agricultural extension	-0.10 (1.56)	-0.15* (2.23)	-0.28	-0.10 (-1.20)	-0.11 (1.34)	-0.15
Number of cases	128	128	128	128	128	128
F statistic	13.20	11.93		4.10	4.04	
R Square	0.55	0.53		0.28	0.28	

Source: India Survey, 1980.

*Significant at 0.05 level. Coefficients are standardized beta; t statistics are in parentheses.

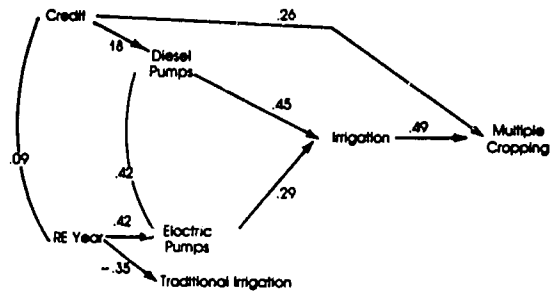
ciations is probably the consequence of the strong direct link between pumps and irrigation illustrated in figure 3.3. Thus, controlling for important complementary inputs and village conditions, the variables most significantly related to the area under irrigation include electric pumps per capita, diesel pumps per capita, and the years of village electrification.

Multiple cropping, as would be expected, was strongly related to the percentage of the village land irrigated. Irrigation is almost a necessity for farming cropland for more than one season, the exception being regions with high levels of rainfall, which can use the residual moisture remaining from the monsoon to grow an additional crop. The relationships among agricultural inputs, irrigation, and multiple cropping are summarized in a reduced form path analysis in figure 3.4. Interestingly, credit availability is positively associated with multiple cropping, even after controlling for other inputs. Credit and the introduction of electricity to a region are related to multiple cropping through the relation of diesel and electric pumpsets to percentage of village area irrigated. In this model, the traditional methods of irrigation are not strongly associated with area irrigated or multiple cropping, reflecting the growing importance of commercial energy for irrigation in rural India. Also, rainfall in the year of the survey was low. Low rainfall affects traditional modes of irrigation more than those that rely on underground sources of water (see Barnes and Binswanger, 1986).

Agricultural Innovations

Several key factors proved to be positively related to the village leader index of agricultural innovation, including rural electrification, diesel pumpsets per capita, market access, and reading of printed materials (see table 3.5). Because water is extremely important for the success of new inputs such as hybrid seeds, the positive relationship of both diesel and electric pumps to innovations would be expected, but it is interesting that traditional sources of irrigation are not significantly related to the agricultural innovations index. The existence of retail or wholesale markets in the vicinity of the village and reading of locally available printed materials are also impor-

Figure 3.4 Relationship Between Agricultural Inputs, Irrigation and Multiple Cropping, India, 1980.



Note: The figure is based on the following set of regression equations. The coefficients are path coefficients (β's) (standardized regression coefficients). t statistics are in parentheses.

$$Y_1 = \underset{(4.55)}{.49\,x_1} - \underset{(0.63)}{.05\,x_2} + \underset{(0.07)}{.007\,x_3} - \underset{(0.89)}{.08\,x_4} + \underset{(3.47)}{.26\,x_5} + \underset{(0.06)}{.005\,x_6}$$

$$x_1 = \underset{(1.94)}{.13\,x_2} + \underset{(6.37)}{.45\,x_3} + \underset{(3.97)}{.29\,x_4} + \underset{(1.90)}{.12\,x_5} + \underset{(1.77)}{.13\,x_6}$$

$$x_2 = \underset{(0.40)}{.03\,x_4} - \underset{(4.25)}{.35\,x_6}$$

$$x_3 = \underset{(2.09)}{.18\,x_5} + \underset{(1.65)}{.14\,x_6}$$

$$x_4 = \underset{(0.96)}{.02\,x_5} + \underset{(5.27)}{.42\,x_6}$$

where Y_1 = percent area cropped more than one season (multiple cropping)
x_1 = percent area irrigated
x_2 = nonmechanized irrigation per capita
x_3 = diesel engine pumps per capita
x_4 = electric pumps per capita
x_5 = credit index
x_6 = rural electrification year

tant factors for agricultural innovation. However, the finding for reading of printed material should be qualified with the knowledge that another study has found that literacy is an effect, rather than a cause, of agricultural development (see Barnes et al., 1982). Thus we would caution readers that some of these findings might be related to villagers' ability to purchase key inputs, which, in turn, might be related to agricultural yields. In a subsequent section the issue of cause and effect will be examined.

The Indian rural electrification policy of encouraging investments in electric pumps appears to have had a substantial impact on farm practices in the countryside, but other

Table 3.5 Regression of Village Characteristics with Leader's Use of Agricultural Innovations, India, 1980

	Agricultural innovation index		
	OLS regressions 1	OLS regressions 2	Pearson's correlations
Electric Pumps per capita	0.23*	--	0.33
Years since village electrification	--	0.22* (2.31)	0.39
Diesel pumps per capita	0.16 (1.85)	0.22* (2.62)	0.30
Traditional irrigation modes per capita	-0.01 (0.13)	0.03 (0.38)	-0.10
Percentage of leaders describing credit as adequate	-0.01 (0.10)	0.00 (0.05)	0.16
Proximity to markets	0.21* (0.251)	0.22* (2.65)	0.32
Proximity to schools	0.06 (0.64)	0.02 (0.26)	0.28
Proximity to cities and transport services	0.03 (0.36)	0.01 (0.11)	0.28
Proximity to means of communication	0.05 (0.46)	-0.07 (0.70)	0.22
Number of newspapers and periodicals read	0.25* (2.38)	0.27* (2.56)	0.37
Index of farmers having trouble getting agricultural inputs	-0.08 (1.05)	-0.07 (0.84)	-0.15
Index of leader's contact with agricultural extension	-0.04 (0.50)	-0.08 (0.95)	-0.10
Number of cases	132	132	132
F statistics	5.46	5.10	
R square	0.33	0.33	

Source: India Survey, 1980.

*Significant at 0.05 level. Coefficients are standardized bs; t statistics are in parentheses.

inputs are also important and should not be neglected. For example, diesel engines certainly are a viable alternative to rural electrification as a power source for pumping, especially for countries with indigenous oil reserves such as Indonesia. Credit and literacy also are important for improving farm practices. But even after controlling for other key inputs, rural electrification certainly seems to have played a significant role in helping to change farm practices in India.

RELATIONSHIP OF FARMING PRACTICES TO AGRICULTURAL YIELDS

The second stage of the analysis examined the relationship between farming practices and crop yields. Both the village leader survey and the village information survey had questions on crop yields per acre.[6]

For developing countries the yield per acre and yield per person are quite distinct concepts. Yield per acre in many cases reflects an intensification of traditional farming methods. As population density increases, farms may divide into smaller units, thus working the land harder in order to support a larger number of people (see Geertz, 1963). On the other hand, yield per person is more of an indicator of capital improvements in agriculture. As more and more machines replace labor, yields per person are improved. But it is quite possible that with the application of more labor to obtain greater yields per unit of land, the yield per person nevertheless could remain constant.

The three farming practice variables which could have a direct impact on crop yields are multiple cropping, irrigation, and agricultural innovation. Agricultural innovations and multiple cropping both relate positively to all four indexes of agricultural production (table 3.6).[7] The surprising finding is that after controlling for the levels of agricultural innovations and multiple cropping, percentage of area irrigated is not significantly related to crop production.[8] The conclusion from these findings is that, as would be expected, farming practices do have a positive impact on agricultural productivity. Villages with higher levels of innovation and multiple cropping also have higher crop yields. Over the long term, a change in

Table 3.6 Regression of Relationship of Yield with Levels of Irrigation

	OLS Regressions			
	Yield per acre		Yield per capita	
	Official	Leader	Official	Leader
Percent of land irrigated	0.03	0.07	-0.11	-0.08
	(0.37)	(0.84)	(1.08)	(0.84)
Use of agricultural innovations	0.27*	0.42*	0.22*	0.30*
	(3.35)	(5.47)	(2.45)	(3.38)
Percent of land multiple cropped	0.40*	0.28*	0.31*	0.24*
	(4.50)	(3.32)	(3.12)	(2.42)
Number of cases	128	128	128	128
F statistics	19.17	24.54	7.18	7.99
R square	0.32	0.37	0.15	0.16

Source: Survey, 1980.

*Indicates significant at 0.05 level. Coefficients are standardized bs; t statistics are in parentheses.

Note: Two different measures of yields are available from the survey. Official estimates are collected from the village records. The leader estimates are from the Village Leader Survey. As indicated, the agricultural innovation index also is a proxy for labor input.

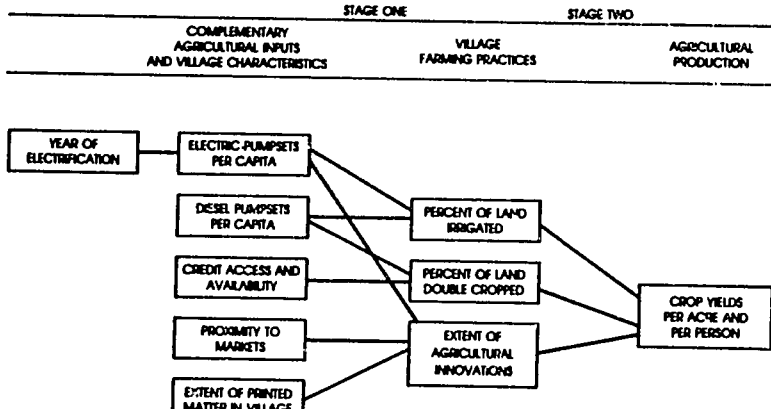
village farming practices leads to an improvement in crop yields, which also can have spillover effects on farm incomes and regional levels of development.

The finding that irrigation is not strongly related to crop yields once levels of agricultural innovations and multiple cropping are held constant is counter to our hypothesis and requires some further explanation. As indicated previously, the second crop of the year generally is grown during the winter season, a period when there is very little rain but the water table is still high. Given the association between irrigation, innovations, and multiple cropping, it would be wrong to conclude that irrigation has nothing to do with crop productivity. It might be better to consider multiple cropping, innovations, and irrigation variables as an interrelated set of farm practices associated with agricultural yields.

This study finds that rural electrification in India significantly contributes to village-level agricultural development, even after taking into consideration such important factors as diesel pumps, traditional irrigation, markets, access to communication facilities, and availability of credit. Rural electrification has an impact on the area irrigated and agricultural innovations. The findings from the regression equations suggest a two stage model of agricultural development, as illustrated in figure 3.5. Rural electrification and the other factors in the left hand column are related to the interrelated set of factors in the middle column, which include agricultural innovation, multiple cropping, and extent of irrigation. These factors in turn are related to agricultural yields. Thus, rural electrification certainly is not the only factor affecting farming practices; the others include the existence of rural markets, credit, diesel pumps, and access to printed information.

In India, rural electrification plays an important role in stimulating agricultural productivity. But rural electrification programs which would not also emphasize water pumping, or which would not involve new agricultural technologies such as hybrid seeds, would have much less chance for improving agricultural productivity, as was the case in Indonesia and Colombia.

Figure.3.5 Diagram of Rural Electrification and Other Inputs Which are Positively Associated with Agricultural Development, India, 1980.

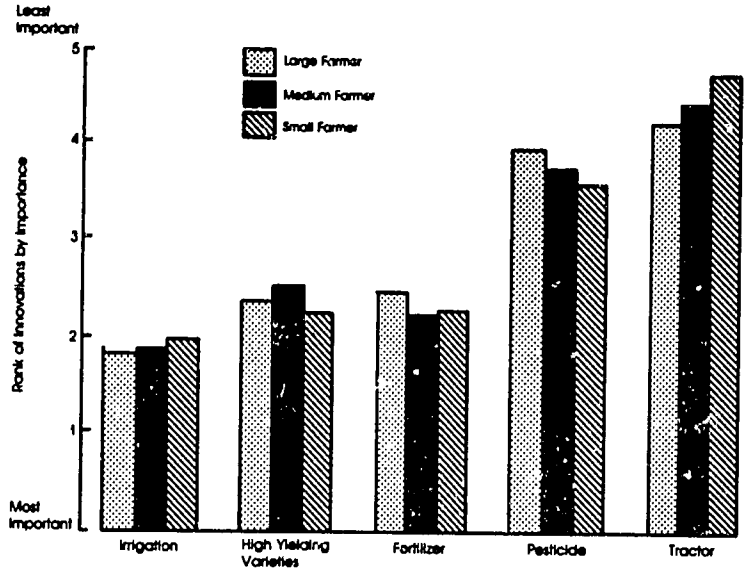


Source: India Survey, 1980.

EVIDENCE AT THE FARM LEVEL

A set of more subjective questions on farm practices answered by farm households tends to confirm the link between irrigation and crop yields (see figure 3.6). The farmers were instructed to rank according to importance five agricultural inputs: irrigation, high yielding varieties of seeds, fertilizers, pesticides, and tractors. The farmers chose irrigation as the most important input. Although irrigation can improve agricultural yields without the other inputs, it is almost a necessary condition for the use of high-yielding varieties. Therefore one should not be too surprised that hybrid seeds and fertilizers are second in importance, followed by pesticides. Pesticides are not used as widely in India as fertilizers or hybrid seeds. However, all of these inputs are now utilized extensively, especially in areas where irrigation is possible.

Figure 3.6 Rank of Agricultural Innovations by Farmers, India 1980.



Source: India Survey, 1980.

Note: Each Category Contains Approximately 50 Farmers and There is no Statistical Difference Between Groups for the Same Innovation.

Tractors were considered the least important agricultural input. For particular regions in India, tractors are still not a profitable investment. For instance, in regions with small farms and paddy rice, which are labor intensive, tractors would not be as useful as for regions growing wheat and other crops. Also, there are few remaining areas where massive reclamation of land is possible through tractor use (see Binswanger, 1978, p. 74). However, in regions such as the wheat-growing Punjab, tractors are useful because they decrease the drudgery involved in farmwork and are used as farm transport. They also may be important where farm labor wages are rising, especially at harvest time. Most farms in India are not yet at the stage where tractors are extremely valuable inputs, as is indicated by the farmers themselves. In fact, given the farm size in India, the power tiller may be a more appropriate technology than tractors.

Due to the importance attached to irrigation, the farmers were asked what source of energy they preferred for irrigation pumping. More than 90 percent of the farmers overwhelmingly preferred electricity for agricultural pumping in spite of the much smaller percentage of the farmers in the sample that had access to electricity. Their preference for electricity probably may result from the subsidies for electricity prices for agriculture and the minimal maintenance required by electric pumps.

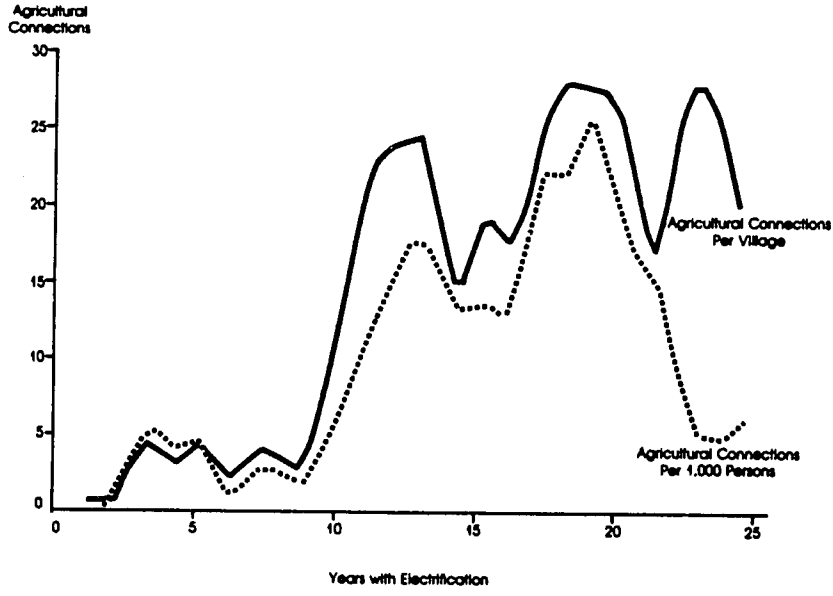
GROWTH OF ELECTRIC AGRICULTURAL PUMPS

Rural electrification is related to agricultural productivity, but this may be a two-way relationship. Wealthy villages with high levels of agricultural production may be better able to bear the financial burden of purchasing pumps, digging wells, and paying for the operating costs of the pumps. A close examination of the growth of electric pumpsets will help to determine whether agricultural innovations are causing the growth in pumpsets or vice versa.

In the agricultural sector, the growth of electric pumps is mediated by a number of factors. The number of agricultural pumps in a region usually does not increase dramatically during the first few years after a village receives electricity, as farmers may wish to wait and see the impact of capital investments made by other farmers before adopting an electrical pumpset themselves; this is called a demonstration effect. The installation of an electric pumpset also may mean abandoning an already used method of irrigation, such as a diesel engine, Persian wheel, or a canal. Additional costs might also result from irrigation investments, including field leveling and construction of irrigation ditches. Because the adoption of an electric pump might mean dismantling, selling, or simply not utilizing an old irrigation method, the farmer may be unwilling to abandon his current irrigation practices unless or until his existing system depreciates physically or becomes highly uneconomical.

The growth rates for agricultural pumpsets and electrical connections confirm that investment in electric pumpsets is a slow and cumulative process. The line in figure 3.7 represents

Figure 3.7 Agricultural Connections by Village Year of Electrification, India, 1980. (3 Year Moving Averages for Villages in 1980 Sample)



Source: India Survey, 1980.

the average number of electric pumpsets by year of electrification for the villages in the study. Only those villages having agricultural connections have been included, on the assumption that those without electric pumpsets either do not yet have electricity or may have other constraints such as a low water table. The figure indicates a slow but steady increase in agricultural pumpsets after village electrification; i.e., the villages with a longer history of electrification have a larger number of electric pumpsets. For the total sample of 76 villages with agricultural connections, the mean growth rate of connections of pumps per year is 1.24.[9] Thus, for an average village in the sample, a little over one connection per year is added for every year of electrification.

It is quite important for the agencies providing rural electrification to be able to forecast the expected connection rates and hence the cash flows that will be derived from ex-

tending electricity to particular types of villages. Also, a major question for these agencies is whether they should intensely electrify a few villages with favorable conditions for agricultural growth, or whether they should follow a strategy of electrifying a large number of villages. The relationship between initial village conditions in 1966 and the number of agricultural connections for villages with agricultural pumpsets was examined through a regression analysis. Unfortunately, groundwater availability data were not included in this study. Also, the price of electricity is not included, because the rates are virtually the same for the different states. However, we have limited the sample to those villages with at least one agricultural pumpset, which would mean that there is sufficient groundwater for at least one pumpset.

For the 1966-1980 period, only year of electrification has a positive long-term impact on the growth of connections. The longer a village has been electrified, the greater the number of agricultural pumpsets (table 3.7). A significant negative finding is that regions which started out in 1966 with a significant amount of double-cropped land had a lower than average number of agricultural pumpsets by 1980. This means that the regions without already well-developed irrigation networks seem to be better environments for the growth of electric pumpsets. Alternative irrigation systems such as canals or diesel engines are a hindrance to the adoption of electric agricultural pumpsets. In promoting electric pumps for agricultural use, planners should thus avoid villages with extensive irrigation systems already in place. They should also be concerned with whether adequate credit is available for investment in pumpsets and wells.

Interestingly, agricultural innovations in 1966 are not related to the 1980 levels of agricultural pumpsets. This finding is significant in the context of the previous section, which found a positive correlation between rural electrification and 1980 levels of agricultural innovations. It would appear that previous levels of agricultural innovations are not strong determinants of the subsequent number of agricultural connections, which would mean that *rural electrification may be an important cause of agricultural innovations.* The reasoning is that innovations and rural electrification are associated over the long term (see Barnes and Binswanger, 1986, for a more rigorous panel analysis). Since innovations would not seem to be a long-term cause of growth in agricultural connections, one

Table 3.7 Multiple Regression Between 1980 Total Number of Electric Pumps and Village Characteristics, India, 1980

	1980 Total electric pumps	
	OLS regression	Pearson's correlation
Years since village electrification	0.53*	0.57
Yield per acre, 1966	-0.13 (0.73)	0.05
Level of agricultural innovations, 1966	-0.02 (0.12)	0.03
Percent of area cropped more than once, 1966	-0.32* (2.28)	-0.38
Man/land ratio, 1966	0.10 (0.71)	0.08
Diesel engines per capita, 1966	0.06 (0.40)	0.18
Number of cases	37	
F statistics	3.97*	
R square	0.44	

Source: India Survey, 1980, 1966.

*Indicates significant at less than the 0.05 level. Coefficients are standardized bs; significant t statistics are in parentheses.

could speculate that high levels of agricultural innovations may be directly attributable to rural electrification.

SUMMARY AND CONCLUSIONS

The India study indicates that the productive impact of rural electrification is to promote agricultural pumping and, to some extent, agricultural innovations. Agricultural innovations and double-cropping, in turn, are associated with improvement in agricultural yields. The implication is that rural electrification, through its impact on agricultural pumping and use of agricultural innovations, has a net positive effect on agricultural development in Indian villages. India's policy of subsidizing rural electrification does seem to be having a positive impact on agriculture. Although it is probably true that electricity from coal and hydropower is being substituted for

diesel power, diesel engines are still quite prevalent in rural India, and they also are positively associated with factors leading to improved agricultural yields.

Some interesting observations can be made about government policy and the agricultural impact of rural electrification in India as compared to Colombia and Indonesia. Neither Colombia nor Indonesia has attempted to improve rural productivity through rural electrification, either through agricultural pumping or through driving other farm machinery. In contrast to India, neither country has programs to promote the use of electricity in agriculture. In Colombia very few farmers have pumps for irrigation, and the use of improved varieties of seeds is negligible. In Indonesia some of the tobacco farmers were unaware that electricity could be used for irrigation pumping and expressed a desire for diesel pumps. Of course, the rural electrification schemes had only been in operation a short period of time in Indonesia, and, as the India study indicates, growth of agricultural pumpsets is a slow, cumulative process. Also, kerosene and diesel are subsidized in Indonesia, which may inhibit any switch from diesel oil to electricity for agricultural pumping.

The impact of rural electrification in India as compared to Colombia and Indonesia indicates that positive impacts of electricity may be determined by government policies, complementary development programs such as improved agricultural inputs, and perhaps unique regional characteristics. Needless to say, the irrigation approach adopted by India is not applicable to all countries, because of climatic and geographical differences. Rural electrification programs offer substantial opportunities for agricultural development, but such opportunities for productive uses may be hampered by failure to implement complementary programs. To increase the productive impact, in some countries more concerted effort may be needed to coordinate rural electrification with other relevant programs.

NOTES

1. In this chapter we define agricultural development as improvements in crop productivity per unit of land area or per unit of labor. Therefore, the tertiary industries connected with agriculture are not included here, but they will be included in the next chapter, which is devoted to industrial development.

2. Four of the Intensive Agricultural Development Programme (IADP) pilot districts are included in the India study samples as representatives of advanced agricultural areas. These districts are Ludhiana, Burdwan, West Godavari, and Bhandara.

3. The validity of all indexes for the study has been tested through factor analysis. A principal components factor analysis was performed for all subscale variables in order to determine how well a single factor or continuum could summarize all variables. For example, in the case of contact with extension agents the correlation between the five subcomponents and the principal factor ranged from .30 to .88. Also, only one factor was generated for the principal components factor analysis, indicating that the linear combination of the variables is justified. Instead of utilizing factor scores as the index, each variable has been given an equal weight by adding the values for the variables to provide an index for contact with extension agents. The same procedure is used to ensure the internal validity of, and to construct all other scales in, the analysis.

4. For the purpose of this study, the percent of area irrigated is total land irrigated divided by cropped land (including area cropped for more than one season). Multiple cropping is the percentage of land area that is farmed more than one season.

5. The correlations for diesel engines per capita and for electric pumpsets per capita with percentage of irrigated land are both quite strong at 0.64 and 0.54, respectively. Even more remarkable is the finding that there is a strong association between the number of years since a village has had electricity and percentage of irrigated land, with a correlation of 0.30. The same pattern generally holds true for multiple cropping.

6. The crop yield variables from the village information survey were collected either from existing records

in the panchayat or block offices or from estimates by knowledgeable officials. The leader's yield per acre index was constructed from the village leader survey, which asked the village leaders to estimate their village's average yield of the three major crops. Their responses were utilized to construct the leader yield index. Thus, from the village level survey and the village leader survey it was possible to construct two yield per hectare and two yield per person indexes. The agricultural production indexes were constructed by multiplying the crop yields per acre by an average crop price for the districts in the study. The resulting value per acre figures were weighted according to an index of the percentage of land area covered by each individual crop. The index is the average rupee value of crop production per acre in the sample villages. It is encouraging that the leader and village indexes of crop production are highly correlated at 0.86, indicating a high degree of reliability of the answers to survey questions.

7. The agricultural innovations index contains measures of village leader use and evaluation of the effectiveness of fertilizer, green manure, new implements, and improved seeds. Thus, it is an index of relative innovation in the village. Although labor was not measured, a high level of innovation use in the index would mean greater labor intensity. Since this is a village-level analysis, it would be difficult to quantify labor input.

8. The coefficients for agricultural innovations range from 0.22 to 0.42, and all are significant at the .05 level. The coefficients for multiple cropping are quite similar, ranging from 0.24 to 0.40. But none of the coefficients for the percentage of area irrigated (ranging from -0.11 to 0.07) are significant.

9. The line indicates that this average growth rate per year fluctuates somewhat from year to year, but the rate of growth increases after about 9 years of electrification. The number of connections added per year by the villages electrified 9 years or under is 1.08, and for those electrified 10 years or more the rate is higher at 1.34.

4
Rural Electrification and Productivity in Small-Scale Industries and Commerce

Industrial development today is almost inconceivable without electricity. In industrialized societies and developing societies alike, electricity is the energy that drives the great maze of industrial machines. It would seem obvious that electricity is necessary for the development of industry. But our question centers specifically on whether rural electrification will bring about the development of *decentralized industries*, so that economic benefits will accrue to people living in rural areas. Will new industry and commerce relocate to or develop in rural areas once they receive electricity? Are industries with electricity more productive than the industries without electricity already in rural areas?

Advocates of rural electrification contend that electrification is a necessary precondition for the development of rural industry and commerce and that it will provide employment, improve rural incomes, and lead to growth in rural areas which will counteract the present trend of massive growth in urban areas. According to their view, rural industries stimulate the growth of small towns and growth centers distant from the major cities, bringing essential services to rural areas. These predictions parallel some interesting observations in a 1920 essay on the potential impact of electrification on factory location in America (Bradford, 1925, pp. 91-95).

> The effect of cheap [central grid] power...is likely to add somewhat to the movement of factories away from the great cities and to change the map of our industrial power-using centers by adding to the number of small and medium-sized manufacturing cities and towns....The massing of population in urban centers, which is partly a result of the urban locations of factories, will also be

> affected by cheap power. Central grid power will operate almost certainly as a force making for decentralization. With the factories as they move to the country will naturally move also the workers who formerly clustered at the mill gates in the city, and with this spreading out of population will disappear some of the ills that come from having too many families per acre of ground.

Today advocates would add that electricity will also stimulate the development of new industries in rural areas.

The critics counter that the record to date of small-scale industrial and commercial development in the rural areas with electricity has been poor; the growth of rural industries in developing countries simply may not parallel the experience of the United States or other now developed nations. Electricity has not produced the bonanza of growth conceived by the rural electrification planners. The industries that have been established are predominantly grain milling units, which could be powered by diesel engines rather than electricity from a centralized grid. According to critics, industry should not locate in rural areas until such problems as inadequate transport and communications facilities are alleviated. Larger towns and factories can be provided with electricity without placing the nation and its utilities under the financial burden of covering the whole country with an expensive power distribution system. Alternative energy programs for rural areas may be a more appropriate and less expensive energy strategy.

However, by failing to extend electricity to rural areas, much development potential may be lost. John Mellor (1976) argues for an employment-oriented decentralized strategy of growth for developing nations, premised on large investments in rural infrastructure, including electricity. The development of urban large-scale factories without comparable investments in rural areas might result in the uneven development patterns typified by the so-called dual economies observed in many Third World countries. According to Mellor, direct investment in public services that will facilitate small-scale industrial and commercial growth actually should have precedence over the construction of large-scale factories.

This chapter presents the conclusions from the surveys conducted in India, Colombia, and Indonesia. Rural electrification programs were found to have an impact on the develop-

ment of small-scale industries and commerce. Rural industry growth rates were noticeably higher for villages with electricity than for those without it, although the number of businesses in rural areas still remained somewhat low. For instance, in India there were on average less than two industries per village. The conditions determined to be conducive to the growth of industry and commerce include adequate markets and credit and a high rural literacy rate.

PROFILE OF RURAL BUSINESSES

Rural commerce and industry in India, Indonesia, and Colombia are typical of those in many areas of the developing world; food processing, commercial shops, and repair shops were the principal businesses identified in the study (see table 4.1). Of the three countries, Indonesia had a greater diversity of shops and manufacturing firms, reflecting the high level of development in the specific region sampled. The business sample in Indonesia was the most comprehensive of the three studies, including a census of all 131 businesses in the area studied. These businesses include manufacturing, services, food, and commercial businesses. A few examples of the types of businesses are furniture making, rice milling, sawmills, and general stores. Almost all of the businesses in the sample adopted electricity when it became available. Therefore, the Indonesian analysis can best be described as an assessment of the short-term benefits of electrification for a relatively advanced region. However, these short-term benefits may persist over time and may well turn out to be long-term benefits.

The Indian study surveyed industrial establishments but did not include India's traditional caste/artisan occupations. Blacksmiths, potters, weavers, carpenters, and leather workers make up the caste occupations typical in Indian villages, and these traditional occupations, which in many instances are one-family businesses, have been the focus of many ethnographic studies. The Indian survey covered only flour mills; food services, including bakeries; sawmills; and other industrial and commercial units. Almost nine out of ten of the industries sampled in India were grain processing firms.

Table 4.1 Business Types in India, Indonesia, and Colombia, 1980

Type of industry	Percent of total industries
1. India (total census of village industries)	
Grain processing	87.4
oilseed crushing	9.8
Cotton ginning	9.8
Pulse processing	9.1
Food services (including bakeries, etc.)	4.9
Saw mills	4.9
Others	3.5
Commercial establishments	n.a.
2. Indonesia (total census of village industry, services, and commerce)	
Manufacturers	36.6
Furniture (wood or metal), tailors/ready-made clothing, building materials, ice makers, pottery, bamboo mats, nets, printer, plastic bags, jeweler	
Services	16.0
Sawmill, rice huller, battery charger, builder, radio repair, car repair, bicycle repair, tailoring services	
Agricultural/food	23.7
Food (bread, tofu, etc.), tofu refiner, milk producer, tobacco curer	
Commercial	30.0
Wood store, restaurant/tea shop, general store, private savings and loan company, outlet for purchasing tobacco leaves	
Other	1.0

Table 4.1 (Continued)

3. Colombia (community survey)	
Industry	36.8
Workshops	6.5
Mills	2.9
Carpentry	10.7
Brick factories	8.9
Sugar mills	5.6
Other	2.1
Commerce	63.2
Stores	16.0
Bakeries	1.4
General stores	12.3
Bars/canteens	11.0
Tailors	9.4
Other	3.0
Services	n.a.
Gas station, lawyer, boarding house, repair shop, private lender, drug store, doctor, midwife, market, commerce (local production), clothing shop, agricultural input stores	

Source: India Survey, 1980; Colombia Survey, 1980; Indonesia Survey, 1980.

Note: n.a. stands for not available.

The household survey in Colombia found that many households owned some kind of business or shop. The majority of businesses were commercial shops selling such goods as cigarettes, sodas, beer, bread, food, and kerosene. There were a significant number of specialty shops in the communities, selling such items as baked goods, ice, and work clothes. A small percentage of the sample businesses were engaged in artisan activities and repairs. A large number of the businesses, ranging from fishing to small coal mines, could not be easily classified.

Business Development Patterns in India and Colombia

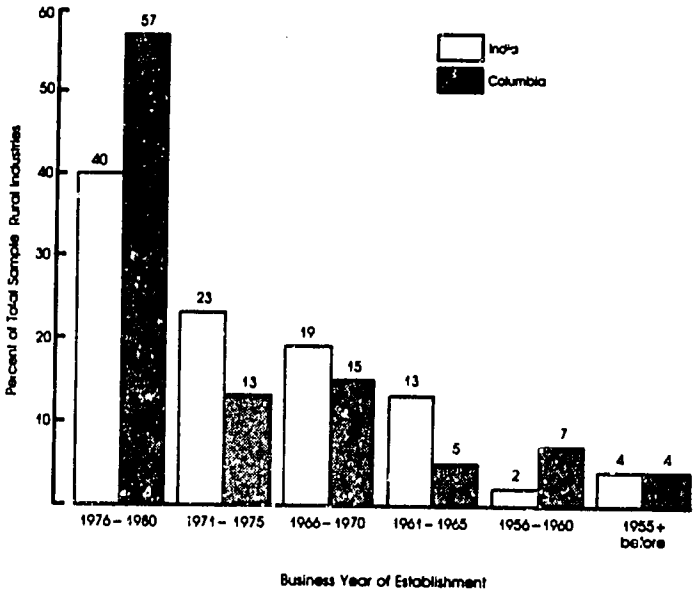
Many previous studies of the impact of electrification on rural businesses have been criticized because they survey only existing industries, thus leaving out those that have gone out of existence. Because previous surveys on industries were not available, this study too has only been able to analyze existing industries. As a way of circumventing this difficulty, the year in which the existing businesses were established was collected for India and Colombia in order to determine the rate of business establishment for particular time periods. Since the Indonesian communities had had electricity for such a short period of time, the pattern of business development was not examined.

The development of small businesses should be viewed as a natural part of the dynamic development process. Developing rural businesses typically are extremely small, and many are family-run establishments that change owners and sometimes go out of business after a few short years. Most businesses in India and Colombia were started during the last 5 to 10 years, suggesting, as expected, that there is a high turnover rate of rural businesses (see figure 4.1), as is also the case in developed countries. Because the sample for Colombia includes commercial shops as well as small-scale industries, the percentage of businesses started during the last 5 years there was even higher than for India. But it is remarkable that 15 percent of businesses in India and Colombia have survived for 15 years or longer.

Village electrification is positively associated with business development. For India, the start-up year for industries was highly related to the year of electrification of the village. As is illustrated in figure 4.2, when year of electrification is controlled, the post-electrification era for the villages has a higher level of industrial activity. During the first 5 years after electrification, over 38 percent of the village industries still operating in 1980 were established.[1] Even after the fifth year of electrification, there was still a higher level commencement of businesses than during the pre-electrification period.

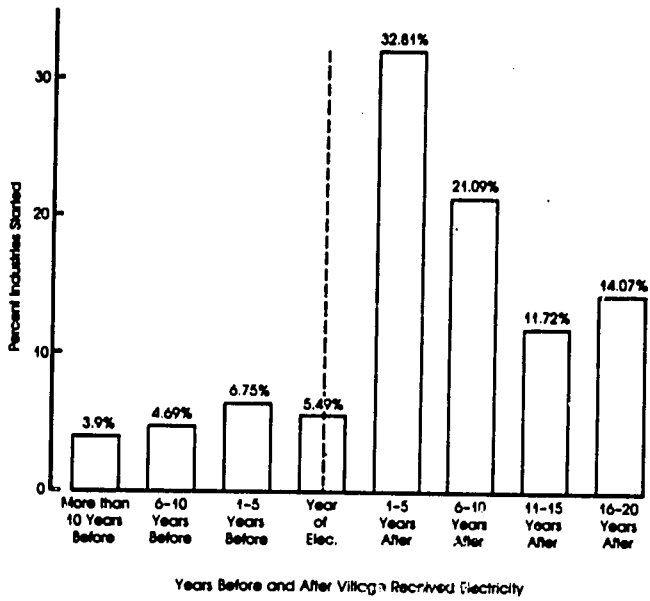
The increase in business activities also is reflected in employment patterns for the villages. By 1971 about half of

Figure 4.1 The Year of Establishment of Existing Businesses, Colombia, India, 1980.



Source: India Survey, 1980. Colombia Survey, 1980

Figure 4.2 Year of Business Establishment Adjusted For When Village Received Electricity, India, 1980.



Source: India Survey, 1980.

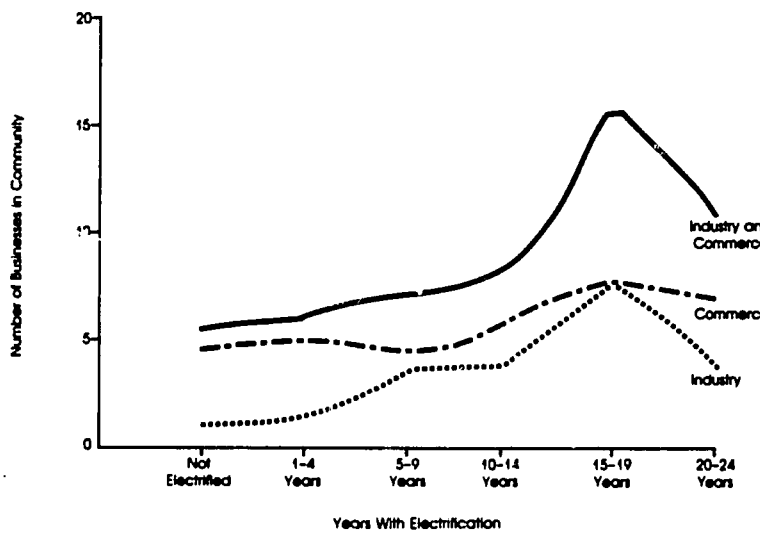
Note: Sample Base: 128 Industries.

the villages in the India sample had received electricity. As of 1971 twice the percentage of workers were employed in industry in the village sample with electricity as compared to the villages without electricity (6 percent compared to 3 percent). Interestingly, household manufacturing also proved to be positively associated with electrification, which suggests that the advent of new industries in the villages had not negatively effected home industries. Only in the Punjab, which has more specialized industries, were there fewer people employed in household industries within villages with electricity. The conclusion is that in India rural electrification has stimulated the development of rural industry and that in two similar regions,

one with electricity and one without, the area with electricity will have more business activity.

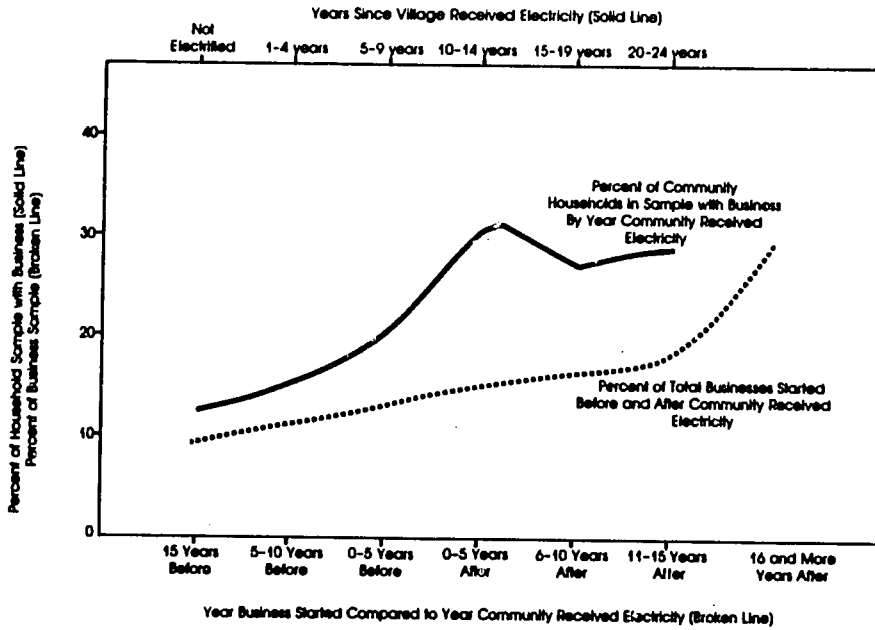
For Colombia the relationship between electrification and business activity is similar to that in India. Even though the absolute level of business activity is somewhat low in Colombia, three different analyses have confirmed that the longer a community has had electricity, the higher its level of business activity (see figures 4.3 and 4.4). First, the absolute level of industry and commerce is positively associated with year of electrification. Second, percentage of households with a business is higher in villages with electricity and tends to increase over time. Finally, most of the businesses in the sample were started after the community received electricity, as is illustrated by the dashed line in figure 4.4. The findings of this study are consistent with findings from several studies in the Philippines (see Costas, 1982; Madigan, 1981, pp. 12-14).

Figure 4.3 The Increase in Rural Industries by Years of Electrification, Colombia (Community Survey), 1980.



Source: Colombia Survey, 1980

Figure 4.4 Increase of Rural Businesses with Rural Electrification, Colombia (Household Survey), 1980.

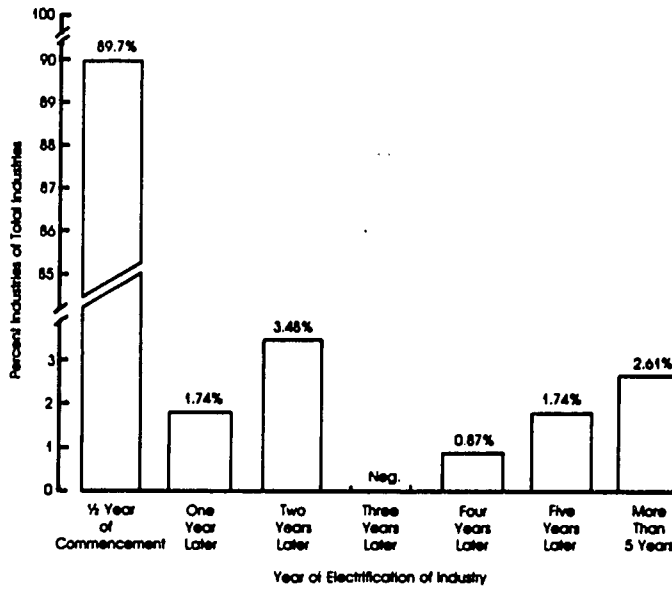


Source: Colombia Survey, 1980

Electricity Use in Businesses

The response of business to electrification appears to be quick and dramatic for rural industries. In India when villages have electricity virtually all industries commence operations with electricity (see figure 4.5), and as more villages receive electricity more industries start up using electricity. During the 1961-1965 period only 7 out of 10 industries began operations with electricity, while during the 1976-1980 period, when electrification programs were more intensive, the figure rose to 9.6 out of 10.0. Thus it is virtually guaranteed that in a village with electricity a new industry will start with electricity. Likewise, in the villages with electricity in Colombia, 9 out of of 10 businesses had adopted electricity, either by starting with or switching over to electricity, compared to only one

Figure 4.5 Electricity Adoption by Existing Industries (Percent) in Relation to Year Village Receives Electricity.



Source: India Survey, 1980.

Note: Sample Base: 128 Industries.

(presumably with electric generators) out of 20 in communities that had not yet received electricity. The same pattern was found in Indonesia, where most businesses adopted electricity within one and a half years after the region came under the rural electrification program.

The evidence is quite persuasive that business development is enhanced by electrification programs. Although the number of rural industries per village is still low in India and even in Colombia (at about two per community with electricity), rural businesses do appear to be taking advantage of electricity for lighting and other end uses. In Indonesia almost all of the businesses use electricity for lighting, but electricity's replacement of diesel engines for driveshaft power is less common, primarily because of heavy diesel subsidies in Indonesia.

INTERVILLAGE AND INTERFIRM COMPARISONS

Electricity can light shops to extend the business day and can power machines such as grain mills, but although the value of electric power for industry is well known, there have been very few comparisons between firms with and without electricity. The benefits of electricity actually should be easy to observe and identify for rural firms.

The previous section established that in villages with electricity almost all shops and industries adopt electricity once it is available, and in addition there are more businesses in villages with electricity as compared to those without electricity. To further evaluate the effect of electrification on businesses, an analysis of the benefits of electrification at the firm level is necessary. For India we are able to examine the profile of firms with and without electricity for both household and nonhousehold industries. For Colombia and Indonesia, owners of the firms with and without electricity were asked questions on the utility of electricity.

Indian Small-Scale Industry and Household Manufacturing Firms

Village leaders in the India survey were asked the question, "What has been the consequence of rural electrification on industrial growth?" The answer of seven out of ten leaders was that the impact had been significant. Although the number of industries in Indian villages is still somewhat low, the subjective impression of the leaders is verified by an examination of the differences between firms in villages with and without electricity. The villages with electricity tend to have more industries and more industrial employees, and the firms have lower fuel costs, higher labor productivity, and a greater diversity of processed or manufactured products (see Samanta and Sundaram, 1983, p. 142). However, one problem with comparing villages is that both firms with electricity and a small number of firms without electricity are present in the villages that have electricity.

Direct comparisons between firms with and without electricity are necessary to clarify some of the benefits of electricity (see table 4.2). On average, the capital size of firms

Table 4.2 Basic Comparisons Between Electrified and Nonelectrified Industries, India, 1980 (mean for firms)

Variables[1]	Electrified industry	Nonelectrified industry
Size of industrial capital (Rs.)	39,536	18,142
No. of full-time employees	2.68	2.14
No. of part-time employees	0.20	0.10
Capital productivity	0.77	1.01
Labor productivity (Rs.)	10,964	8,367
Capacity utilization (percent)	31%	33%
Fuel cost to total (percent)	53%	69%
Net return on gross fixed assets	44%	32%
Product diversity coefficient	2.46	1.57
No. of industries[2]	122	21

Source: India Survey, 1980.

[1]Definitions of variables: Size of capital is equal to the gross fixed assets, including land and buildings, in rupees. Capital productivity is the ratio of gross sales (in Rs.) to gross fixed assets (in Rs.). Labor productivity is gross sales (in Rs.) per unit of labor input. Labor input is estimated as number of full-time employees plus half the number of part-time employees (assuming it to be the statistical average of employment input of a part-time employee). Capacity utilization is the production in 1979-80 as a ratio of capacity, on a one-shift basis. Percent fuel cost to total cost is the cost (in Rs.) incurred for all sources of energy except human and animal labor, as a percentage of total operating expenses (in Rs.). Net return on gross fixed assets is equal to total sales--total costs divided by gross fixed assets. Product diversity coefficient is the ratio of all products manufactured across all units divided by the total number of units.

[2]The sample base for each indicator differs slightly.

with electricity is almost twice as large as that of firms without electricity, reflecting greater investment in equipment. Because of the greater size, more workers are employed in firms with electricity. Labor productivity is higher, probably because capital is substituted for labor in firms with electricity, so the machines improve the productivity per worker. Fuel costs as a percent of total firm costs are lower in firms with electricity in spite of the fact that electric rates for rural industries are three times as high as for agricultural pumping which is heavily subsidized. The smaller firms without electricity tend to use less fuel than the larger ones but apparently are less efficient in their use of energy per unit of cost. For the smaller firms without electricity, fuel costs make up a considerable part of the overall cost of operation. While grain processing was still the major service provided by the surveyed industries, both for those with and those without electricity,

the products of the firms with electricity tend to be somewhat more diverse. Thus the findings for the village level are confirmed by the comparison of industries.

Household manufacturing or cottage industry is sometimes considered to be in competition with commercial industry. One classic example of this competition is from the late nineteenth century when India exported cotton to Great Britain. The English mills manufactured the cotton into cloth and then returned the finished product to India, where it enjoyed a substantial price advantage over the domestically produced cloth. In many places household cloth manufacturers were virtually eliminated. There is concern that the introduction of more capital-intensive industries with electricity into villages might eliminate labor-intensive cottage industries. While this may occur over the long run, the comparisons made between cottage industries with and without electricity reveal that electricity seems to benefit household manufacturing. Although there were only a small number of cottage industries in the India survey (67), most of the cottage industries with electricity had extended hours and improved income for their rural households. Superior lighting is the major impact of electrification for home industries, rather than the use of appliances or power tools. Thus, there was no demise of cottage industries for the villages in the sample, at least over the short run.

Indonesian and Colombian Business Comparisons

Comparisons between businesses with and without electricity were not possible for Indonesia and Colombia. Instead, business owners were asked a series of questions concerning electrification. Most businesses in the Indonesian sample had received electricity during the previous year and a half, so the owners should have been able to evaluate the short-run impact of electrification. In Colombia most of the businesses had been established recently, so that the owners could easily reflect on the difficulties they might have encountered starting the business without electricity.[2]

Businesses develop and improve for many reasons. In Indonesia the owners were asked specifically whether electric-

ity had provided the basis for business development, and for Colombia the question specifically asked how the businesses had developed (see table 4.3). In Colombia just less than half the sample reported improved sales and business conditions, and a significant percentage of the businesses were using new equipment. In Indonesia about half of the businesses indicated that they had "developed" due to electricity. The results indicate that some new business had developed over and above what would have existed if electricity had not been introduced into the area. However, are these figures for Colombia and Indonesia high or low? After all, they show that about half of the businesses did not develop with electrification. Access to electricity is not the only factor that is necessary for the development of a viable business sector. Market conditions, access to credit, relative prices of the products sold, and other factors can affect business improvement or decline.

The specific end uses of electricity for business development included such things as lighting, refrigeration, motors, and ovens. The productive uses of electricity for business are presented in table 4.3. In Indonesia the various types of businesses used electricity in quite different ways. The service and manufacturing industries made use of electric appliances; commercial establishments benefited from indirect community changes, such as improved security and economic conditions; food shops used electricity primarily for lighting. In the evaluation of productive uses of electricity in Colombia, the respondents identified the activities that would have to be eliminated if electricity were not available. Once again lighting proved important, as did a possible reduction in work hours and refrigeration. In all, two-thirds of the Colombian sample indicated that they would experience some difficulty in running or maintaining their businesses without electricity.

Table 4.3 The Benefits of Electricity for Rural Businesses, Indonesia and Colombia, 1980

Part A: Cited Advantages or Possible Improvements from Electricity

Indonesia: Types of advantages	Percent of electrified businesses	Colombia: Aspects of business that could be improved if electrified (combination first and second choices)	Percent of nonelectrified businesses
Better/more convenient lights	71.0	Lighting	54.8
Cheaper than other fuels	24.0	Refrigeration	56.3
New machinery possible	16.0	Motors	16.0
Extended work hours	19.0	Ovens/stoves	6.5
Improved security	9.0	Fans	14.3
Other	5.0	Machines	3.2
No advantages	10.0	Other unspecified	4.0
No. of cases	123 businesses with electricity		20 businesses without electricity

Part B: The Use of Electricity in Rural Business and Problems that Would Occur Without Electricity

Indonesia: Primary end use responsible for developing business (Sample of businesses that developed)	Service	Mfg.	Commercial	Agric./Food	Colombia: Problems that would occur without elec	Percent of electrified businesses
Lighting	33%	53%	58%	100%	Eliminate refrigeration	25%
Elec. Equipment	67%	47%	0%	0%	Work shifts reduced	29%
Indirect effects of community change	0%	0%	42%	0%	Eliminate sewing	0%
					Other	11%
					None	33%
No. of cases		43 businesses with electricity			107 businesses without electricity	

Source: Indonesia Survey, 1980; Colombia Survey, 1980.

Note: Percentages sum to greater than 100 because of multiple answers to the question.

The electrification of businesses in Indonesia did not lead to a significant increase in employment. The use of electric lights led to an extension of work hours in businesses with electricity (see Brodman, 1982, pp. 36-39), but this apparently did not result in any extensive hiring of new employees. Instead, the existing employees were asked to work longer hours. Employer-employee relations in these villages involve informal ties, which often include providing financial assistance when the employee is sick and the giving of gifts at holidays. On the other hand, the employee often must take over responsibility for running the business if the owner is absent

from the workplace. This mutual relationship leads to employee-employer confidence and trust. The consequence is that rather than hire new employees, the employer extends the work hours of current employees, and they are compensated by an increase in their salaries. Thus, the consequence of the close employer-employee relationship would be that the employer would not lay off the worker in bad economic times and also would not expand or hire new workers during good times.

Thus, the operation of machines or appliances in Indonesia by the small number of employees in the sample had not led to new employment or higher pay per hour even though it is likely that productivity had increased. But neither had the introduction of machines into the businesses caused any decline in the number of persons employed. Apparently the employers consider electrical equipment a means to improve productivity and product quality, and not much thought is given to cutting back on present employment. The consequence may be a greater income gap between the owners and the workers, but this could not be evaluated in the study.

GROWTH OF ELECTRICITY-USING BUSINESSES

The location of villages within a service economy might be a factor in the development of small businesses. Epstein (1970), in her classic work on the development of two villages in a recently irrigated region in South India, found that the village with newly irrigated land became economically more dependent on agriculture. By contrast, the village in the area which was not irrigated became a service center, acting as a connection between the agricultural village and the larger society. Wanmali (1982) has found that as a region advances, a hierarchy of service centers develops, including those providing higher and lower order services. This kind of specialization may result in an increase of pumps and agriculture-related items in some villages, while others may become commercial centers. Thus, village conditions for the growth of agricultural pumpsets appear quite different from the conditions necessary for the development of business and commerce.

Analysis of the potential for growth of electricity-using businesses was approached differently in India than Indonesia.

The Indonesian study examined the complementary conditions through interviews with businesses that had been able to use electricity productively. The Indian study covered the factors associated with greater than average growth of business electrical connections in villages with different socioeconomic profiles. Thus, the Indonesian study is based on a comparison of business conditions and the Indian study focuses on comparisons among villages. Unfortunately, for Colombia we have no information on the conditions for the growth of business.

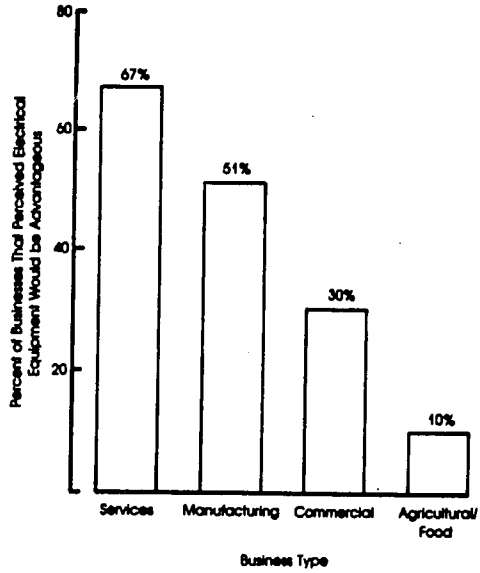
Complementary Conditions in Indonesia

While many of the businesses in Indonesia now utilize electricity, there still is tremendous potential to enhance productive activities (see Brodman, 1982). High tariffs and costly installation charges for electricity for small businesses that use driveshaft power discourage the use of electricity. Of the 27 businesses in the region that could use either electricity or diesel fuel for driveshaft power, 18 reported that the high electric installation costs made diesel engines preferable to electric motors.

The importance of the price of electricity is highlighted by the response of Indian and Indonesian grain mills to electricity prices. In India, an oil-importing country where diesel fuel is taxed heavily, most of the grain mills immediately switched from diesel to electricity. In Indonesia, electricity is not utilized extensively for motive power in grain mills because competitive fuels such as diesel are subsidized in this oil-producing country. Even with the high price for electricity, providers of services and manufacturers perceive electricity use as more advantageous than commercial and food businesses do (see figure 4.6). Thus in Indonesia most of the productive uses of electricity are for lighting, appliances, and hand tools, and this situation is not likely to change until diesel prices are raised or the electricity price is lowered.

Business development in the Indonesian villages has been inhibited by capital scarcity, poor product marketing

Figure 4.6 Percent of Businesses that Perceived Electricity to be Advantageous, Indonesia, 1980.



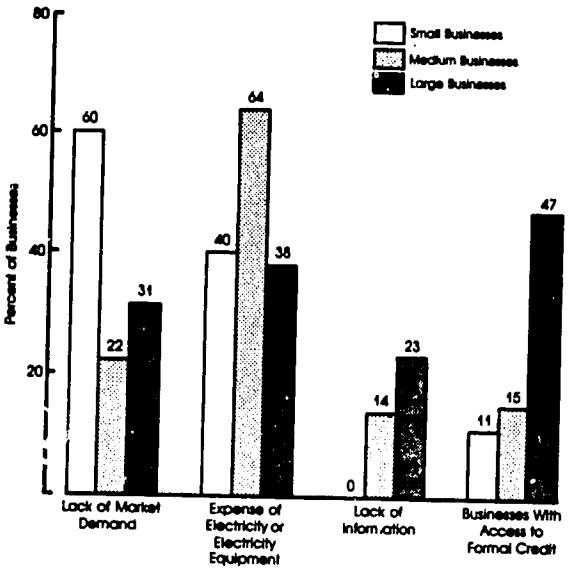
Number of Cases: Services = 18; Manufacturing = 45; Commercial = 30; Agricultural/Food = 30.

Source: Indonesia Survey, 1980.

channels, and inadequate information on electricity (see figure 4.7). While smaller businesses are able to increase profits from the use of electricity at about the same rate as larger firms, they do not have the same access to capital in the form of bank credit. One problem with existing credit programs for small and medium businesses is that most were in existence prior to electrification of the region. Therefore most of the credit programs have been oriented towards agriculture, and land has been a collateral requirement for most loans. As a consequence, small businesses do not qualify. This may be a short-term problem which will improve as the system adjusts to financing rural business. But planners should be aware that introducing electricity into an area may alter rural credit needs from predominantly agricultural to more business-oriented.

Marketing products is another limitation endemic to

Figure 4.7 Reasons For Not Using Electrical Equipment. Small Businesses Lack Market Demand and Credit, Indonesia, 1980.



Source: Indonesia Survey, 1980.

Note: Sample for Reasons For Not Taking Advantage of Electricity is 47 Cases; Sample For Credit Question is 123 Cases.

many small businesses, with or without electricity. Market opportunities for rural businesses in most cases center around agricultural goods and services and household domestic needs. In some instances marketing opportunities can be improved through programs such as cooperative marketing schemes, but in many cases success in marketing is related to the health of the local economy. Without a healthy rural economy the best marketing scheme is doomed to failure.

Rural electrification programs in the United States were accompanied by intensive information programs identifying the potential uses of electricity. By contrast, in Indonesia at the time of the survey businesses did not have any information on the comparative costs or maintenance required for electric motors as compared to diesel engines. Many large businesses were uninformed or misinformed about the potential uses of

electricity. The relative newness of the electrification program in Indonesia might be responsible for the inadequate distribution of comparative information on the advantages and/or disadvantages of electricity to date, but information dissemination might be a very cost-effective way to stimulate electricity use and rural production.

Two survey results from the Klaten area of Indonesia highlight the need for programs that complement electricity. Many businesses are now using and are still planning to use diesel engines for driveshaft power even though electricity is available, and some businesses indicated they would like to use electricity productively but cannot acquire the credit to buy the equipment. For Indonesia, the electrification schemes should be coordinated with credit, marketing, and/or information programs that address related needs of electricity-using businesses. Also, pricing policies for both diesel fuel and electricity need to be examined to determine what price levels would be most beneficial for the general economy.

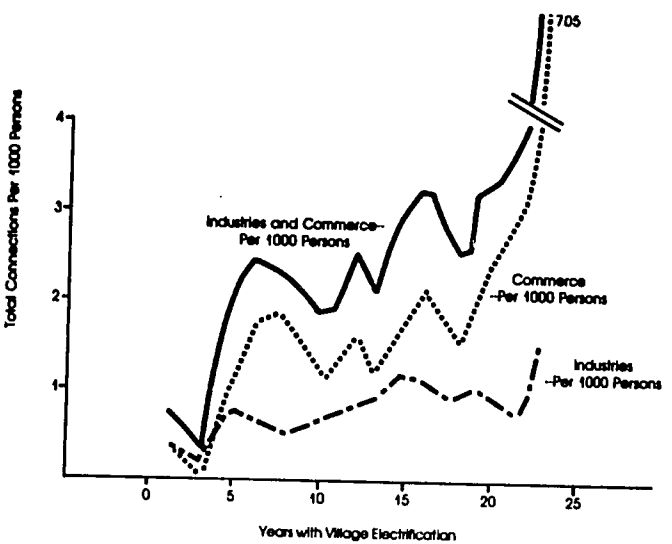
Business Connection Growth in India

Many studies on rural electrification and business development in India include an analysis of "central places" or growth centers (see Sen et al., 1974). Village industry and commerce tend to grow the fastest in villages that service surrounding villages (Small Industry Extension Training Institute, 1979). Business development may be retarded due to the absence of local entrepreneurship, delays in sanctioning connections, a lack of coordination between the utilities and other agencies, and/or an irregular supply of electricity (Jain, 1975). A report by the Center for Studies of Small Scale Industries (1979) confirms that inadequate capital, lack of credit, and uncertainty about sales and markets constrain the growth of rural industries. "Human" capital also may be essential for business development. The classic work by Schultz (1964) stresses the importance of education for agricultural development. Educated business owners may be more capable of operating and expanding their business, and an educated population may be a more favorable market for business products.

The analysis of business connections in India reveals that both "human" and "physical" capital are important for growth of rural businesses. Villages with a longer history of electrification have a higher level of industry and commerce (see figure 4.8). As was indicated, after villages receive electricity, businesses obtain an electrical connection almost as soon as they can. Although the sample is from a broad cross section of villages at different levels of socioeconomic development, and thus includes only a limited number of villages that would be classified as growth centers, the average number of commercial establishments in this study is 5.19 per village, and for industries the number is 1.61. However, electricity by itself does not cause dramatic numbers of new businesses to be established. Once most of the existing businesses have adopted electricity, the number of new connections slows, simply because many fewer businesses are starting in the villages. The slow development of business connections is quite different from the steady growth in agricultural connections found in the previous chapter.

To identify the village conditions conducive to greater

Figure 4.8 The Level of Industrial and Commercial Connections Per Capita, by Year of Electrification, India, 1980.



Source: India Survey, 1980.

than average growth in number of connections requires an examination of the relationship between previous village conditions and the current number of village connections (see table 4.4).[3] Village population size is a major determinant of the number of industrial and commercial connections. Very small villages simply cannot support a large number of businesses, because there just are not enough people in the surrounding area to buy the products or services. Without markets, businesses obviously will not be established. Several other variables are related to the number of 1981 connections, *even after controlling for village population.* Adequate credit, literacy, and

Table 4.4 Regression of Industrial/Commercial Connections with Village Characteristics in India, 1980

	No. of industrial and commercial electrical connections in village 1980		No. of industrial and commercial electrical connections per 1,000 persons	
Variables	OLS regression	Pearson's correlation coefficient	OLS regression	Pearson's correlation coefficient
Year since village electrification	0.23* (2.19)	0.36	0.21 (1.80)	0.39
Crop yield 1966	-0.04 (0.39)	0.18	-0.13 (1.06)	0.03
Agricultural innovation 1966	-0.11 (0.90)	0.24	0.05 (0.38)	0.28
Proximity to transportation 1966	0.10 (0.92)	0.29	0.12 (1.02)	0.20
Credit availability 1966	0.24* (2.31)	-0.26	-0.19 (1.63)	-0.12
Proximity to city 1966	-0.15 (1.57)	0.02	-0.18 (1.62)	-0.05
Population density 1961	0.02 (0.29)	0.12	0.00 (0.02)	0.05
Population 1971	0.51* (5.10)	0.51	0.07 (0.68)	0.07
Percent literate 1971	0.35* (3.23)	0.28	0.41* (3.26)	0.43
F statistic	6.76*		3.39*	
No. of cases	69	69	69	69
R square	0.50		0.33	

Source: India Survey, 1980.

Note: *means significant at .05 level. Significance levels are not given for correlation coefficients. Coefficients are standardized bs.

year of electrification all are positively related to the number of business connections. Although the Indian and Indonesian sample areas and research designs are quite different, the conclusions are remarkably similar. Adequate credit and rural markets are essential complementary conditions to rural electrification for the establishment of viable businesses.

SUMMARY AND CONCLUSIONS

Rural electrification does have a significant impact on rural industry and commerce. Firms in rural areas generally are small, with a high turnover rate; they require every advantage in order to stay in operation. Electricity may be one factor that contributes to the establishment and survival of many rural businesses. The number of businesses is generally higher in rural areas with electricity, and comparisons between regions with and without electricity reveal that there is a systematic increase in the number of businesses in the regions with electricity. The types of industries that have started or continue operation are typical of those found in other developing nations. They include grain mills, saw mills, furniture makers, and general stores. In all three countries in the study, almost all of the businesses adopted electricity once it became available. In addition, virtually all new enterprises started in regions that already have electricity adopt it within their first year of operation.

One consequence of having a higher level of industrial and commercial development is greater nonagricultural employment. One might expect that investments in electrical equipment would lead to fewer workers because capital in the form of machines would substitute for labor. However, although labor productivity is higher for firms with electricity, there is no evidence that employees are being put out of work by machines. Instead the reverse is true; there seems to be a higher demand for business or industrial labor in regions with electricity. Since the Indonesian study was for a relatively short time period, over the longer term the patterns in Indonesia may turn out to be similar to those in India and Colombia. In the case of Indonesia the higher demand was not satisfied by hiring new employees, but rather by extending the

paid hours of existing workers. In India and Colombia there were a higher number of business or industrial workers in regions with electricity.

Household manufacturing is not hampered by rural electrification. If anything, the use of electric lights may improve productivity in cottage industries. Certainly it is true that many household industries have gone out of existence because of competition from urban-based industry. Village potters can no longer compete with the mass-produced pots and buckets from factories in urban centers. However, the difficulties of household industry and artisans are not a consequence of competition from local rural industries, which are predominantly agricultural or service-oriented. The local rural industries stimulated by rural electrification do not appear to compete with household manufacturing. Electric hand tools are not used in most household industries; the primary benefit of electricity is lighting.

The fuel substitution patterns found in India and Indonesia highlight the importance of energy prices. India is an oil importing country and maintains a fairly high price for petroleum products, while Indonesia is an oil exporting nation which heavily subsidizes diesel power. Even though electricity for industry is not as heavily subsidized in India as electricity for agricultural pumping, it is used for most rural driveshaft power applications, including grain mills. By contrast, in Indonesia the grain mill and industrial owners with diesel engines have not purchased and do not plan to purchase electric motors. A study in Ecuador, another oil producing country with an extremely low price of diesel, also found that electricity was not used for driveshaft power in agro-industries. Thus, as long as diesel fuel subsidies are maintained in these countries, there will not be as much use of electricity for driveshaft power applications.

Yet even though electricity appears to improve levels of rural industry, the level of rural industry even in regions with electricity remains low. For instance, the average number of rural industries in India was only two per village with electricity, with only somewhat higher levels in Indonesia and Colombia. The sample in Indonesia is from a more advanced region, which may explain its higher level of business activity. The expectation that electrification will lead to an explosion of business activities in rural areas is likely to remain unfulfilled. The question is still open as to whether the large capital

expenditures on electrification projects are worth the net benefits derived from rural business development by itself. Nevertheless, electrification of regions does encourage additional business development and improves rural production.

The complementary programs necessary to stimulate rural business development may relate to the external and internal growth constraints on rural industry and commerce. The failure of many small businesses may be a consequence of internal business problems, including poor management or low education level of the business leader. The external constraints in many instances are related to rural infrastructure, such as rural roads. Other external constraints include market conditions and access to capital. The Indian and Indonesian studies strongly support the notion that sufficient capital and adequate markets are necessary for the development of small businesses. Rural electrification programs that do not include or evaluate markets and credit availability are likely to witness slower than average growth of businesses. A shortage of credit may hold back business growth because borrowers in the rural areas lack the necessary start-up or expansion capital. However, growth centers will evolve in agriculturally advanced areas, and programs to facilitate small-scale business would be conducive for growth in these regions.

Human capital also plays an important role in the establishment of rural business. A higher level of literacy in a region may translate into entrepreneurs' founding new businesses and being able to better manage their businesses once they have them established. An educated population may also be more likely to purchase appliances and other goods and services, thus providing a better market for businesses. The important role of human capital in business development emphasizes the need to examine more critically the social impact of rural electrification, which is the focus of the next chapter.

NOTES

1. These figures are probably somewhat inflated, because, as indicated, many of the businesses had commenced operations during the last 5 years, and these relatively high rates would be averaged into the figures for the villages that received electricity during the 1976-1980 period. But similar patterns of business development were found in all four states in the study so this pattern is not affected by unique regional characteristics.

2. One qualification of the results is that questions on the benefits of electrification may predispose respondents to give positive answers.

3. Since the villages with electricity for 20 years or more are larger than the rest of the sample, it is misleading to attribute the increase during this period to the long-term impact of electrification. Hence these villages have been excluded from the analysis.

5
Electricity and Rural Social Change

The arguments in favor of rural electrification often have centered on its potentially powerful transformative effect on rural households. Imagine two rural households, one with electricity and one without. In the evening, the household with electricity is a beehive of activity. Children are reading, the mother is busy mending clothes, and the father is listening to a radio program. In contrast, the kerosene lantern or candles in use in the household without electricity emit a dull light inadequate for reading or close work such as sewing. As a consequence, the family retires early after a fairly unproductive evening. While these contrasting pictures may be somewhat exaggerated, they do reveal some of the multiple social benefits anticipated by advocates of rural electrification.

The critics of rural electrification consider unrealistic the prospect that rural households will benefit significantly. According to them, rural electrification can benefit developing societies only through improvements in rural productivity and thereby an increase in rural incomes. Providing a light bulb or two for a few probably high-income families through expensive rural electrification programs does not make sense in the context of other development priorities. Even if some households benefit from access to electricity, are the benefits worth the substantial investments and subsidies presently required for rural electrification? This chapter is concerned with understanding in detail the social impact of rural electrification at both the household and community level. Among the many questions to be answered are whether or not rural electrification improves the quality of rural life, increases literacy and education, and diminishes community out-migration.

SAMPLE RURAL HOUSEHOLDS AND THE ISSUE OF CAUSALITY

The samples of the India and Colombia studies were designed in order to gain some understanding of the complex relationship between rural electrification and household income. The rural households in the India and Colombia samples are quite diverse. In Colombia the sample includes regions characterized by very little irrigation. The coverage also includes a coffee-growing region with large plantations. For India the sample typically is from the semi-arid tropics with extensive irrigation. The mean income and education level is much higher in Colombia than in India. The breadth of population types provides sufficient data to examine common and/or unique social impacts of rural electrification. First, household income is examined to draw a profile of the sample, and then the broader social impacts of electrification in rural households are identified in later sections.

The studies randomly selected households with and without electricity within high- to low-income occupational groups in order to insure that there would be a wide range of incomes in both the electrified and nonelectrified household categories.[1] The figures in table 5.1 present income broken down by electrification. For India, total income is higher in households with electricity for every occupational category, and in Colombia the average income is higher in four out of five occupational categories. Thus, families with electricity on the average have somewhat higher incomes even within the same occupational categories. The same pattern also exists for education.

Because there are relatively poor households with electricity and comparatively wealthy households without electricity in the sample, the research can statistically sort out the impact of electrification by comparing households with essentially similar levels of income or education. For instance, households with higher incomes, as would be expected, have higher levels of appliance ownership than poorer households. But, as will be seen in the next section, poorer households with electricity also have higher levels of both electric and nonelectric appliance ownership than households with similar levels of income without electricity.

Table 5.1 Income, Education and Household Electrification by Social Class, India and Colombia, 1980

Households' Social Class (Mean)	India				Colombia			
	Income (rupees)		Education (years)		Income (pesos)		Education (years)	
	With Elec.	Without Elec.	With Elec.	Without Elec.	With Elec.	Without Elec.	With Elec.	Without Elec.
Total farmers[1]	n.a.	n.a.	n.a.	n.a.	9515	5540	12.39	8.93
Large	21697	12940	5.96	4.91	n.a.	n.a.	n.a.	n.a.
Medium	8503	6618	5.90	4.93	n.a.	n.a.	n.a.	n.a.
Small	5638	4133	4.35	3.67	n.a.	n.a.	n.a.	n.a.
Shopkeeper/business[2]	6175	4340	5.77	4.50	9212	8254	12.25	9.00
Artisans[3]	5148	3032	3.12	2.98	11068	11916	16.22	7.33
Agricultural laborers	2805	2204	1.71	1.51	3641	4561	10.01	6.31
Others[4]	n.a.	n.a.	n.a.	n.a.	9677	6670	11.26	6.61
Total	9291	5158	4.76	3.64	10037	5862	11.95	7.48

Source: India Survey, 1980; Colombia Survey, 1980.

[1]For Colombia, category contains farm owners, farm renters, and cattle ranchers.
[2]For Colombia, category contains storekeepers, poultry owners, sailboat owners, fishermen, and butchers.
[3]For Colombia, category contains auto conductors, state workers, and artisans.
[4]For Colombia, category contains domestic workers, those unable to work, miners, handiworkers, others in commerce, etc.

APPLIANCE OWNERSHIP

Appliance ownership can directly affect the quality of rural life. The use of appliances-lights, stoves, televisions, radios-does have a direct social impact, whether good or bad. For instance, some may consider television viewing good because it integrates households into the larger society, while others may criticize it for taking time away from productive activities or more direct social interactions. In addition, it is quite possible that electric appliance use in rural households may be instrumental in changing rural energy use patterns. Also, the purchase of appliances might possibly have a secondary effect in stimulating the development of small or medium-sized industries within the country. The tremendous growth in demand for appliances in rural areas in the United States was partly the consequence of rural electrification programs. Rural electrification was particularly important for the catalog merchandising companies. But, as indicated, an explosion of demand for appliances may not occur in developing countries because of the lower level of rural household incomes. Thus, in this section an inventory of household energy-using appliances is presented for Colombia and India.

Profile of Appliance Ownership in India and Colombia

Appliance use is an important consequence of electrification and deserves explicit attention. Household appliances are cited as improving the situation of women in rural households (Lay and Hood, 1979). Labor-saving appliances can improve the situation of women by decreasing the amount of drudgery involved in household work. For instance, a recent study (Goddard et al., 1981, p. 12) found that the four most often used electrical appliances for domestic work in rural Costa Rica included electric irons, refrigerators, blenders, and washing machines. Of course, per capita income in Costa Rica is relatively high, and other less developed countries may be unable to sustain the same level of appliance use. A recent study (Tourkin et al., 1981) in Indonesia found that only a

small percentage of households could afford appliances, but two electric appliances that were quite common were irons and televisions. Also, the purchase of rural appliances may have important indirect impacts through stimulating the development of industries producing consumer goods.

The similarities in appliance ownership patterns for the India and Colombia samples are more striking than the differences (see table 5.2). In both countries appliance ownership was higher for households with electricity, which can be partially explained by the electricity-using nature of many appliances.[2] As would be expected, the percentage of households owning appliances generally is higher in Colombia, which has a higher per capita gross national product (GNP) than India. Because of the higher incomes in Colombia, in some instances there is higher appliance ownership in households both with and without electricity. But the surprising finding is that there is a substantially higher degree of appliance ownership than was previously assumed for developing countries. The Indonesian study also found higher than anticipated use of appliances other than lights. Almost half of the sample with electricity in the Indonesian study had a household appliance that was not a light, and one-quarter of the sample owned large appliances such as televisions, refrigerators, sewing machines, or water pumps. This appears to imply that electrification does not simply involve the use of electric lighting, as had been previously thought, but involves many other appliances.

The consensus of recent studies is that lighting is the foremost positive benefit of rural electrification. According to several studies, electric lighting extends the day of households by two to three hours (Butler et al., 1980; Mandel et al., 1980). The most commonly cited advantages of lighting by electricity rather than kerosene are that electric lights are brighter, less polluting, and in some instances less expensive. Of course, cost comparisons depend on the level of subsidies for kerosene and/or electricity. Other consequences are an increase in household productivity and a greater feeling of safety and security for the family. In some instances, members of communities with electricity feel less isolated with the advent of electrification (see USAID, 1981).

Lighting is a necessity for almost all of the households in both India and Colombia and, as might be expected, in households with electricity virtually all lighting is electric. But in India some of the households with electricity still have

Table 5.2 Appliance Ownership in Rural Households, India and Colombia, 1980

Appliance Type	India		Colombia	
	With Electricity	Without Electricity	With Electricity	Without Electricity
	Percent of Households			
Lighting				
Electricity	100	n.a.	97	1
Gas/Kerosene	16	35	*	52
Candles	n.a.	n.a.	*	34
Flashlight	66	44	n.a.	n.a.
Stove				
hot plate/electric	0	0	23	*
kerosene	39	12	28	16
Wood	n.a.	n.a.	25	56
Coal	n.a.	n.a.	15	14
Leisure				
Electric radio	33	0	44	0
Transistor radio	47	39	42	65
Record player	3	0	n.a.	n.a.
Television	1	0	61	.2
Households goods				
Iron	23	2	87	48
Electric iron	n.a.	n.a.	81	
Other iron	n.a.	n.a.	6	47
Sewing machine	32	10	34	12
Table fan	32	0	n.a.	1
Ceiling fan	24	0	n.a.	n.a.
Refrigerator	1	0	30	2
Transport				
Bicycle	69	43	n.a.	n.a.
Motorcycle/moped	5	0	n.a.	n.a.

Source: India Survey, 1980, Colombia Survey, 1980.

*Means less than 1 percent.
Note: n.a. means not applicable.

kerosene lanterns, which are probably used for backup in case of a power failure. Because only one in three households without electricity in India uses kerosene lanterns, apparently many either use candles or no lighting at all. By contrast, in Colombia half of the households without electricity used kerosene, while about one in three illuminated their household with candles. The more extensive use of commercial fuels for lighting in Colombia may reflect the relatively higher household incomes.

Cooking accounts for a substantial percentage of energy use in these rural households. Some estimates indicate that

cooking in rural households consumes as much as 90 percent of total household energy consumption. However, electricity is seldom utilized for cooking in developing nations. Fuelwood, charcoal, agricultural wastes, dung, and kerosene are the main sources of energy for cooking and remain so after electrification. In previous studies only Costa Rica was identified as making extensive use of electricity for cooking (see Goddard et al., 1981), with about 22 percent of connected households there cooking with electricity.

Traditional fuels are the principal cooking energy source in both India and Colombia; these include wood fuels, dung, and agricultural wastes for India and coal, wood fuels, and charcoal for Colombia. But a substantial number of households with electricity in India have kerosene stoves for cooking. This is because cooking with electricity would require expenditures well beyond the means of most rural households (Sen, 1981, p. 28). The same general patterns of traditional fuel and kerosene use hold for Colombia, with the exception that about one in five households with electricity have electric hot plates or stoves, which was more extensive than anticipated. The households without electricity were more reliant on traditional fuels such as fuelwood.

The use of household appliances (irons, sewing machines, refrigerators, fans) was much higher in Colombia than in India. In India about 1 in 4 households with electricity had an iron. Reflecting the higher per capita incomes in Colombia, about 9 out of 10 of the households with electricity had irons.[3] The ownership of sewing machines is almost identical for the two countries: about 1 in 3 households with electricity and 1 in 10 without electricity owned sewing machines. Refrigerator ownership once again reflects the higher standard of living in Colombia, where just under 1 out of 3 households with electricity had refrigerators, compared to virtually none for India. Because of the differences in climate in the two countries, the percentage of households with electricity in India with table and/or ceiling fans was higher, at 43 percent compared to 10 percent for Colombia. Colombia has a much cooler climate, especially in the mountainous regions. However, the extent of fan ownership in India is quite surprising, reflecting the fact that households are willing to make a substantial investment in the comfort a fan might bring during the summer.

Since leisure time is an important component of the quality of rural life, the households were surveyed for radios, televisions, and record players. Both surveys distinguished between radios powered by batteries and those powered by electricity from the grid, and the results for India and Colombia are remarkably similar. For India 33 percent of households with electricity had plug-in radios, as compared to 44 percent for Colombia. But in both countries households with electricity also possessed a high number of battery-run transistor radios. Of course, households without electricity also owned transistor radios. About 1 in 3 of the households without electricity in India owned transistor radios, compared to 2 out of 3 in Colombia. For television ownership the trends were quite different for India than for Colombia. There are virtually no television broadcasting stations sending signals to rural India, which accounts for the fact that few of the Indian households with electricity had televisions. By contrast, in Colombia over half of the households with electricity owned a television set, which is remarkably high for what is a relatively expensive luxury item. As will be seen later, the ownership of televisions has had a significant impact on use of leisure time in Colombia.

To summarize, rural electrification makes a significant and independent contribution to appliance ownership. The level of appliance ownership in the Indian, Colombian, and Indonesian samples was generally higher than expected and was not limited to the ownership of a light bulb or two. The level of television ownership in Colombia and Indonesia was quite surprising, as was the level of fan ownership in India. There is definitely substitution of electricity for kerosene or candles for lighting in India and Colombia. Although some of the households with electricity have electric hot plates in Colombia, in general electricity appears to be too expensive an alternative for cooking in developing nations. Household goods such as irons and sewing machines are quite prevalent in both countries, but refrigerators are in use only at a modest level in Colombia. Appliance ownership generally was higher in Colombia than in India, as higher per capita incomes facilitate growth in appliance ownership.

Relationships Between Appliance Ownership and and Income, Education, and Electrification

In order to examine the relationship of appliance ownership with income, education, and electrification, an additive index has been constructed that can be used in a multiple regression analysis.[4] Reflecting the patterns found in table 5.2, the correlation between household electrification and the appliance ownership index is 0.49 for India and 0.40 for Colombia. While this confirms findings from previous studies of rural electrification, the correlation may be the consequence of higher income households' being more likely to adopt electricity and more able to afford the appliances. Thus, the next task is to sort out the electrification-income-education relationships and how they relate to appliance ownership.

The results of the Indian and Colombian appliance ownership analysis indicate that all three independent variables - income, education, and household electrification - make positive, independent contributions to household appliance ownership (see table 5.3). The interpretation of the findings is that even for households with similar levels of income and education, households with electricity have more appliances than households without electricity. This means that electrification at any given level of household income on the average is associated with a higher level of appliance ownership. Households with electricity probably own more appliances because of the whole new range of appliances that become available for purchase, such as television sets, fans, plug-in radios, and electric irons. In this analysis, with the causal influence of household income eliminated, it was found that electrification still makes a positive and significant contribution to appliance ownership. One can predict with confidence that at the same levels of household income, those with electricity will have more appliances than those without electricity. Of course, the same can be said for income and education.

Since appliance ownership is one indicator of the quality of rural life, we would conclude that income, education, and electrification all would contribute to its improvement. The similarity of the results from India and Colombia would suggest that the income, education, electrification, and appliance relationships are universal patterns that might be expected to appear after electrification in other developing countries.

Table 5.3 Regression Between Appliance Ownership and Household Electrification, Income, and Education in India and Colombia, 1980

	Appliance ownership index	
	OLS Regression	
	India	Colombia
Existence of household electricity	0.37* (9.89)	0.31* (8.50)
Total income	0.37* (9.47)	0.18* (5.12)
Education	0.21* (5.56)	0.31* (8.40)
Number cases	402	535
F statistic	111.69	84.01
R square	0.46	0.32

Source: India Survey, 1980; Colombia Survey, 1980.
Note: *Indicates significant at .05 level. Coefficients are standardized bs; t statistics are in parentheses.

CHANGES IN LIVING PATTERNS

This section examines some of the implications of electrification for changes in rural household activities. Advocates of rural electrification have indicated that major changes in activities and patterns of behavior occur in households with electricity. High quality lighting provides more time in the evenings for studying, working, social visits, and entertainment, along with a host of other productive activities. The most common findings in the literature on rural electrification are that children are more able to read at night and that there is a greater feeling of safety in households with electricity. In fact, the evidence already presented is quite persuasive in showing that electricity substitutes for other sources of energy for lighting.

In India and Colombia reading for children was improved with rural electrification, but the findings are inconclusive on several other important issues. The data on India presented in table 5.4 are for households with and without electricity. For Colombia, recall questions were asked of households that had received electricity recently; that is, households were asked about their present activities and their activities before electrification. The impact of electrification on the household behavior of men, women, and children seemed to have been more dramatic in Colombia than in India. However, it should be remembered that the questions for India and for women and children in the Colombia study were for an entire day's activities, whereas Colombian male respondents were questioned only on their activities during the evening, when they would more likely be at home.

The Colombian results seem to be greatly affected by the extensive presence of television.[5] The men and women in the sample had greatly altered their living patterns to accommodate television viewing in the evening. Almost half of the men and women in the sample viewed television in the evening, as did over half of the children. Since before electricity virtually no time was spent in watching television, this change represents a tremendous impact on the share of time devoted to other activities. For instance, time spent reading seems to have declined substantially for adults, as have productive activities, social visits, and radio listening for the adult population. These activities have probably been replaced

Table 5.4 Daily Activities Affected by Rural Electrification, India and Colombia, 1980

Activity	India (all day)		Colombia (evening only for males)	
	With Electricity	Without Electricity	After Electricity	Before Electricity
	Percent of Activity			
Respondent (male)				
Reading	n.a.	n.a.	18	35
Television	n.a.	n.a.	43	0
Social visits	34	38	29	68
Working	88	90	22	56
Radio	n.a.	n.a.	62	97
Female				
Reading	n.a.	n.a.	16	47
Television	n.a.	n.a.	44	0
Social visits	18	15	35	70
Working	41	36	12	60
Radio	n.a.	n.a.	63	95
Domestic work	78	83	57	65
Fuel collection	9	19	n.a.	n.a.
Child				
Attended school	38	36	n.a.	n.a.
Reading	42	33	72	43
Television	n.a.	n.a.	54	10
Working	9	6	0	0
Domestic work	15	15	23	46
Play	39	38	n.a.	n.a.

Source: India Survey, 1980, Colombia Survey, 1980.

Note: n.a. signifies not available.

by television viewing. Domestic work in the evenings also has declined for the women in the sample. Television obviously has the potential to be a very powerful instrument for social change in rural Colombia, but some of the consequences also might be negative.

Even though television viewing seems to have caused a decline in reading among adults in Colombia, children have substantially increased the time spent reading in the evening. According to the survey, children apparently were spending more time reading than before the house had no electricity; and this was so despite the dramatic increase in the percentage of children watching television. These findings are also supported in the India study, where there were virtually no television sets. In India the percent of children attending school was virtually the same for households with and without electricity. However, the time spent reading was substantially higher for

children in households with electricity. Since school attendance is the same, we would infer that the differences in the percentages of children reading sometime during the day or evening was due to the electrification of the household, which gave the children more of a chance to read in the evenings. The decision to take a household connection might even be swayed by the number of children in school.

The substantial differences found in the use of time in the Colombian sample were not found in the Indian study. Of course, the Indian study measured activities of households with and without electricity, while for Colombia the responses were to recall questions, and this may be responsible for some of the differences. Social visits and working by women or men were not found to be affected by whether a household had electricity in India. However, domestic work for women was less in households with electricity, which is perhaps a consequence of the different income levels of the sample groups. A significant finding is that fuel collection was substantially lower for households with electricity, which might suggest that these households purchased rather than collected wood for cooking. Households with electricity were more likely to use kerosene or purchase fuelwood for cooking than the households without electricity, especially since electric light would aid in cooking after dark. Cooking with kerosene without lights is not as easy as cooking over a fire, which provides much of the light for preparing the meal.

Another difference between India and Colombia is that the Colombian households with electricity had changed their sleeping patterns (see table 5.5). They tended to stay up longer at night, going to bed about 20 minutes later than they did before electrification. Once again, television may be responsible for this change in household behavior in Colombia. By comparison, in India there had been no significant change in sleeping patterns. The comparisons between the households with and without electricity in table 5.5 indicate that both samples were going to bed at around the same time, approximately 9:30 p.m., and the length of their sleep was also the same.

To summarize, rural electrification seems to have had a substantial impact on social activities of the Colombia sample. There was less reading among adults, fewer social visits, and less work in the evenings. The social impact of television obviously is a two-edged sword. Social and productive activities in

Table 5.5 Number of Waking Hours By Electricity Use, India and Colombia, 1980

	Households Waking Hours (Mean)					
	India			Colombia		
	With Elect.	Without Elect.	Minutes Diff.	With Elect.	Without Elect.	Minutes Diff.
Head of household	n.a.	n.a.	n.a.	15.22	14.85	22
Housewife	15.92	15.79	7.8	15.34	15.01	20
Children	14.00	14.29	-17.4	14.66	14.21	27

Source: India Survey, 1980; Colombia Survey, 1980.

Note: n.a. signifies not available.

the evening are being replaced by television viewing, but this could also have positive social impacts, including broadening the horizons of rural residents, introducing them to new technologies for work, and exposure to new products through advertising. The introduction of any new technology can have both positive and negative consequences for society, and the debate over the relative merits of television will continue. In India, with next to no rural television broadcasting, the results are not as dramatic. The positive impacts are that, for whatever reason, fuel collection seems to occur less in households with electricity, while time spent reading improves for children. The reason for the more pervasive impact of electrification on household behavior in Colombia is probably because of the higher incomes and greater access to television.

QUALITY OF RURAL LIFE

As the perception of the quality of rural life is quite subjective, the questions elicit impressions of many aspects of one's life. The previous discussions of appliance use and changes in living patterns should be reflected in these quality of life impressions. Since rural electrification and income are associated with higher levels of appliance use, one might hypothesize that the perception of the quality of life would be

enhanced in those households with electricity and higher incomes.

The India study measured the perception of the quality of life through four survey questions with self-anchored scales. Each respondent was asked to compare his quality of life to (1) his father's time, (2) five years ago, (3) his neighbor's quality of life, and (4) the quality of life he anticipated in the future. These questions were presented along with the scale in figure 5.1. Compared to their counterparts without electricity, the households with electricity appeared to have a perception of a generally higher quality of life. The difference was fairly large for the comparisons with their father's time, undoubtedly a period without electrification, and with their neighbor today, who probably would not have electricity. The conclusion from data presented in figure 5.1 is that the households with electricity perceive their quality of life to be higher than households without electricity.

Income probably also is related to the respondents' perception of the quality of their lives. In order to insure that neither income nor level of education was causing the quality of life differences evident in figure 5.1, a multiple regression was conducted controlling for income and education. The results presented in table 5.6 indicate that income definitely is associated with a more positive perception of quality of life. However, this does not alter the findings for electrification. Even for households at similar levels of income and education, household electrification still is positively related to two measures of the quality of life. From the analysis, it can be concluded that both income and electrification are associated with a higher perception of one's quality of life.

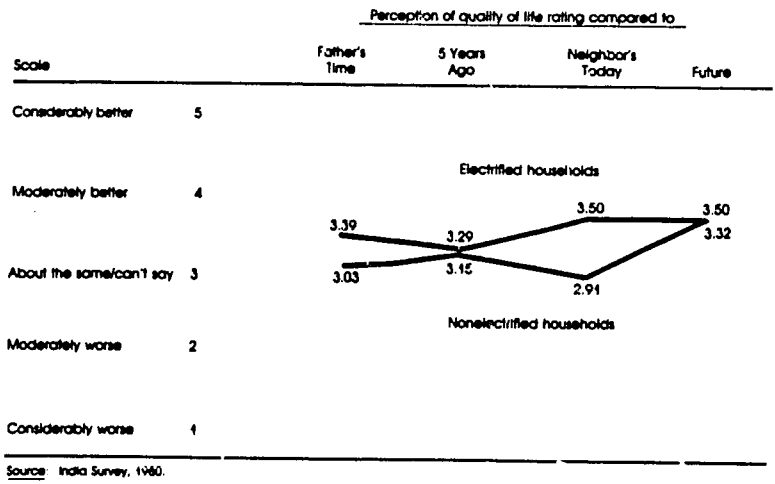
While electrification made a difference in the quality of life perception compared to one's father's time and compared to one's neighbors, there was very little difference in the comparisons with five years ago and for the future. Of course, many of the households had had electricity for more than five years, which may explain the lack of significance for that time period. According to figure 5.1, the households with electricity perceived their present and future quality of life levels to be about the same. This contrasts with the households without electricity, which perceived that the future would be much better for them than their current situation. They may even have been anticipating the electrification of their home sometime in the future.

Table 5.6 Regression Analysis of the Relationship of Electrification, Income, and Education with Quality of Life, India, 1980

	OLS regression			
	Quality of life rating compared to			
	Father's time	5 years ago	Neighbor	Future
Household with electricity, 1980	.12* (2.51)	.04 (0.81)	.23* (5.05)	.09 (1.22)
Income	.11* (2.27)	.11* (2.17)	.20* (4.19)	.06 (1.87)
Education	.00 (0.15)	.08 (1.70)	.13* (2.87)	.06 (1.02)
Number of cases	400	400	400	400
F Statistic	5.02	4.22	26.08	3.35
R Square	.03	.03	.16	.02

Source: India Survey, 1980.
Note: * indicates significant at .05 level. Coefficients are standardized bs; t statistics are in parentheses.

Figure 5.1 Comparison of Perception of Quality of Life for Households With and Without Electricity, India, 1980 (means).



Source: India Survey, 1980.

The conclusion from the quality of life questions is that electrification and income have important consequences for the perception of quality of life among these rural people, especially in comparisons of the quality of life during the father's time and compared to that of neighbors. The households without electricity feel that there will be an improvement in the quality of life sometime in the future.

The previous sections have examined some of the direct microsocial impacts of rural electrification. The next sections analyze some of the more macrosocial impacts, including associations with migration and literacy.

MIGRATION

An important justification of rural electrification is that migration from rural areas will be diminished. Because of the problems of "overurbanization" experienced by some devel-

oping countries, reduction of rural to urban migration would be very desirable. The concept of overurbanization, which is somewhat controversial (see Lipton, 1980), is that the growth of large metropolitan areas is occurring too fast in developing nations. The theory is that those in rural areas are pushed toward the urban centers by the lack of employment opportunities at home. High rural population density (that is, overpopulation) is perhaps the characteristic most often measured in studies of overurbanization, but the rural factors cited as causes of overurbanization include all the social ills and difficulties of rural life, such as lack of employment; poor infrastructure, including poor schools and roads, and little or no electrification; and the general low quality of rural life in developing nations. Davis (1980, p. 4) pessimistically cautions that the expanding foodgrain production of the last 25 years in Asia seems to have run its course and we should expect a continued push of rural populations to urban regions.

The corollary to the push theory is that urban areas act like magnets pulling the rural populations to jobs, higher incomes, and higher quality of life. Although all developed countries have undergone a substantial transformation from predominantly rural to urban populations, the theory of overurbanization holds that the process is occurring much too fast in developing nations and that it would be prudent to stem the flow so that a more orderly transition would be possible. Examples of urban congestion like that of Mexico City tend to reinforce the notion that stemming rural to urban migration is desirable in developing countries.

Advocates of rural electrification expect that the anticipated improvement in the quality of life will keep rural populations from migrating and consequently will alleviate problems associated with overurbanization. The critics claim that there is no evidence to support the contention that rural electrification affects migration in any way at all. However, beyond anecdotal information, there have been no studies on the relationship between migration and electrification, and thus this is the first attempt to examine this complex subject.

The assertion that migration from rural areas will be stemmed by rural electrification must be considered in the context of the many different reasons for migration. First, most migration in developing countries is job related. People typically migrate when the local economic opportunities are limited or when there are greater opportunities elsewhere.

Second, seasonal migration must be distinguished from longer-term or permanent migration. Seasonal migration for harvests or other farm-related work is very common in developing countries and typically involves rural-to-rural migration. Third, education also can be a significant reason for migration from rural to urban areas, since most of the educational opportunities are in towns or urban areas.

Rather than diminishing migration, it is possible that rural electrification may increase out-migration, if it in any way has the anticipated impact on socioeconomic development and rising expectations. Migration patterns in industrial societies at the time rural areas were receiving electricity were quite different from those expected to result from rural electrification in developing countries. Industrial societies are characterized by highly mobile populations, but there is much less migration in developing countries. Thus, the expectation that rural electrification will cause socioeconomic development in rural areas seems inconsistent with the assumption that it will reduce out-migration. If the United States were taken as a case example, migration from rural areas would be overwhelmingly associated with rural electrification. If electrification raises expectations, then it would be expected that out-migration of young persons seeking wider opportunities in the form of jobs or education should increase rather than decrease. The increase of out-migration also may well be matched by the in-migration of others seeking work in a community with electricity. As the level of specialization increases in a society, a general increase in migration would be expected. Thus our expectation of increased migration is contrary to the accepted wisdom of rural electrification advocates. The results for India and Colombia will be examined separately.

Migration in India

During the 1960s the shift of population to urban regions in India was fairly small. Population increased at about the same rate in both the urban and the rural areas. While India has experienced a steady growth of urban industries, it has also had tremendous agricultural growth. Although many analysts have feared job displacement from the modernization

of agriculture, jobs actually have expanded in the agricultural sector, sometimes even causing shortages at harvest time. Thus, there may be increased employment opportunities for the laborers due to agricultural development, but more well-to-do rural families may lose members because of migration for education and more specialized jobs in cities.

The purposes for which persons migrated, including employment ("other" category), work in agriculture, and obtaining an education, are presented in table 5.7. More than two-thirds of permanent migration was for employment or "other" reasons, and a high proportion of these migrants are now working for the government. By contrast, only a small percentage of permanent migrantion was for work in agriculture. Education is very important, since about one-quarter of the migration was for obtaining a higher education.

Turning to the comparisons between villages with and without electricity, we see that migration for education is significantly lower in villages with electricity. Of course, villages with electricity might have better educational facilities, possibly resulting in a lower number of migrants from these villages. By contrast, migration for employment or "other" reasons is significantly higher for villages with electricity. The reasoning that electrification would increase rather than decrease migration is partially confirmed by the findings, with the exception that there is less migration for education in the communities with electricity.

The findings of the survey are contrary to the expectation of advocates of rural electrification but are in line with the reasoning that rural electrification should raise the expectations of villagers. The villages with electricity had more permanent out-migration but less seasonal out-migration for work than the villages without electricity. Permanent out-migration typically involves movement to towns or cities. The percentage of total permanent migrants moving to towns is 88 percent for villages with electricity compared to 78 percent for villages without electricity. Thus, the movement to other rural areas, presumably for agricultural employment, is not as great in the communities with electricity. Seasonal migration is typically rural-to-rural migration and involves migration for harvests. Seasonal migration is less in the villages with electricity, probably because of an increased demand for labor due to more extensive irrigation and higher crop yields.

The association between electrification and migration

Table 5.7 Percent of population migrating in villages with and without electricity, India, 1980

	Villages		Percent of households with electricity in the village
	With Electricity	Without Electricity	
	(Mean %)	(Mean %)	(Correlation)
Migration type (% of village population that migrate for:)			
Permanent work	2.39	1.23	0.33*
Seasonal work	2.28	3.93	-0.23*
Place of permanent migration (% of permanent migrants moving to:)			
Town	88.62	78.75	0.15*
Village	11.37	21.24	-0.15*
Purpose of migration (% of permanent migrants moving for:)			
Education	20.97	29.24	-0.25*
Agriculture	4.86	4.07	0.04
Other reasons	73.64	64.82	0.31*
Government service**	44.09	34.53	0.02
Education of migrants (% of permanent migrants with education of:)			
5 years and above	73.83	81.42	0.18*

Source: India Survey, 1980.

Note: *Denotes statistical significance at the .05 level.

**Figures are a subset of "other reasons."

may be affected by other important factors (such as level of development). But as can be observed from the regression analysis presented in table 5.8, even after controlling for other factors electrification remains positively associated with permanent migration, migration to towns, and migration for employment or "other" reasons, and also remains negatively associated with migration for education. From the chapter on agriculture it should be remembered that electrification and percent of area double cropped are positively associated, which might imply that there may be an indirect impact of electrification on seasonal migration. In any event, farming land for more than one crop during a year should improve the local occupational opportunities and reduce village out-migration for seasonal labor.

The Indian migration findings can be summarized by saying that permanent migration increased, especially for

Table 5.8 Regression of Relationship between Migration and Electrification, India, 1980

	Percent Migrating			Percent Permanently Migrating for		
	Permanently	Seasonally	To town/City	Education	Agric.	Other Jobs
Percent of Households with electricity in village	0.34* (2.785)	0.01 (0.12)	0.27* (2.40)	-0.31* (2.50)	-0.12 (0.96)	0.32* (2.59)
Diesel engine pumpsets per capita	0.12 (1.13)	-0.03 (0.13)	-0.245* (2.45)	-0.03 (0.26)	0.30* (2.67)	-0.09 (0.80)
Nonmechanization modes per capita	-0.09 (0.96)	0.15 (1.65)	0.09 (1.07)	-0.10 (1.09)	-0.09 (1.00)	-0.01 (0.18)
Yield per hectare**	-0.01 (0.07)	0.04 (0.30)	0.04 (0.35)	-0.02 (0.21)	-0.00 (0.02)	0.01 (0.07)
Agricultural innovation index	0.04 (0.42)	-0.14 (1.34)	0.10 (1.04)	0.06 (0.53)	0.03 (0.28)	-0.08 (0.74)
Percent of area double or triple cropped	-0.15 (1.37)	-0.24* (2.26)	0.18 (1.74)	0.01 (0.05)	-0.11 (0.98)	0.08 (0.698)
Proximity to major services	-0.16 (1.68)	-0.05 (0.54)	0.16 (1.73)	-0.13 (1.29)	-0.02 (0.15)	0.14 (1.36)
Proximity to schools	0.07 (10.67)	-0.11 (1.15)	-0.32* (3.47)	-0.07 (0.68)	0.19 (1.92)	-0.08 (0.817)
Proximity to means of communications, (post office, telegraph, cinema, etc.)	0.17 (1.73)	0.00 (0.03)	0.18* (1.94)	0.02 (0.25)	-0.09 (0.81)	0.01 (0.10)
Number of villages	126	126	121	121	121	121
F statistic	2.77	2.53	4.42	2.30	1.49	1.78
R square	0.17	0.16	0.26	0.16	0.10	0.13

Source: India Survey, 1980.

Notes: Coefficients are standardized b; t statistics are in parenthesis.

*Denotes statistical significance at the .05 level.

**Results for yield per person were the same.

employment. Although seasonal migration was somewhat related to electrification, other factors were more important, including the percent of area double cropped in the villages. The dominant purpose of permanent migration is for employment, especially in government service, and the rate of migration for employment is higher in villages with electricity. The notion that migration is deterred by rural electrification is challenged by the India research. On the other hand, the increase in out-migration occurring in communities with electricity should be considered as consistent with the goal of economic development. If electrification stimulates small-scale

industrial and agricultural development, there would be a greater migration both in and out of rural communities.

Migration in Colombia

Migration in Colombia also was predominantly related to employment opportunities. A recent study by Santamaria (1980) found that Colombians tend to move for economic reasons; almost two-thirds of the immigrants in the study had left their birthplace seeking higher wages, better jobs, or the possibility of owning land. The commercialization of agriculture in Colombia, especially plantations in the coffee-growing region, has resulted in an expansion of the labor force. This has caused quite distinct regional population movements, with persons migrating from the central areas into the coffee regions. Migrants are moving to regions with a higher demand for skilled and unskilled labor and are settling down in small towns. In the last 35 years, the number of small cities with populations between twenty and thirty thousand has tripled in Colombia.

Community in-migration can be examined through data on the length of residence of the rural households. The length of residence should reflect the degree to which newcomers move into the community, since communities with quite stable populations would have few immigrants. In Colombia this present study found that the families in households with electricity had not resided in the community as long as those in households without electricity. The figures in table 5.9 indicate that over 13 percent of the households with electricity had arrived in the community during the previous 5 years, compared to 8 percent of the households without electricity. Similarly, the number of residents who had lived their entire life in the community was 49 percent for households with and 55 percent for households without electricity. The communities with electricity, therefore, tend to have more dynamic populations, although the differences are somewhat small.

Community out-migration was more difficult to measure as families that had moved out of the communities could not be interviewed. However, the respondents were asked whether "a household member had left the community" and the "reason

Table 5.9 Migration in Communities With and Without Electricity, Colombia, 1980

	Communities with electricity	Communities without electricity
In-migration of sample		
Percent of households arrived last 5 years	13.8	8.4
Percent arrived more than 5 years ago	36.9	36.7
Percent lived entire life in communities	49.0	54.9
Total	100.0	100.0
Out-migration of sample		
Percent of families with members who migrated	35.1	29.9
Reason for above out-migration		
Education	2.3	6.5
Economic (work, income)	61.7	51.6
Family	16.3	22.6
Other	19.5	19.4
Total	100.0	100.0

Source: Colombia Survey, 1980.

for migration." Communities with electricity were more likely to have lost population. The reasons stated for family members' leaving the community were overwhelmingly related to jobs and income; 61 percent of the households with electricity and 51 percent of those without cited economic reasons for community member migration. By contrast, family reasons accounted for about one-fifth of the total out-migration, and the number migrating for education was low. The communities with electricity tend to have both a slightly higher influx and a higher outflux of population.

So far, the results are consistent with our hypothesis that electrification is associated with a higher degree of migration, both in and out of the communities. However, in table 5.10 the regression analysis does not confirm this finding. Thus, the relationship between rural electrification and migration is not clear for Colombia. There were more communities with electricity in the coffee-growing region sample. After

Table 5.10 Regression of Migration in Colombia, 1980

	OLS regression		
	Number of family members migrating in last 5 years	Household head's duration of residence	Migration index
Years with electricity (0-25)	0.03 (0.63)	0.14* (3.03)	0.10* (2.17)
Income	0.13* (3.05)	0.05 (1.04)	0.12* (2.85)
Education	-0.02 (0.38)	-0.13* (2.79)	-0.12* (2.51)
Central region dummy variable	0.21* (4.44)	0.04 (0.85)	0.18* (3.97)
Coffee region dummy variable	0.03 (0.68)	-0.17* (3.46)	-0.10* (1.94)
Number of cases	529	529	529
F statistic	6.39	5.29	8.15
R square	0.06	0.05	0.07

Source: Colombia Survey, 1980.

Note: For migration index, 2 equals some family out-migration and long duration of head in community (people are moving out but not moving into community), 1 equals either high out-migration and high in-migration or low out-migration and low in-migration (population is stable or those moving out are replaced by those moving into community), and 0 equals least out-migration and short-term residence (people are moving into community). Coefficients are standardized bs; t statistics are in parentheses.

*denotes statistical significance at the .05 level.

controlling for education, income, and region, electrification was found to be positively correlated with the duration of residence of the head of household but not correlated at all with the number of family members migrating. The coefficient (bottom row in table 5.9) for the coffee-growing region is negative, indicating that this region had more in-migration than other regions. After controlling for region, it appeared that electrification is associated with less out-migration, which is contrary to our hypothesis. Migrants in Colombia are moving into the predominantly electrified coffee-growing region, but movement within the regions is not related to electrification. The impact of rural electrification on migration, if any, would have to be an indirect impact through the creation of new jobs, essentially in the coffee-growing areas.

Conclusion

Employment was the most important factor in migration decisions in both India and Colombia. Over 60 percent of the sample in India and Colombia reported that the primary reason for migration was employment or income-related activities. However, the questions in the India and Colombia surveys were quite different, so the migration findings are somewhat hard to compare. In India, electrification was positively related to out-migration to towns and cities to obtain jobs and education and was negatively related to seasonal out-migration, probably because of the improvement in agricultural employment. In Colombia employment opportunities in the extensively electrified coffee-growing regions had tended to cause an influx of new persons into the communities, but this was apparently offset by the lack of migration within the regions. The hypothesis that electrification increased migration was confirmed in the case of India, where the electrification programs are directed towards productive impacts. In Colombia, where the productive impact of electrification has not been as substantial, the hypothesis that electrification causes a dynamic movement of rural populations has not been confirmed. The effect of electricity on migration may be more due to the impact of the type of electricity use in a community rather than on its mere existence there.

EDUCATION AND LITERACY

The role of education and literacy in rural development has been an important and somewhat controversial issue in the development literature. In the widely read works of Lerner (1958) and Schultz (1964), education is considered to be a prime mover of development. Recent cross-national studies have affirmed that there is a positive correlation between national levels of literacy and socioeconomic development. The consensus is that literacy and education are fundamental for a society that is advancing to higher levels of development and to a more complex division of labor. However, other research has questioned whether literacy is the cause or the effect of develop-

ment (see Barnes et al., 1982). But regardless of the direction of causality, no one would question that education is one of the key "human capital" inputs for societies at higher levels of development.

A strong positive relationship between rural electrification, income, and education has been a common finding in several rural electrification studies (Madigan, 1981; Madigan et al., 1976; Herrin, 1979; Saunders et al., 1978). These studies imply and in some cases conclude that electrification is one of the causes of higher income and educational levels. But an alternative explanation might be that wealthy households-who are better able to afford electrical service in the first place-probably connect to the central grid at a higher rate than poorer households. In addition, since most previous studies were at the household level, the relationship between electrification and aggregated literacy rates-that is, percent of the community that can read-could not be examined. In this study it was possible to control for income in the Colombian household analysis and for village level of agricultural development in the Indian study. Therefore the relationship of development and rural electrification to literacy and education can be examined.

Strong Positive Relationships in India and Colombia

Rural electrification could be positively related to literacy and education for several different reasons. Earlier it was mentioned that rural electrification in both India and Colombia is associated with children's reading at night. In addition, electric lights would be quite attractive for educated adults and families with school age children, because they allow reading during the evening hours. This might lead to higher than average growth rates of electrical connections for villages where literacy rates are high. In addition, rural schools and teachers may be more likely to locate in communities with electricity, thereby providing the infrastructure for increasing rural literacy over the long term. Thus, if rural electrification stimulates the growth of education, and if highly educated adults are more likely to adopt an electrical connection, then rural electrification may well be both a cause and an effect of rural literacy. This section will first examine the association

between rural electrification and education and then turn to a multivariate analysis to sort out some of the intervening factors.

In both India and Colombia there is a strong positive relationship between rural electrification and literacy and education. Table 5.11 provides the census and survey data for India for the village level; for Colombia household data are presented. In India the average percent literate in villages without electricity was 18.9 percent. This figure is slightly lower for the villages newly experiencing electrification, but then improves for the villages having electricity longer. The number of children attending school as a percent of the total number of school-age children no doubt has long-term consequences for the rural literacy rate. While village leaders may exaggerate the number of children attending school, the school attendance trends presented in table 5.11 mirror the literacy rates from the census materials. Among households that had had electricity for less than 5 years or were without electricity, less than half of the eligible children attended school, while well over half of the eligible children attend school in villages that had had electricity 6 or more years.[6]

The relationship between rural electrification and education is quite similar for India and Colombia. The Colombia household survey measured the level of education of the heads of household and the number of newspapers and magazines read in the household. As indicated, the level of education in Colombia was substantially higher than in India (see table 5.11 and 5.12). But, as in India, the level of education for the Colombia sample improved significantly with length of electrification. Heads of households in communities with 19 years of electrification or more averaged 5 years more schooling than for heads of households in communities with no electricity. The same trend was found for the number of newspapers and magazines read by the family, with more being read in communities with electricity for a long period of time. The correlation coefficients for both head's level of education and magazine/newspaper readership are positive and significant. The results indicate that rural electrification is highly related to education and literacy for both India and Colombia.

Table 5.11 Rural Electrification and Indicators of Education, India and Colombia, 1980

Years of electricity in village	India (village level) % literate in village	% of eligible children attending school	Proximity to school (Index)	Colombia (household level) Household head's level of education (Mean)	Newspapers/ magazines per household (Mean)
No electricity	18.8	47.9	3.4	8.1	1.5
1-5 years	17.3	46.2	4.5	9.4	1.8
6-10 years	20.5	53.6	5.0	12.2	2.2
11-15 years	26.0	67.1	5.1	13.3	2.2
16-20 years	23.4	59.2	4.8	n.a.	n.a
20 and above	26.3	52.4	6.5	n.a.	n.a
Correlation	0.25	0.17	0.39	0.31	0.21

Source: India Study, 1980; Colombia Study, 1980.

Note: n.a. stands for not applicable.

Table 5.12 Regression of Relationship Between Rural Electrification and Literacy, India and Colombia, 1980

	A. India (village survey) Percent literate	Percent of eligible children attending school	Distance from school		B. Colombia household Head's level of educ.	Magazine/ newspaper reading
% of household with electricity	0.23* (2.52)	0.51* (6.07)	0.28* (2.83)	Household with elec. dummy variable	0.28* (6.131)	0.25* (5.49)
Distance from schools	0.17* (2.07)	0.20* (2.58)	n.a.	Income	0.19* (4.50)	0.22* (5.21)
Agricultural innovation index	0.10 (1.17)	0.01 (0.16)	0.11 (1.17)	Central Region dummy variable	0.12* (2.84	0.05 (1.24)
% double cropped	0.21* (2.30)	0.22* (2.66)	-0.15 (1.5)	Coffee region dummy variable	0.02 (0.42)	-0.07 (1.50)
Yield per acre	0.09 (0.90)	-0.01 (0.13)	0.08 (0.74)			
Proximity to services (goals)	0.00 (0.05)	-0.08 (1.00)	0.12 (1.27)			
Distance from mass media	0.15 (1.80)	0.09 (1.09)	0.19* (2.04)			
Total villages	128	117	128		528	528
F statistic	9.55	14.33	5.01		23.42	19.45
R square	.36	.48	.19		0.15	0.12

Source: India Survey, 1980; Colombia, 1980.

Note: Coefficients are standardized bs; t statistics are in parentheses.

*denotes statistical significance at the .05 level.

Intervening Causes

The purpose of the regression analysis is to determine whether the strong relationship between rural electrification and literacy can be explained by some intervening causes, such as distance from school, the economic level of the community, or household income. It is quite conceivable that since communities with electricity have more schools, then the relationship between electrification and education may really be due to the presence of schools. In a multivariate analysis, the intervening factors can be controlled in order to determine whether electrification has any impact for communities the same distance from schools.

For India rural electrification was significantly related to education and literacy even after controlling for the other important factors. As expected, proximity to schools is a very important factor in determining literacy and education (see part A of table 5.12). However, even allowing for the effect of proximity to schools, rural electrification remains positively related to the education variables.[7]

In Colombia, rural electrification also was found to be positively related to education (see part B of table 5.12). Both household electrification and income are significantly related to the head's level of education and the newspaper and magazine readership index, even after controlling for the regional differences. Unfortunately, we were unable to control for other factors such as proximity to schools, but the findings suggest that rural electrification is significantly associated with education. Even at the same levels of income, households with electricity are likely to have a higher level of education than their counterparts without electricity.

Conclusion

The evidence is strong that rural electrification and literacy are complementary programs. At this point, no claim of a causal relationship can be made, but the significant cross-sectional and regression results suggest that rural electrification at the very least facilitates improvement in educa-

tional levels. Whether by providing electric lights for reading or improving the environment of village schools, electrification and education are associated even when taking into account several other potential intervening characteristics such as household income and village level of development. For India and Colombia both, rural electrification and education programs have mutually reinforcing consequences.

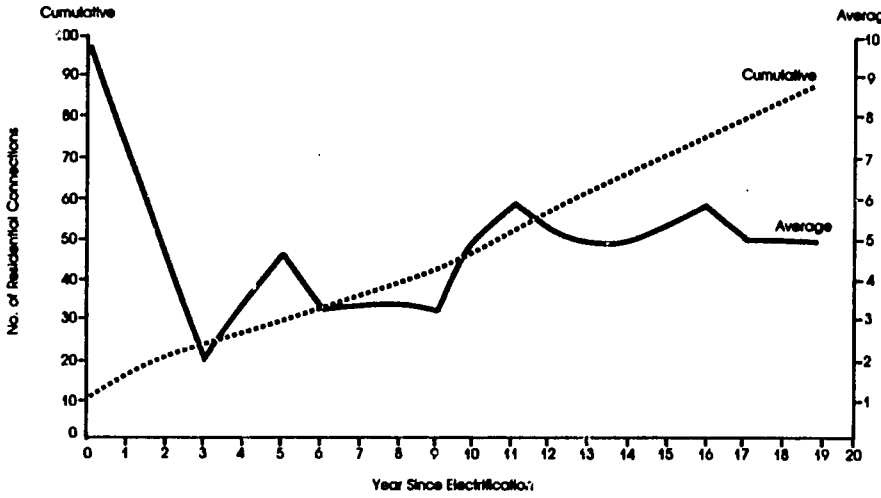
GROWTH OF HOUSEHOLD CONNECTIONS

The anticipated rate of growth in household connections provides planners with a basis for assessing the financial viability of rural electrification programs. In many instances the rates of connection growth for developing countries have been somewhat disappointing (see PEO, 1965), bringing into question the economic justification for rural electrification projects. Thus, a detailed description of household adoption rates and the factors associated with faster than average growth gives new insight into the circumstances that contribute to successful projects in order to more effectively plan future activities. Most of the following discussion centers on India, since the electric company data for household electricity in Colombia proved to be unreliable.

The growth patterns for household electrification were examined for the first 20 years after electrification for the 90 villages in the sample with at least one household connection. Fot the first 3 years after a village receives electricity, there was an initial surge in electricity adoption by rural households, probably reflecting pent up demand. As indicated by the solid line in figure 5.2, during the first two years of electrification the villages on average experienced an adoption rate of 9.6 and 7.4 households per year, which was then followed by a steady yearly growth of adoptions of about four households per year. This means that for an average village the number of households with electricity increased from about 10 in the first year of electrification to over 86 households in the nineteenth year. This is further illustrated in figure 5.3, which shows that the villages that have had electricity the longest have a high number of households that have added electricity.

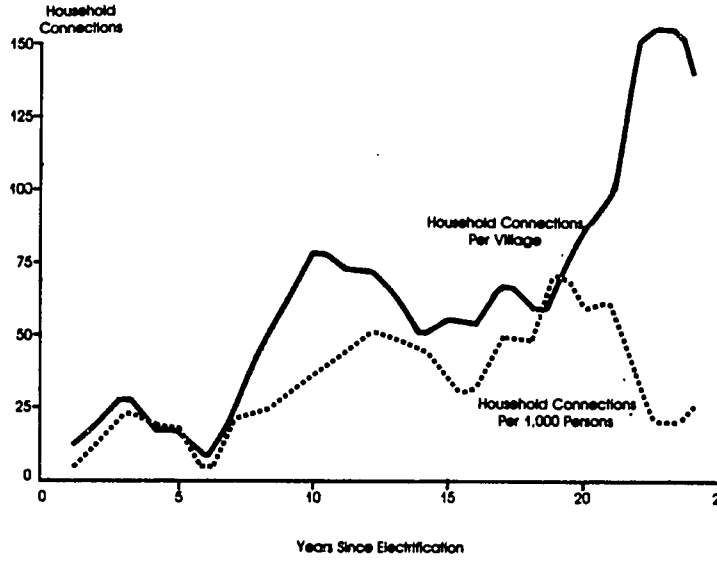
To this point we have examined the relationship

Figure 5.2 Average Yearly and Cumulative Household Adoption of Electricity per Village, India, 1980.



Source: India Survey, 1980.

Figure 5.3 Household Connections by Village Years of Electrification, India.



Source: India Survey, 1980.

between year of electrification and number of households adopting electricity. In order to determine the village conditions which might sustain an above average growth of adoptions, a regression analysis was conducted including a variety of village-level variables from the 1966 baseline study. The results are presented in table 5.13 for total households with electricity and per capita household adoption.[8] The total number of households adopting electricity for the 54 villages with data available in the 1966 study, as expected, is highly related to the village population. This is not surprising, in that the higher the number of households in a village, the more potential families there are for adopting a connection. However, after controlling for village population, it was found that three other variables were related to the number of households with electricity in 1981. These are year of electrification, percentage of the population literate, and, finally, a negative relationship with percentage of the land cropped more than one time during the year. Although many of the remaining variables-including man/land ratio, an index of power reliability as of 1980,[9] agricultural innovations-were not found to be significant, many have bivariate correlations with total connections, which can be useful indicators for village selection in rural electrification planning.

The passage of time and high levels of rural living will be expected to bring about a long-term increase in electricity adoption. The notion that houshold adoption stops after a few years is mistaken. Given the low level of households that presently have electricity, the slow continuous adoption of electricity in rural areas will continue. Literate households may have an added incentive to adopt electricity, simply because they can take advantage of electric lighting to read. The extent of the relationship between previous levels of literacy and subsequent levels of household adoption is really quite surprising. In the context of our previous discussion on literacy and education, some doubt may be raised concerning the causal connections between rural electrification and literacy. However, as indicated in the previous section, the villages with electricity also had higher than average school attendance, which in time would lead to higher literacy rates. The conclusion is that rural electrification and education are mutually reinforcing programs.

Table 5.13 Growth of Household Electricity Adoption, India, 1980

	Total village Household adoption, 1980		Household adoption per 1,000 persons, 1980	
	OLS Regression	Pearson's Correlation	OLS Regression	Pearson's Correlation
Years since village electrification	0.15 (2.27)	0.49	0.28* (2.12)	0.42
Village population, 1961	0.71* (9.92)	0.83	0.07 (.51)	0.22
Percent literate, 1961	0.31* (4.18)	0.46	0.55* (3.92)	0.50
Credit shortage, 1966	-0.04 (-.52)	-0.31	-0.15 (-1.05)	-0.22
Percent of land double cropped, 1966	-0.29* (2.87)	0.10	-0.17 (-1.3)	-0.02
Man/land ratio, 1966	-0.04 (-.53)	0.20	-0.13 (-.98)	-0.09
Power reliability, 1980	0.12 (1.74)	0.20	0.06 (.51)	0.04
Agricultural innovation index, 1980	-0.12 (-1.66)	0.24	-0.08 (-.55)	0.24
Yield per acre, 1966	0.12 (1.55)	0.36	0.04 (.25)	0.21
Proximity to transport	n.a.	n.a.	-0.22 (-1.70)	-0.04
Number of villages	54		54	
F statistic	24.56		3.67	
R square	0.85		0.46	

Source: India Survey, 1980.

Note: n.a. stands for not entered.

*denotes statistical significance at the .05 level. Coefficients are standardized bs; significant t statistics are in parentheses.

SUMMARY AND CONCLUSIONS

The impression from the recent literature is that rural electrification implies only electric lighting for a small percentage of rural households. This study has found these impressions to be wide of the mark. The positive benefits include increased appliance use, more reading - especially for

children - a higher quality of life, and a decrease in seasonal migration for India. The levels of appliance use in both India and Colombia are higher in households with electricity. Over 60 percent of the sample with electricity for Colombia had televisions, and over 40 percent of the sample with electricity in India possessed fans. Perhaps because of television ownership, the living patterns in Colombia were changed substantially by electrification. The lifestyle changes for India were fairly minor, but they included children's reading more at night. In India the subjective perception of quality of life in households with electricity was higher than in households without electricity, which do not receive the social benefits of electrification. Education and electrification are highly related and appear to be mutually reinforcing.

Rural electrification in some instances has not met expectations. The anticipated benefits accrued from productive work at night as well as more social visiting have not materialized in Colombia. The significant increase in television viewing may be responsible for curtailing these activities. Adult reading also has not improved in Colombia. Without television, the changes in lifestyle for India are not as dramatic. Electrification does not alter sleeping hours or change patterns of work during the day. Migration in Colombia is only marginally affected by electrification, while in India it may contribute to some permanent village out-migration. Also, in Colombia some concern has been raised that the cost of electrical connections and television sets, all highly desired by rural households, may take money away from more basic needs for poor households, such as education and food.

In conclusion, the social benefits of electrification are quite substantial. The evidence suggests that electrification has an impact on rural households, even after taking level of income into consideration. Electric lights, televisions for Colombia, and fans for India are the major appliances powered by electricity. Rural households seem to be willing to sacrifice a substantial amount of income to acquire electricity which may have both positive and negative consequences. One criticism of rural electrification programs is that the benefits are unequally distributed among the rural population. The equity of rural electrification will be examined in the next chapter.

NOTES

1. Even after controlling for occupation for both the samples, there is still a slight positive correlation between electrification and household income. But for India and Colombia the correlations, which are 0.22 and 0.13, respectively, are smaller than would be expected in a normal random sampling design.

2. It was decided to include electric and nonelectric appliances together in this and other analyses because they represent actual qualitative differences between the households. One could compare only nonelectricity-using household appliances between the households, but that would not capture the real differences between levels of appliance use.

3. It should be noted that almost all of the households with electricity that possess an iron have electric irons.

4. The appliance ownership index was created by simply adding the number of different appliances owned by the Indian and Colombian households. Electric and nonelectric appliances are included in the index. Even though households without electricity cannot use electric appliances, the index reflects the reality that households without electricity are not able to purchase electric appliances.

5. It will be remembered that 61 percent of the households with electricity in the Colombian sample had a television set.

6. With a correlation of 0.62, there is a very significant bivariate relationship between rural electrification and school attendance. Furthermore, the correlation coefficients between literacy and measures of rural electrification are positive and significant at 0.25 for year of electrification and 0.42 for per capita connections. However, literacy rates and per capita connections vary substantially between states.

7. The differences in electrification and literacy between states might also be responsible for the electrification/literacy relationship. For instance, the Punjab has high literacy, extensive electrification, and a high level of agricultural development, but the differences for the villages within the Punjab are not significant. But in an analysis not reported here, a control for "state" did weaken the relationship. Interestingly, however, the findings for school attendance did not change significantly even after controlling for "state," lending

even more support to the positive association between electrification and education.

8. The lines in figure 5.3 are the 3-year moving average for the total adoptions and adoption per 1,000 persons for the villages. Of course, the individual data points for the village vary significantly above and below these lines, and much of the variance can be explained by factors other than year of electrification. During the early period of electrification in India the largest villages were electrified first. Because the villages are large, they can easily support a higher number of connections. On the other hand, for the villages receiving electricity during the last 15 years, the per capita connection and the total connections tend to parallel one another, probably reflecting the fact that both large and small villages were connected to the central grid during this period.

9. Power reliability and the man/land ratio have been cited as important determinants of connection growth in an early report (see Samanta and Sundaram, 1983). It is reasonable to expect that the adoption might be higher in more densely populated villages, where stringing the lines would be easier. The power reliability measure is for the year 1980, since no data were available for 1966. We reasoned that the conditions in 1980 would be positively related to the earlier time period, but this might not be the case. In any event, contrary to expectations, the analysis indicates that both of these variables are not significant and other factors are more important in predicting the level of connections for the villages in this study.

6
Electric Power and Rural Poverty

The Achilles heel of many rural development projects is that their social and economic benefits are unequally distributed. Numerous examples may be cited: large irrigation canals often benefit large farm owners; credit programs are monopolized by already influential community members; agricultural modernization programs may be contributing to land concentration, thus pushing small farmers into the ranks of the agricultural laborers; rural development extension officers tend to concentrate their efforts on influential or "innovative" farmers. To ensure the participation of the poor in development programs, the U.S. Agency for International Development (USAID) adopted a policy to help the "poorest of the poor." But the question remains whether the "poorest of the poor" can benefit from large, capital-intensive projects such as rural electrification. Does rural electrification exacerbate or ameliorate existing rural inequality in developing nations?

The advocates and the critics of rural electrification are nowhere further apart than on the question of rural inequality. Advocates contend that rural electrification is an instrument *to redress inequalities in developing nations*, as the contrast between rural and urban amenities is due in part to the availability of electricity. They point out that only 10 percent of funding for power-related projects is allocated to rural electrification. Frank Denton (1979, p. 2) graphically depicts the differences between urban areas with electricity and rural areas without electricity in the Philippines. He observes that the cities with electricity have neon lights, night clubs, movies, department stores, good hospitals, and factories. By contrast, in the countryside where there is no electricity, all activities cease at sunset because of the poor alternatives to electric lights, so rural families have unproductive and unentertaining evenings. Advocates reason that the stark urban-rural differences in developing nations are a con-

sequence of poor infrastructure and low productivity and that electrification can improve the rural standard of living so that it is closer to that in urban areas. They further assert that delivering electricity to rural households, farms, and businesses not only will close the gap between urban and rural lifestyles but also can narrow the class distance between the rich and the poor within rural areas by creating new jobs and permitting the rural poor to raise their economic status.

The critics object, saying that the expensive electricity distribution systems will serve only the wealthiest families and thus reinforce existing inequities and distribution of wealth. It is well documented that the adoption of electricity by rural households is highly dependent on income level. Thus, while the rich will be able to partake of all the benefits of electrification, such as the use of modern appliances and lighting, the rural poor may not be able to afford electricity; in fact, they may not even be permitted to have access to electricity because their houses are of substandard quality. In this context, Smith (1980, p. 87) has argued that rural electrification goes to the wealthier regions, to the wealthier villages in these regions, and to the wealthy households, farms, and businesses within these villages. In addition, critics claim that rural electrification has no impact on rural productivity and that the money allocated to the construction, generation, and maintenance of expensive rural electrification systems would be better spent on projects that more directly improve the lives of the rural poor.

In this chapter the equity impact of rural electrification is examined from several different perspectives. Among the several possibilities to be examined is whether there is a relative widening of class differences, with either overall improvement in the quality of life or an improvement of the higher income groups with none for the lower classes. Other questions to be discussed are whether land is being concentrated into fewer farms as a result of the greater ability of large farmers to take advantage of electric power, what the differential impact on women and children is, and whether electricity has more of an impact in developed rather than in less developed regions. Finally, there will be an examination of whether equity impact varies over the short and long term.

EQUITY WITHIN RURAL COMMUNITIES

The cause and effect relationship between rural development, poverty, and income distribution may take several forms. One possible scenario is that development improves real income while narrowing the gap between the rich and the poor, which is reported to have occurred in Taiwan during the 1960s (see Chinn, 1979). Conversely, real income might actually decrease for the rural poor during development, which apparently happened in Java during the 1960s (see King and Weldon, 1977). The most common pattern for developing countries is for both the poor and the rich to experience increases in real income, but with an increasing gap between socioeconomic classes.

Existing evidence suggests that the direct impact of rural electrification for rural households, especially over the short term, worsens rural inequality. While the poor are not totally excluded, in just about all countries the poor adopt electricity at a lower rate than more wealthy households. For instance, in the Philippines, it was estimated that households with incomes below the poverty level (P 6,000 per year) could not afford electricity (Mandel et al., 1980). However, a Philippines survey found that while households with incomes above P 6,000 per year adopted electricity at a higher rate, nevertheless about one out of five households below this level did adopt electricity (Madigan, 1981, p. 11). In higher income countries such as Costa Rica, the adoption rate is even greater. About seven out of ten households within reach of the lines adopted electricity, and over half of these households were below the poverty line (USAID, 1981, p. 1). The household adoption rate for India is much lower, reflecting the lower income per capita, but the rate still improves as incomes rise. Thus, it is evident that income has a very important impact on whether or not a family adopts electricity. This is true both within and between countries; poor countries, like poor households, have lower adoption rates.

This strengthens the general argument against rural electrification - that it will improve the condition of wealthy families but not have much impact on the rural poor. To better assess the equity impact of rural electrification, this section examines who adopts electricity and how this affects their quality of life, whether electrification adversely affects land

equality, and what the long-term relationship is with rural poverty.

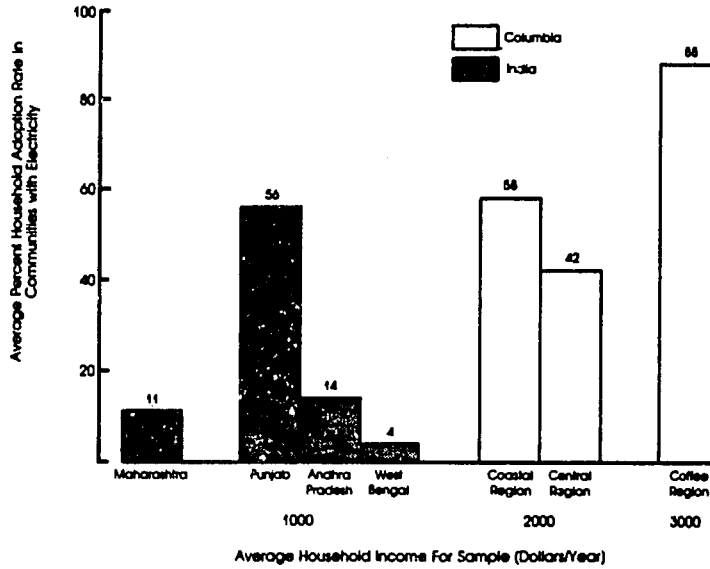
Income Class and Electricity Adoption

Generally, rural electrification programs in communities with high electricity adoption rates are more equitable. As already discussed, there is ample evidence that lower income families adopt electricity, but at a much lower rate than more wealthy households. The factors discouraging the adoption of electricity by the poor include high connection charges, high electricity tariffs, and poor housing conditions. Yet for the Colombia sample, household electrification was so pervasive, especially in the coffee-growing region (see figure 6.1), that the electrification programs benefited both rich and poor households. Because household income is much lower in India, the adoption rate for India was much lower.

This distribution of rural income also appears to have an impact on the extent to which communities adopt electricity. The existence of a fairly large middle class, as opposed to extremes of poverty and wealth, would be a much more favorable climate for household adoption. A wealthy region with a high degree of inequality would sustain only very low levels of electricity adoption. Results from the India survey demonstrate this point. The Punjab has the highest level of electricity adoption, while West Bengal, followed by Andhra Pradesh, has the lowest. The Punjab typically has a more equal distribution of income than Andhra Pradesh. The low rate of electrification in West Bengal may well be due to the high degree of inequality in this region, but the electrification program in the state has had other problems, including extremely low reliability, which would also discourage adoption of electricity.

Lower income households may also be unable to mobilize the necessary financial resources or influence to obtain electricity from the electricity authorities. In the India survey, persons in the lower paying occupational categories took as long as 10 years to obtain electricity, compared to an average of 6 years for the more highly paid occupations (see Samanta and Sundaram, 1983, p. 202). This occurred despite the survey respondents' assertions that electricity went to "anyone who

Figure 6.1 Rural Electrification Adoption Rate is Generally More Extensive in Higher Income Regions, India and Colombia, 1980.



Source: India Survey, 1980; Colombia Survey, 1980.

wanted it" rather than "mainly to influential persons" in the village. In Indonesia the perception of most households in the sample was that wealthy households benefit more than poor households (see Brodman, 1982, p. 71), with the implication being that it is harder for the poor to afford or obtain electricity for their houses. Thus, it is apparent that at least over the short term, the benefits of electricity go primarily to the more wealthy households in the community.

Improvements as a Consequence of Electricity Adoption

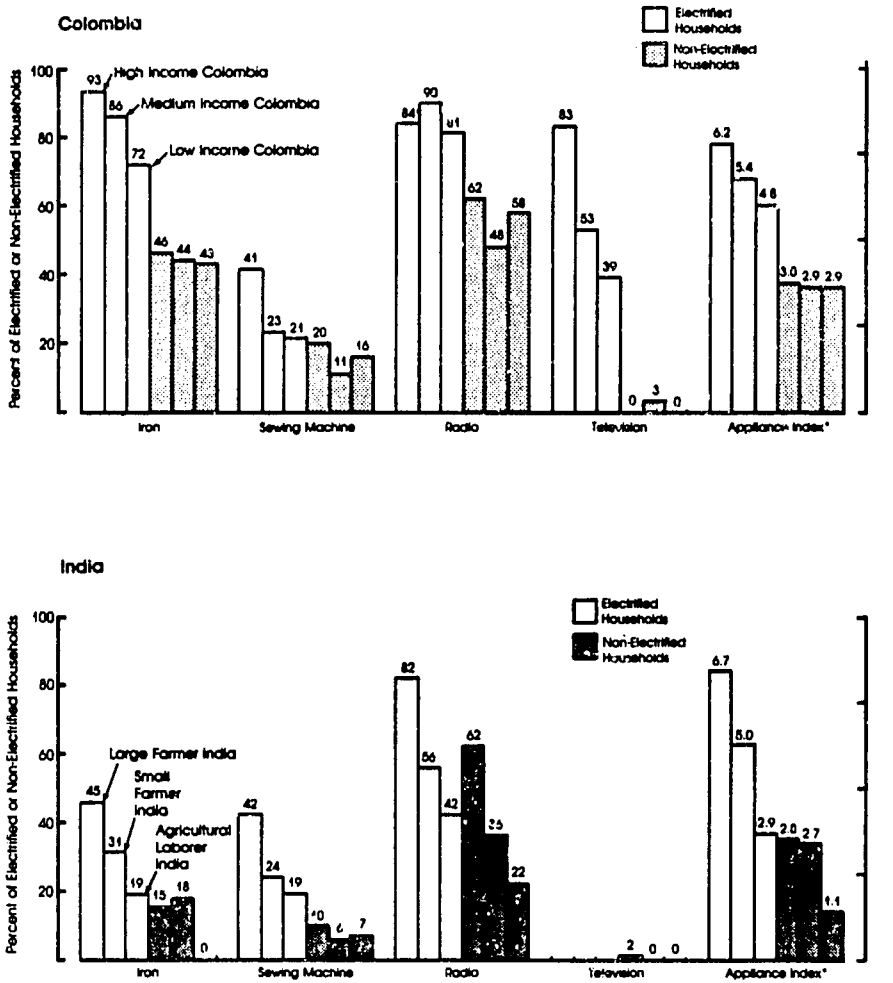
After adopting electricity, wealthy households also may

derive more benefit from electrification, since they are able to purchase more appliances and consequently improve their quality of life more. Of course, this is not unique to developing societies. Whereas lower income families in developed societies may not be able to afford such items as central or even window air conditioners, in developing societies lower income families similarly may not be able to purchase such items as radios and fans.

The levels of appliance ownership may vary both within and between developing nations. Households in countries with high income per capita can afford to purchase more appliances. Appliance ownership depends both on household income and to some extent on culturally defined consumer behavior. For instance, irons are valued in both India and Colombia, but, as indicated in figure 6.2, the ownership of irons is higher in Colombia than in India. Within both Colombia and India the ownership of irons is highly dependent on the level of household income. A higher percentage of high income families own irons as compared to low income families in both countries. Because Colombia in general has high levels of income, even the lowest income households there are more able to afford irons than households in India. On the other hand, sewing machines are highly valued in India. As a consequence, even though household income is lower in India, the percentage of households with sewing machines is about the same for both countries, but once again the high income classes are more likely to own sewing machines.

Electrification also may play a role in increasing the variation in number and types of appliances owned. Households without electricity do not have as wide a range of choice of appliances. For instance, in Colombia the ownership of electric irons varies with income for households with electricity, but households without electricity at all income levels own very few nonelectric irons. This suggests that electrification may stimulate the introduction of a variety of new consumer products, whose purchase will be related to the level of household income. In Colombia, television ownership is also positively associated with income, but ownership is not possible without some form of electricity (see figure 6.2). This line of reasoning suggests that within regions with electricity both the rich and the poor are prospective purchasers of new appliances. The distribution of electric appliances favors the rich, *but the level of benefits for the rich and the poor households with*

Figure 6.2 Increase in Appliance Ownership According to Presence of Electricity, Income, and Occupation, India and Colombia, 1980.



* Appliance Index Scales Are Different For India and Colombia.
Note: Categories for Colombia include High, Medium, and Low Income Groups.
Categories for India include Large Farmer, Small Farmer, and Agricultural Laborers
Columns For Non-Electrified and Electrified Categories Are Not Additive and Represent Total Percent of Households for Each Category.

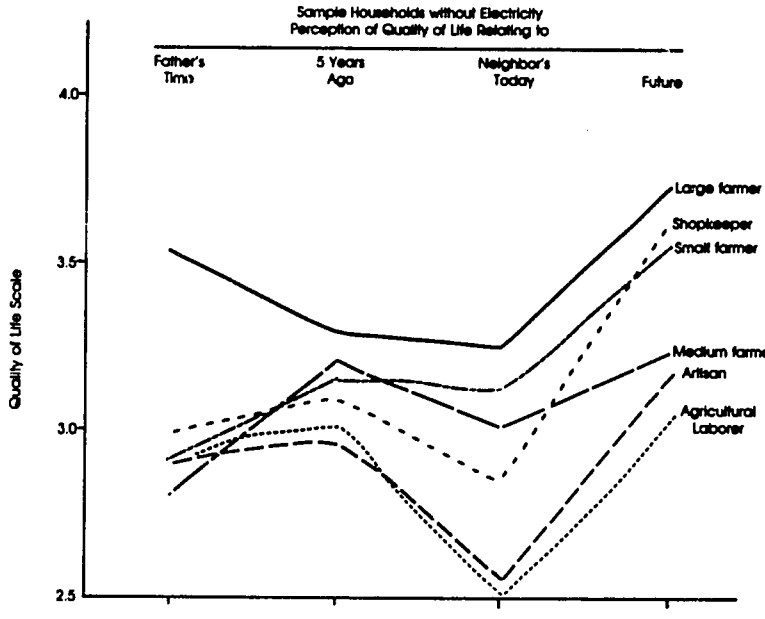
electricity is higher. This scenario shows appliance ownership improving for all classes, but with a larger gap evolving between the rich and the poor.

Lighting, irons, radios, fans, and other appliances all can have an impact on people's perceptions of the quality of rural life. The India survey collected information on the households' perceptions of their quality of life in the past, present, and future. The responses are categorized by income class and electrification status in figures 6.3A and 6.3B. For the India sample without electricity, the quality of life was perceived by large farmers to be much higher than by the other occupational groups. The low-income agricultural laborers and artisans rated their quality of life the lowest, and the other groups range in between these extremes.[1]

Electrification appears to increase the overall quality of life and narrow the gap between the middle and upper income households. While the life of the poor seems to have improved somewhat, it is still fraught with much uncertainty and is lagging behind that of the middle and upper income groups. Just as the appliance analysis indicates that wealthier income groups own more appliances than lower income groups, the perception of the quality of life by the sample with electricity is both higher and more heterogeneous than among the sample without electricity. The large farmer with electricity still rates quality of life more highly for the past, present, and future, but the other occupational groups with electricity are closer to the large farmer in their assessments than are the same groups in the sample without electricity. Thus, middle income households with electricity have narrowed the gap on the large farmer concerning quality of life. However, much uncertainty still exists for the small farmers and agricultural laborers. These lowest income groups are still at the bottom in their assessment of quality of life. The small farmer feels that the past was much worse than the present, perhaps reflecting upward mobility, but they also are fearful of the future. The agricultural laborer, by contrast, perceives that the past was better than the present, but is optimistic about the future.[2] To summarize, the quality of life of the middle income households appears to improve both relatively and absolutely with rural electrification. The poorest households with electricity rate their present quality of life as low but are optimistic about the future.

Figure 6.3 Perception of Quality of Life for Households With and Without Electricity, India, 1980.

A. Households without Electricity: Large Farmer Has Highest Quality Of Life Perception.

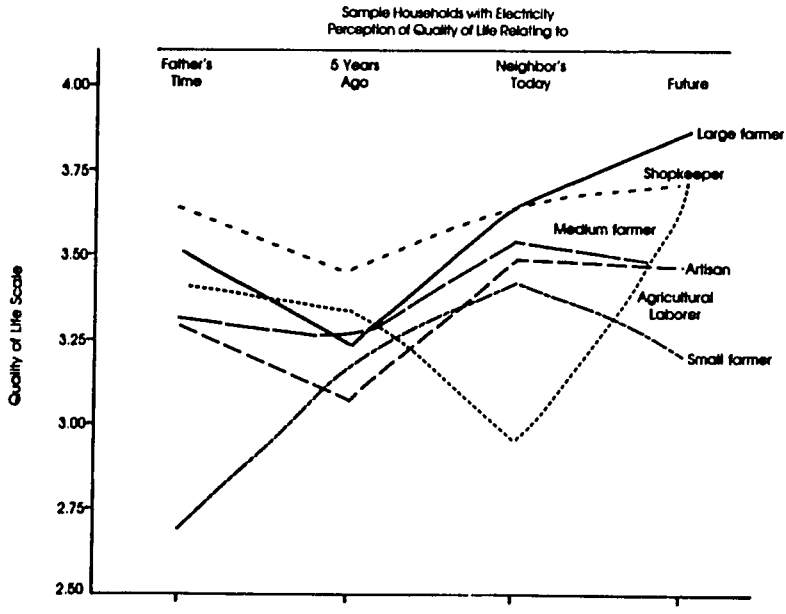


Note: For scale, 1=considerably worse, 2=moderately worse, 3=about the same, 4=moderately better, 5=considerably better.

Source: India Survey, 1980.

Figure 6.3 Perception of Quality of Life for Households with and without Electricity, India, 1980.

B. Households with Electricity: Middle Income and Large Farmers Have Similar Quality Of Life Perception.



Note: For scale, 1 = considerably worse, 2 = moderately worse, 3 = about the same, 4 = moderately better, 5 = considerably better.
Source: India Survey, 1980.

Land Inequality

The transformation of traditional agriculture to more modern forms has raised the specter of capitalist farmers' buying out smaller farmers and displacing tenants, resulting in a greater land concentration among fewer cultivators. Many documented historical cases of agricultural change reinforce this notion. The English enclosure movement has been held responsible for transforming peasants into urban laborers in England during the nineteenth century, and increased rural landlessness was one result of Japan's commercialization of agriculture.

Even though farmers in Japan were encouraged to stay on the land, population growth caused an increase in landless labor.

Rural electrification conceivably could cause increasing landlessness and inequality through the modernization of agriculture. Electric pumps and threshers could displace labor and enhance the income of large farmers. As a consequence of this improved income, large farmers might then purchase new land from more marginal farmers who cannot afford the capital expenditures to improve their farming practices. As indicated, the small farmers and landless laborers are in a very vulnerable position within Indian society. The result would be an increase in land concentration among large farmers with electricity.

If this scenario is true, then the number of years that a village has electricity should be related to higher village land inequality. But India has land ceiling and land reform laws; although they have been rather ineffective in land redistribution, they have prevented many large farmers from acquiring new land (Ladejinsky, 1973, p. 542).

The evidence from India suggests that rural electrification is not related to land inequality. Village leaders were asked to identify the ten largest farmers and estimate how much land they owned in order to construct a measure of land concentration for the sample villages. If rural electrification is related to land inequality, then year of electrification should be positively associated with land concentration (see table 6.1). But outside of the control variable for village size (percent of farmer population represented by the top 10 cultivators), there appears to be no long-term association between land concentration and rural electrification or agricultural development. Neither rural electrification nor agricultural development seems to have adversely affected land distribution. This may be due to the land ceiling laws, which have been ineffective in preventing large farmers from retaining land but have prevented many from acquiring new land. Other recent studies also have found that agricultural development is not a cause of greater rural inequality in India (see Barnes and Vanneman, 1983; Attwood, 1979).

Colombia is a country with large regional differences in size of landholdings. The coastal region is characterized by modern agriculture, cattle farming, and large landholdings, while the coffee-growing region is oriented towards export agriculture but has much smaller farms than the coastal region.

Table 6.1 Regression of Rural Electrification with Land Inequality, India and Colombia, 1980

	India (village survey) Percent of land owned by top 10 landowners		Colombia (household survey) Farm landholding size		
	OLS regression	Correlation coefficient		OLS regression	Correlation coefficient
Yield per acre	.08	-.07	Income	.36*	.41
			Education	.04	.19
% of area irrigated	-.04	.26	Year of electrification	.06	.08
Year of electrification	-.05	.03	Central region dummy	-.44*	-.09
10 cultivators as % of farmer population represented by top 10 landlords	.50*	.53	Coffee region dummy	-.47*	-.23
Number of cases	117 villages			213 households	
F statistic	11.36			19.28	
R square	.28			.31	

Source: India Survey, 1980; Colombia Survey, 1980.

Note: *Means significant at less than .05 level; coefficients are standardized bs.

The central region is distinguished by traditional farms and small landholdings. The Colombia farm level analysis of electrification and size of landholding might be expected to reveal that large farms are among the first to adopt electricity. However, once the effect of regional differences in landholdings has been controlled, only income is related to farm size. Neither education nor year of electrification is associated with greater than average farm size. It was previously noted that rural electrification in Colombia does not have much impact on productivity, and therefore perhaps it would not be expected to play a significant role in increasing farm size. Another explanation might be that large farms are located further from the electricity distribution facilities.

Land inequality is certainly not exacerbated by rural electrification, nor apparently is it improved. There is some evidence that land fragmentation is alleviated in India (see Samanta and Sundaram, 1983), where investment in irrigation facilities might encourage farmers to own adjacent plots of

land. But factors other than rural electrification appear responsible for land inequality, as is evident in the differing patterns of land ownership in the different states in Colombia.

Rural Poverty in India

Rural poverty in India involves issues such as the productivity of agriculture, nonfarm employment opportunities, minority groups, and distribution of landholdings. The classic study of rural poverty in India by Dandekar and Rath (1971) identifies land and employment opportunities as the key factors relating to rural poverty and income distribution. The means of production in rural India relate to the ownership of land. Therefore, an equitable distribution of land among cultivators, along with high agricultural productivity, should result in less village-level poverty. High agricultural production may benefit landless laborers (scheduled castes and other minorities), since farmers would be able to substitute hired labor for family labor and hire additional help for their farms. In the process the farmers may be required to pay higher daily wages to farmworkers because of the increasing demand for agriculture labor. While nonfarm employment opportunities may be very important for reducing rural poverty, in India there are very few such opportunities, and most of the opportunities that do exist are in the larger villages.

Several crude indicators of rural poverty were available from the Indian survey, including the percentage of the village population paying taxes on their property and the percentage of the village population that leaders identified as "living in acute poverty."[3] In the survey analysis, rural electrification related negatively both to the percent in acute poverty and to the percent of the eligible population paying minimal taxes (see table 6.2). Thus, villages which have had electricity the longest also have less poverty than those without electricity. Yield per acre is positively related to percentage paying minimal taxes, probably because of the undermeasurement of land as an asset, but it is negatively related to percentage of those in poverty. Villages with a high degree of irrigated area - typically the rice growing areas - have a higher percentage of the population in poverty. These findings are not surprising, since

Table 6.2 Regression of Rural Electrification and Other Village Characteristics With Indicators of Rural Poverty and Percent of Villagers Paying Different Levels of Taxes, India, 1980

	Percentage of population living in acute poverty	Percentage of taxpayers paying		
		Rs. 0-2	Rs. 2-10	Rs. 10+above
Village population	-.10	-.24*	-.02	.33*
	(-.93)	(-2.32)	(0.21)	(3.36)
Year of electrification of village	-.32*	-.20	.10	.12
	(-3.23)	(-2.02)	(.97)	(1.21)
Percentage of area irrigated	.36*	-.13	.33*	-.30*
	(3.78)	(-1.36)	(3.36)	(-3.12)
Yield per acre	-.22*	.34*	-.26*	-.06
	(-2.19)	(3.45)	(-2.61)	(-.67)
Land concencentration index	-.10	.06	.02	-.10
	(-1.09)	(.63)	(.22)	(-1.14)
Percentage of scheduled castes in population	-.03	.06	-.03	-.03
	(-.29)	(.61)	(-.31)	(-.33)
Percent working in industry	.00	.11	-.00	-.14
	(.03)	(1.29)	(-.04)	(-1.63)
Number of villages	114	119	119	119
F statistic	4.71	3.34	2.78	4.79
R square	.24	.17	.15	.23

Source: India Survey, 1980.

Note: *denotes statistical significance at less than .05 level; coefficients are standardized bs; t statistics are in parentheses.

the rice regions in India also have a poor record of income distribution. On the other hand, land inequality does not relate to rural poverty, which is counter to expectations. In any event, rural electrification does not appear to be associated with rural poverty.

Women and Children

Existing evidence also indicates that women and children benefit most from household electrification. As was indicated in the previous chapter, appliances may lessen the work

of rural women, and electric lights facilitate school work done at home by children. Supplementing this evidence, two studies in Costa Rica (Lay and Hood, 1979; and Kessler et al., 1981) found electricity to be especially beneficial for rural women. Of course, Costa Rica is a high income country with a high electricity adoption rate. In less developed nations, women and children in poor rural households that are unable to afford electricity would not directly benefit from electrification.

Recent literature on agricultural development and women's participation in the labor force concludes that agricultural development can have an adverse impact for rural women (see Tinker, 1976; Boserup, 1970; Barnes, 1983), but women and children are apparently prime beneficiaries of rural electrification. Lights and appliances can have a significant impact on household work. In the early stages of the rural electrification program in the United States the subsidies for rural electrification programs were justified in part because of the improvements in the quality of rural life, including the elimination of household drudgery by appliance use. Even though appliance ownership in developing countries is much lower, rural electrification programs, and especially programs with household emphasis, may have substantial benefits for women and children.

In the Indian survey, women and children were identified as the groups benefiting the most from rural electrification and the situation in Colombia proved similar. For the rural communities in Colombia, electrification has meant the freeing up of time for more recreational activities, with some emphasis on television watching. After electrification, family members stay at home more. For teenagers and children the most significant benefit is that more of them spend some evening hours studying. Women seem to do evening chores during the day, and some domestic work is lightened through the use of appliances. While in homes without electricity women anticipate doing more productive work in the evenings once they adopt electricity, these positive expectations are not fulfilled. Women seem to work less in the evening and spend more time on leisure activities. Also, an anticipated increase in social activity also does not seem to take place, at least during the evening hours.

Rural electrification programs thus favor women and children. Since women and children spend more time in the

home compared to men, it is quite reasonable that they should benefit the most from household electricity.

Summary of Household Equity

On the question of household equity, the news is both good and bad for rural electrification programs. The bad news is that in countries with extremely low incomes and/or poor records of income distribution, the poor will not be able to afford electricity. Even among households with electricity, the more wealthy will be able to purchase more appliances, thus widening the gap between the rich and the poor. The good news is for those households that adopt electricity, their overall quality of life is enhanced compared to the households without electricity; and to some extent the gap between the middle income and wealthy households is narrowed. Women and children, who spend the most time in the home, benefit more from rural electrification than men, which is not the case in most rural development programs not directed specifically towards women. Rural electrification appears to have a neutral impact on land distribution and rural poverty, neither improving nor worsening it. However, these conclusions from the household analysis need to be compared with the effect of rural electrification on regional equity.

REGIONAL INEQUALITY AND INDIAN AGRICULTURAL PRODUCTIVITY

Politicians have long recognized that development projects can be directed so as to benefit their constituents more than others, and rural electrification projects are no exception. Since large infrastructure projects typically generate additional employment, the direct benefits of rural electrification to regions would include the creation of new jobs. The household benefits of electricity have already been documented. Also, as indicated, rural electrification may well help to improve productivity in agriculture and industry. The socioeconomic bene-

fits of rural electrification programs obviously would be felt most in the particular project area.

Rural electrification might exacerbate regional imbalances by helping developed areas to improve faster than less developed regions. However, not much empirical evidence exists to support or reject this contention. One study for the Philippines found that the advanced areas appear to achieve much more economic development than the poor areas (Mandel et al., 1980). Unfortunately, this study examined advanced and less-developed areas without analyzing trends over time, so it is impossible to determine the differential impact on the two areas. While it may appear that electrification had little impact on the poor regions, in reality the poor regions may be improving substantially, but from a much lower level of development.

One of the criticisms of rural electrification has been that it may only be appropriate for regions with a relatively high level of development. In other words, it will have greater impact in the rich regions, where the people can afford pumps, machines, and appliances, but the poor regions will not be able to take advantage of the many potential benefits of electricity. To make matters worse, rural electrification projects, in many cases, are implemented in the most wealthy regions first, thus increasing the possibility that they will contribute to greater regional inequality.

The villages surveyed in the India study are ideal for examining the regional impact of rural electrification. The village sample was stratified according to the regional level of development of the districts, which included an advanced, an average, and a poor district. Tribal regions were purposely included in the sample design. As a consequence, the different impacts of rural electrification for rich and poor communities can be examined.

Agricultural Yields, Irrigation, and Agricultural Innovations

The regional characteristics relevant to the impact of rural electrification on agricultural development include agricultural wealth, extent of irrigation, and geographic isolation. Since over 80 percent of the rural population in India is

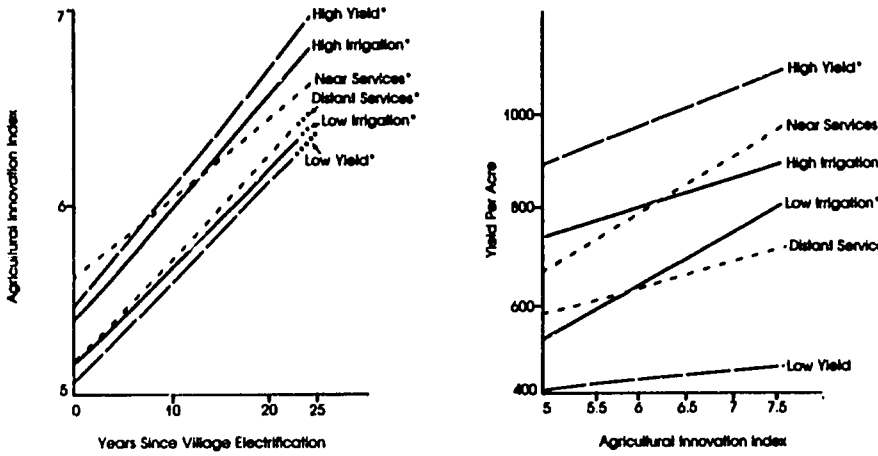
directly employed in agriculture, the level of agricultural production, either per acre or per person, has a significant impact on levels of living. Value of yields in the sample areas ranged from a low of just under 100 to over 1,500 rupees per acre. These differences in yield are important for evaluating the impact of electricity on regional equity. The villages were also divided into those with high and low amounts of irrigated land.

Geographical isolation generally has been considered a constraint on rural development, so the sample was also divided into areas with high and low levels of isolation. Without roads, grain cannot be conveniently shipped outside of the village to distant markets. Lack of communication may mean that the farmers are not exposed to new ideas and farming practices, even those practices being adopted on farms as little as 25 miles away. Advocates of rural electrification have argued that rural electrification will help the more isolated regions catch up by more closely linking them with the larger society. Critics contend that the cost of connecting isolated villages far outweighs the meager benefits derived from electricity.

Differences Between Developed and Less Developed Regions

The expectation was confirmed that rural electrification would be associated with agricultural innovations in advanced regions, but the surprise was that it also is related to innovations in the poorer regions. As indicated in figure 6.4, the highest 3 regression lines slope upwards, which means that year of electrification is strongly associated with innovations for regions with high agricultural yields, with high levels of irrigation, and in close proximity to services. *The unexpected finding was that the less well-off villages that have low yields, little irrigation, and few services also can take advantage of rural electrification.* Even though the level of innovation is lower than in the other villages, the poor villages start out at a lower level, but improve just as rapidly as the more wealthy villages. This means that rural electrification is associated with innovations whether villages are wealthy or poor.

Figure 6.4 Correlations between Rural Electrification and Agricultural Development for Villages at Different Levels of Development, India, 1980.



Note: All lines are regression lines based on India survey data. Dotted lines are projections.
*Denotes significant at .10 level.

Source: India Survey, 1980

The second step in analyzing the impact of electrification on agricultural development is to relate farming practices to agricultural yields per acre. Many studies have found that changes in farming practices benefit the advanced areas more than poor regions. The second figure in figure 6.4 tends to confirm these findings. The high yield villages typically have both higher levels of crop yields and faster adoption of different farming practices, including irrigation and agricultural innovations. Thus, the second level analysis of the relationship between rural electrification and development indicates that some less developed regions improve yield significantly by changing farming practices while others do not.

The conclusion from the analysis is that advanced villages do benefit most from rural electrification, but the less

developed villages also improve their farming practices. Unfortunately, the relationship between innovations and agricultural yields is not as significant for the less developed regions. However, if only the more advanced villages receive electricity, this is likely to create even greater regional imbalances, since the poorer regions will not experience the change in farming practices associated with electricity. The lowest yield villages are helped less by electrification than the other villages, but not because farming practices were unchanged. The low yield villages had much lower levels of irrigation than the rest of the villages. Even with improvements the innovation levels were still so low that there did not seem to be much effect on crop yields. Also, the new hybrid seeds for unirrigated barley, sorghum, and other crops have not been as effective as those for rice and wheat varieties. Thus, in the next section we examine the effect of rural electrification on development in different cropping regions.

Rice, Wheat and Other Crops

The rice growing regions in India historically have been more productive than other areas. With traditional means of irrigation and heavier than average rainfall, these regions have prospered relative to the more dry areas in India. But the wheat areas have had the greatest increase in yields during the last 15 years. Rice yields are quite high, and they also have improved, but they have been overshadowed by the dramatic growth of wheat. As indicated above, the lowest-yielding areas are those that produce neither rice nor wheat, and especially those areas dependent upon dry land farming for producing barley, sorghum, and other grains. Thus, the relationship between rural electrification and crop production has been analyzed for villages with high percentages of rice, wheat, or "other crops" under cultivation (see table 6.3).

As expected, the yields in the rice and wheat growing regions of the sample were higher than in areas growing other crops. Because of the heavy rainfall during monsoons in the rice areas, a smaller percentage of the land is irrigated than in the wheat regions. In the rice areas, much of the water supply is dependent on unregulated streams (see Sanderson and Roy,

Table 6.3 Pearson's Correlations Between Electricity and Development in Rice, Wheat, and Other Cropped Areas, India, 1980

	Villages with high percentage of rice cultivation		Villages with high percentage or wheat cultivation		Villages with high percentage of other crops[1]	
	Years of elec.	Crop yields/acre	Years of elec.	Crop yields/acre	Years of elec.	Crop yields/acre
Area under irrigation (percent)	-.019	.374*	.494*	.403*	.422*	.589*
Area double cropped (percent)	.160	.490*	.187	.246	.185	.354
Agricultural innovation (index)	.412*	.455*	.420*	.225	.428*	.447*
Number of cases	59 villages		43 villages		53 villages	

Source: India Survey, 1980.

Note: *Denotes statistical significance at less than .05 level.

[1]Other crops include sorghum, millet, corn, barley, cotton, jute, and sugar cane.

1979, p. 37), and in many cases there is a problem of soil waterlogging. However, the rice regions have relatively high levels of double cropping, taking advantage of the moisture remaining in the soil from the heavy monsoons to produce a second crop during the same year. Thus, it is not surprising that for rice regions year of electrical service is unrelated to the percentage of the village area under irrigation. Farmers in those regions apparently continue to rely on either the traditional or canal irrigation techniques or natural rainfall, which is adequate to produce the already very high yields.

As indicated above, the wheat areas have been at the forefront of the "green revolution," and have dramatically improved their crop yields during the last 15 years. In those areas, in contrast to the rice regions, diesel or electric pumps are essential for improved crop production, as the yields for hybrid wheat varieties can only reach their greatest potential through a combination of irrigation and intensive fertilizer use. Thus, the positive association between year of electrification and irrigation was expected for the wheat growing areas.

More surprisingly, there was also a strong association between rural electrification and irrigation in the regions

growing other crops, such as coarse grains, pulses, and sugar cane (see table 6.3). Many of these areas traditionally have relied on rainfall for growing crops. Since the rains sometimes fail, the high risks discourage investment in the new technologies. Although these regions generally have poorer yields than either the rice or wheat growing regions, irrigation can mean the difference between extremely poor yields and more moderate levels of production. In fact, being able to irrigate during light monsoon years-periods in which crops would previously have failed-may provide a buffer against the droughts that have plagued the marginal farming areas in India. Also, after irrigation the farmers growing coarse grains typically switch to higher value cash crops such as cotton or sugar cane. Thus, it is an interesting twist that in this case *rural electrification actually helps the less developed regions more than the developed, rice growing regions.* By aiding the less developed regions, rural electrification may lessen some interregional disparities by providing power for much needed irrigation in the traditionally drier farming regions in India.

Interregional disparities certainly have not been seriously worsened as a consequence of rural electrification, and may have even improved. In both the advanced and less advanced villages, rural electrification is associated with improved farming practices. Unfortunately, the lowest yield villages appear unable to effectively translate improved farm practices into higher crop yields. Perhaps this reflects the fact that there have been no technological breakthroughs in low yielding coarse grains for dryland farming areas. When irrigation is introduced there is a change to the higher value crops such as rice, wheat, and sugar cane.

SUMMARY AND CONCLUSIONS

The critics and the advocates of electrification both may be partly right concerning the equity effects of rural electrification projects. Higher income households generally benefit the most from the introduction of electricity into a region, since they are able to afford the installation and monthly charges of an electrical connection and also have the ability to purchase appliances for entertainment and for helping with

household work. But the poor who do adopt electricity are better off than their counterparts without electricity. The minimum advantage for poor households is higher quality of lighting, which appears to improve their quality of life. In high income countries and countries with more equal distribution of incomes, electrification programs will be more equitable, since the benefits will be more widely spread among all income classes. Rural electrification areas also should become more equitable as time passes, since as new families adopt service, electricity will reach a higher percentage of the rural population. Also, wealthy households appear to be given priority for receiving permits for household connections early in projects, so the small farmers and lower class households must wait longer to obtain electricity for their homes.

Interregional disparities in crop production may be diminished by rural electrification in combination with improved farming practices. The villages that benefit most from electricity are those with a high percentage of farmland under crops other than rice. In these villages rural electrification is associated with irrigation and greater use of agricultural innovations, resulting in higher crop yields. Also, irrigated farming is typically much more labor intensive than rainfed agriculture, so one might speculate that the additional demand for labor would benefit the low income classes, especially the agricultural laborers. The one negative finding is that cultivators in the poorest villages with very little irrigation have changed some of their farming practices in areas with electricity, but these changes have not really translated into significant increases in crop yields.

Women and children benefit more directly from having electricity in the house than men, since they generally spend more time in the home. Children spend more time reading in households with electricity. Women have better light for working and reading, and appliances may well eliminate some of the drudgery involved in household work. Rural electrification is one of the few development programs not specifically designed to help women and children which nevertheless have very favorable consequences for them.

The short-term outcomes of rural electrification are much less favorable than the long-term consequences. Rural electrification in its earliest stages has an adverse impact on rural equality. Typically, the most populated and most advanced villages are the first to obtain electrical service.

Also, the wealthiest households adopt electricity in greater numbers than do the poor households, especially in the first five or even ten years of a project. For very poor countries rural electrification programs may be inequitable for a long period of time. However, the long-term benefits of rural electrification appear to be less inequitable. In Colombia the electricity adoption rates are quite high and households at different income levels have adopted and benefited from electricity. In India some poor farming areas have improved crop yields as a consequence of rural electrification, and they may improve yields enough to narrow the productivity gap with the higher yielding rice areas.

Extending electricity to the most populous and most advanced regions first is one of the most important reasons for equity problems with rural electrification. Isolated and poor rural areas generally are the last to receive electricity. However, the cost structure involved in implementing rural electrification projects is the most important reason for adopting such a policy. In order to place the socioeconomic consequences of rural electrification in a financial perspective, the next chapter reviews the benefits and costs of rural electrification.

NOTES

1. This assessment of the future by all households is rather optimistic, once again debunking the myth that Indian peasants are fatalistic and therefore resistant to change.

2. The agricultural laborers and the small farmers are in quite a vulnerable position in India society. Just a few bad harvests may push the small farmer into the agricultural laborer ranks. Agricultural labor is a low income and generally a lower caste occupation.

3. It should be cautioned that both of these poverty measures are somewhat imprecise. The identification of those living in poverty by village leaders involves a subjective judgment of poverty which may not be consistent from one state or region to another. The taxes levied in the village are for household property and do not include farmland, thus grossly underrepresenting land assets. Because the indicators of poverty are not very precise, these findings on rural poverty should not be taken as definitive, and further analysis is necessary to define the role of rural electrification.

7
Can Developing Nations Afford Rural Electrification?

The expense of providing electrical energy to rural areas is an important part of the controversy over rural electrification. If electricity were extremely cheap to produce and distribute, then it would be substituted freely for many other types of energy, including wood for cooking, diesel for agricultural pumping, and kerosene for lighting. However, extending electricity to rural areas is even more expensive than meeting consumer demand in the more densely populated urban regions. Power losses, long high and low tension lines, and transformers are all very costly. Also, since capital for such development projects is generally scarce, electricity distribution programs in rural areas must meet certain criteria of efficiency and cost, maximizing development impact while not creating too much financial strain on utilities.

The socioeconomic benefits of rural electrification have already been examined. These benefits must be balanced against project costs to determine at what price developing nations can afford to implement such programs. Also, the costs of grid electricity need to be compared with those for alternative local systems in order to evaluate which technologies offer comparable service for less cost. Thus, the key components of the evaluation involve the extent of subsidy in rural electrification, whether alternative energy technologies are competitive with centralized systems, and what levels of development or conditions are necessary to justify rural electrification projects.

Rural electrification subsidies are not unique to developing nations. For developed nations, subsidies generally were necessary in the early stages of rural electrification projects. The relatively slow growth of consumer demand in rural areas of the United States, combined with the high expense of extending the grid to rural areas, prompted Franklin Roosevelt

in 1936 to sign into law a bill authorizing subsidized loans for rural electrification. Although many of these government subsidies were eliminated once electricity became a prominent part of rural life, electricity prices still are controlled by politically appointed commissions which insure that the electricity industry makes an adequate rate of return.

The situation is different in these in many developing nations. The dramatic growth of rural demand for electricity in the United States has not been replicated in these nations. The dilemma for their electric industry is that cost recovery depends either on raising prices or on improving load to make fuller use of fixed investments in plant and equipment. Raising prices may have the undesired consequence of curtailing consumer demand and limiting electricity use to higher income households. But prices that do not reflect the long-run marginal cost of producing and distributing electricity may cause shortfalls in operating capital for utilities and thereby inhibit service over the long term.[1]

The benefit-cost research in this chapter clarifies some of the complex financial issues of rural electrification. The chapter reports the findings from an Indian case study on the nature and extent of benefits and costs involved in central station generation and the cost of alternative forms of electricity generation. Before turning to the case studies, the existing evidence on the benefits and costs of rural electrification is reviewed.

BENEFIT-COST METHODOLOGIES

Most benefit-cost research on rural electrification in the past has been based on a wide spectrum of assumptions. Costs may be calculated on the basis of (1) the rural electrification distribution scheme alone, (2) the distribution and the average cost of generating electricity, or (3) the distribution and the incremental investment costs necessary to produce electricity (marginal cost). The calculation of benefits always includes the tariff revenue (willingness to pay by consumer) of the utility as a minimum, but two methods of calculating economic benefits are (1) cost savings over alternative forms of energy, and (2) incremental productivity in agriculture and industry. Most

rural electrification studies have found that rural electrification has positive economic rates of return once productive uses are taken into account. But a variety of time periods and discount rates have been used for these analyses, and assumptions concerning what should constitute costs and benefits also vary considerably. The bases for the two main benefit-cost approaches are examined in this section.

Cost

Rural electrification projects typically finance only distribution facilities, and no specific funds are provided for generating stations and transmission. As a consequence, one method of estimating the cost of electricity delivered to the project has been to use the average cost of generating electricity with existing plant and equipment. This typically leads to underestimating economic costs but nevertheless has been used in many benefit-cost studies (National Council of Applied Economic Research, 1967, 1975; PEO, 1965). A second method is to calculate the incremental expense of supply, including adding new generating and transmission capacity, since (1) the rural electrification distribution networks typically will create new demand for electricity in the power system and (2) marginal cost expresses the economic cost of power supply most accurately (see Munasinghe and Warford, 1982, for a detailed analysis). This marginal cost method has been adopted by the World Bank and other donor agencies for evaluating the financial viability of rural electrification schemes.

Benefits

Two distinct methods have been used in existing analyses to evaluate the benefits of rural electrification beyond tariff revenue. They are based on different assumptions of rural energy development. One method is the cost savings approach, which involves calculating the cost to the consumer and society of alternative energy sources for providing the

same service. For instance, the economic costs of using kerosene for lighting or diesel for pumping and small industry are compared with the long-run marginal cost of using electricity for the same end use. Cost savings (negative or positive) can be added to or subtracted from the financial project benefits (revenues as a proxy for customer willingness to pay). Alternatively, the total costs of using alternatives in the absence of the project can be used as the benefit instead of revenue. A second approach is to first determine electrification as the least-cost method to provide energy for incremental economic development, and then attribute net incremental output as benefits. In this case, the incremental economic benefits, such as improved agricultural and industrial development, are included as benefits in the project's economic rate of return (often along with the financial revenues), once it is determined that the project is the least-cost way to achieve the benefits. The net incremental benefit approach is used in the Indian case study.

Both approaches must make numerous assumptions concerning rural energy use, especially since it is sometimes difficult to compare the same end use for different energy sources. One question is whether the use of alternatives such as diesel pumps and engines will increase to satisfy irrigation and other motive power needs in the absence of an electrification program. Another issue is the quality of lighting. In her Indonesian survey of rural electrification, Janice Brodman (1982, p. 15) found that because the quality of electric lighting is superior, respondents use it for longer periods of time than they would kerosene lights. Increased power use may also occur when electricity is introduced into a region because people begin to use refrigerators, fans, television sets, blenders, or other appliances which usually are not powered by alternative energy sources. Thus, providing electricity to a region may actually increase overall energy use, making assumptions concerning cost savings somewhat difficult.

Difficulties in Assessing the Alternatives to Centralized Power Systems

Comparisons between central grid electricity and the

decentralized energy alternatives have been both complicated and rather limited in scope. For instance, rural electrification projects designed to last approximately 30 years, while the generating equipment for a single biogas or diesel generating plant are designed to last only 10 years. Such different time frames make cost comparisons based on similar assumptions difficult (see Tyner and Adams, 1977; Bhatia, 1979). Also, it is inherently difficult to make direct comparisons between programs using alternative fuels to produce nonelectric forms of energy, such as methane from biogas plants for cooking or social forestry projects' wood for heating. For cases where the comparison is between programs such as rural electrification, with heavy emphasis on purchase of equipment, and alternative programs that have smaller investments and in some cases voluntary labor inputs, the estimated rate of return on investment and the established development priorities for the country would constitute the principal grounds for comparing the projects.

Other factors make benefit-cost comparisons even more difficult. Biogas generators may not only provide electricity for a combination of appliances but also gas for cooking. And the amount of electricity provided by alternative technologies is in many instances less than that of central grid service (see Tendler, 1979). For instance, diesel generators may be operated only during the evening hours instead of 24 hours a day. River generation systems typically can provide electrical energy for part of the year, as is common in China, but in many instances are not able to sustain year-round service.

In general, comparing costs per kilowatt hour between the generation of electricity for full service and generation for part-time service may bias results in favor of central grid schemes. On the other hand, comparing costs for limited-service, small-scale generation - for instance, providing electricity only at night or during certain seasons - with a central grid would favor the small-scale generation. Thus, the different levels of service and reliability, along with different kinds of energy use, greatly complicate the process of selecting the most cost-efficient method for meeting village energy needs.

BENEFIT-COST CASE STUDY FOR INDIA

The empirical study of the benefits and costs of rural electrification in India addressed the subject of financial and economic costs and benefits in rural electrification projects.[2] The unit of analysis of most benefit-cost studies is the utility or project. One unique feature of this research is that the village is the unit of analysis. The advantage of this approach is that village profiles can be developed for different combinations of benefit-cost levels, thus identifying villages that are relatively expensive or inexpensive to include in area electrification projects relative to the derived benefits.[3] Although the total financial and economic net present values for a rural electrification project can be calculated by summing the costs and benefits across all villages in the project, this study has not examined any one total project, but examines the financial and economic benefits of extending electricity to particular villages. This benefit-cost research analyzes the extent of financial and economic subsidy/profit involved in rural electrification, how the subsidies could be minimized by selection of villages, and in general whether electrification of certain types of villages is economically justifiable.

The costs and unit prices of electricity in India are roughly comparable throughout the country, so differences in benefit-cost ratios involved in rural electrification depend on the characteristics of the individual villages in the projects. Rural electrification benefit-cost studies have been completed for 30 villages in Maharashtra, Punjab, and Andhra Pradesh. These states are characterized by distinctly different cropping patterns, climates, and levels of development. And within each state villages differ according to their (1) economic and social backgrounds, (2) farming productivity, (3) number of electric connections for agriculture, small-scale industry, commerce, and households, (4) population density, (5) distance of village from the central grid, and (6) type of benefit arising from the electrification project (see table 7.1). For the purposes of this study, economic benefits are defined as revenue and incremental agricultural output.[4] These benefits vary greatly from village to village; in some villages the only benefit is residential lighting, while in others cropping patterns have changed. Inclusion of a wide range of village-level characteristics made it possible to examine how sensitive the rates of return for

Table 7.1 Cost of Electricity Hardware, Number of Connections, and Nature of Benefits for Villages in the Analysis

Village	High tension lines (km)	Low tension lines (km)	Distribution transformers Type	Number of electricity connections: Household No.	Agriculture No.	Industrial No.	Commercial No.	Acres Affected	Type of benefit	Net operating cost/kWh (Rs.)1
ANDHRA PRADESH										
1. Kambalapadu	2.80	2.75	50 KVA	19	1	3	--	3	SWITCH G to R	3.26
2. Gossampalli	--	2.50	--	9	5	1	--	13	SWITCH G to R	1.57
3. Tallagoulapedu	2.06	4.06	50 KVA	13	10	1	--	36*	SWITCH G to R	2.26
4. Krishnagiri	6.25	2.72	63 KVA	18	4	1	1	62*	SWITCH G to R	4.30
5. Garle Dine	5.00	10.00	63 KVA	17	22	1	3	176**	SWITCH G to R	2.61
6. Chittyala	2.20	1.33	25 KVA	7	1	--	1	26**	SWITCH G to R	6.72
7. Kalagampadi	2.80	1.47	25 KVA	41	--	1	--	--	DOM CON	2.31
8. Korukallu	4.30	2.80	25 KVA	72	--	1	3	--	DOM CON	2.16
9. Gerilapadu	9.99	4.02	25+63 KVA	110	--	2	7	--	DOM CON	2.62
10. Mogalu	1.53	4.84	63 KVA	138	--	3	13	--	DOM CON	1.19
11. Navarasapuram	2.80	2.50	25 KVA	28	1 10 HP	--	1	20	ADD OUTPUT R	3.41
12. Yenugevari Lanka	1.66	7.81	25 KVA	100	1 10 HP	--	3	20	ADD OUTPUT R	2.19
13. Arlitaraf	3.40	3.60	100 KVA	9	--	3	--	--	DOM CON	4.37
14. Beempur	5.58	1.90	63 KVA	10	--	3	3	--	COM CON	5.55
15. Lachampur	3.06	2.50	63 KVA	14	--	1	--	--	DOM CON	6.46
16. Sangd	5.42	3.50	25 KVA	28	--	--	--	--	DOM CON	7.22
17. Dhanora	4.50	4.50	100 KVA	12	4	1	--	30	ADD OUTPUT C	5.03
18. Lingi	5.10	2.00	63 KVA	6	1	1	--	7	ADD OUTPUT C	8.03
MAHARASHTRA										
19. Chatanadu	3.20	3.80	50 KVA	84	--	4	10	--	DOM CON	1.52
20. Meni	5.02	6.58	25 KVA	100	--	3	15	--	DOM CON	2.20
21. Dasak	10.80	3.00	50 KVA	132	47	2	4	100	ADD OUTPUT W	1.09
22. Manegaon	--	1.00	--	28	--	--	--	--	DOM CON	1.20
23. Deothana	3.00	1.48	25 KVA	22	4	2	--	10	ADD OUTPUT W	1.79
24. Sarwargaonpore	2.50	3.40	25 KVA	17	1	1	--	3	ADD OUTPUT W	4.48
25. Bhatambla	1.40	0.63	63 KVA	--	3	--	--	15	ADD OUTPUT W	4.04
26. Jawali	5.18	3.00	25	29	18	2	--	55	ADD OUTPUT	1.62
PUNJAB										
27. Sherpur	9.28	34.4	100 KVA	127	170	17	1	550	ADD OUTPUT RW	1.12
28. Jassowal	2.70	6.0	100 KVA	66	43	3	1	550	ADD OUTPUT RW	0.99
29. Khirsabad	1.5	3.0	--	200	8	4	13	40	ADD OUTPUT RW	0.70
30. Mainpur	1.7	1.6	63 KVA	80	6	3	6	25	ADD OUTPUT RW	0.96

Notes: 1A 12 percent discount rate is used.
SWITCH means crop switching, G to R means groundnut to rice.
DOM CON means domestic connection.
ADD OUTPUT means additional output, W means wheat, C is for cotton and R is for Rice.
COM CON means commercial connection.

*Equivalent acres (lands are irrigated twice).
**Acres affected seem to be not proportional to agricultural connections provided.

rural electrification projects were to complementary inputs, and it was thereby possible to identify those policies that would enhance the profitability of rural electrification.

In the research it was found that the villages producing the best financial returns were those with high population densities. Economic returns were greatest in villages with the potential for irrigating one hundred or more acres of land. Drought prone areas and agriculturally advanced regions with-

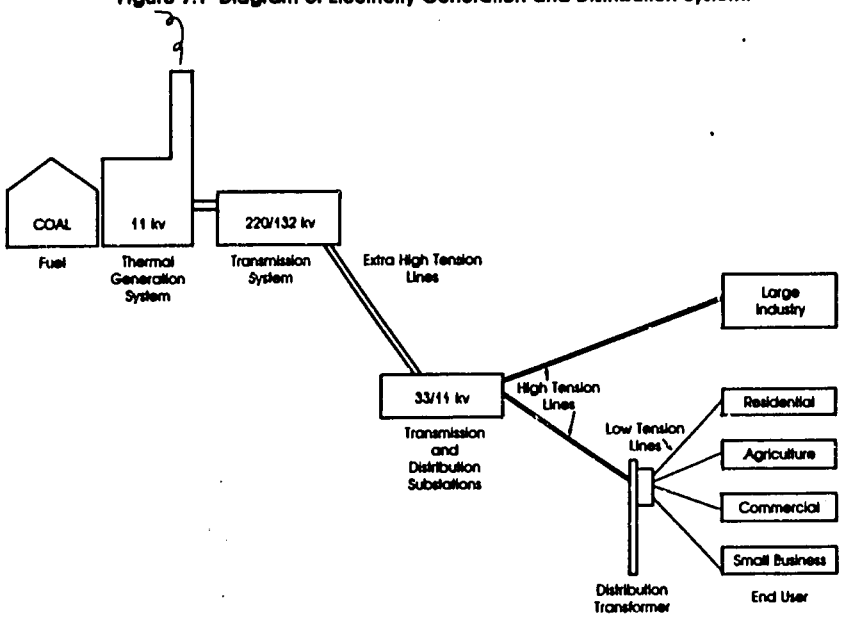
out extensive traditional irrigation facilities were also found to be ideal types of villages to include in electrification projects. Comparisons of the costs of centralized rural electrification with the costs of other energy technologies, such as biogas and photovoltaics, and the use of petroleum products will be examined in a later section.

Costs of Rural Electrification

The total cost of delivering electricity to villages for low voltage consumers was estimated in two steps. First, the marginal cost of bringing electrical energy to the distribution substation near the village was estimated.[5] This cost includes the capital and operating costs of generation, transmission, and subtransmission. The cost of delivering energy to the distribution substations, based on total kilowatts generated in the system, is assumed to be the same for all villages in the study. The second step involves calculating the marginal cost of distributing the electricity from the distribution substation to each village. The cost varies according to the village characteristics, including the population density, distance from substations, and type of customers.

The system for electricity generation and distribution is illustrated in figure 7.1. The generation plants producing the electricity can be hydro, coal, or nuclear fuel powered. The costs in this study include adding a coal-fired thermal generating station to the electricity generation and transmission system, since additional electricity for the system would be met by construction of a new thermal generator plant. Situated next to the generating plant is a step-up transmission station which increases the voltage of the electricity to about 220 kilovolts for distribution over extra high voltage lines. The power is transmitted to a series of regional distribution substations. The distribution substation lowers the voltage in the lines to about 11 kilovolts and delivers the electricity either directly to an industrial user or through high tension lines to transformers which are located near consumers. The transformers once again lower the voltage, and the electricity is distributed through low tension lines (400 volts) to rural consumers. Marginal cost pricing assumes that all end users shar-

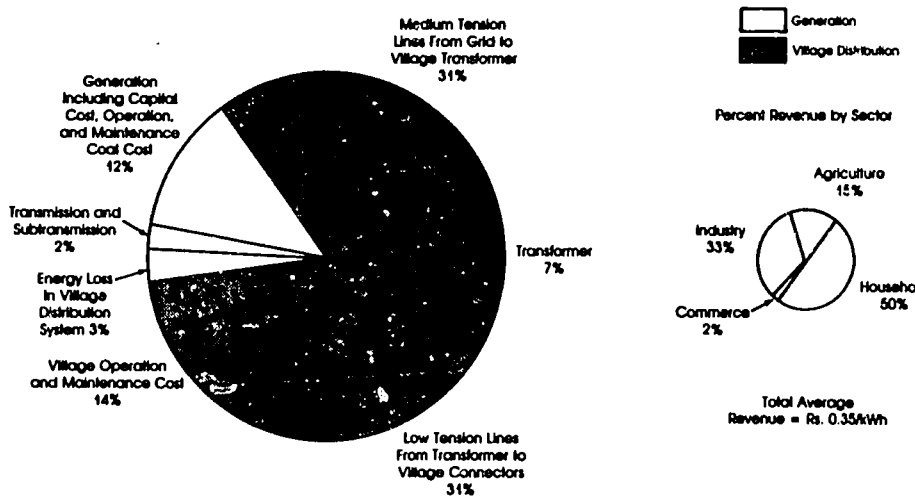
Figure 7.1 Diagram of Electricity Generation and Distribution System.



ing consumption during the peak demand must share the incremental capital costs involved in producing and distributing the electricity right from the generation stage to the customer delivery.

Figure 7.2 breaks down the marginal cost of electricity at the distribution substations (for details, see Venkatesan et al., 1983, pp. 26-32). Generation and transmission costs at the 33/11 kilovolt substation level are determined by the capital cost of construction, labor and wages for operation and maintenance of the facilities, and coal cost for producing the electrical energy, for a total of 30 paise per kWh (see Barnes and Jechoutek, 1984, Annex A). Further transmission involves delivery of the energy through extra high tension lines to the distribution stations, with the cost of transmission 4.00 paise per kWh, and that of subtransmission 1.4 paise per kWh. For convenience, at this point it is assumed that the total electrical energy lost in the distribution system below the 33/11 kilovolt substation level is 18 percent, which would add 7.2 paise per kWh to the cost. Thus, the long-run marginal cost for delivering energy to the distribution substation, including total system

Figure 7.2 Present Value of Long-Run Marginal Cost and Percent Revenues Per Consumer Class for Typical Village in India, 1980.



Note: Village is Assumed to Have 30 Household Connections, Five Electric Pumpsets, and One Commercial and One Industrial (Grain Mill) Connection, by Year 5 of the Project and No Additional Connection During the Next 25 Years.

electricity loss, is approximately 42.6 paise per kWh, which is similar to costs reported in other recent studies. These figures are estimates and it will be assumed that 40 paise per kWh is the long-term marginal cost of delivering electricity to the village distribution system.

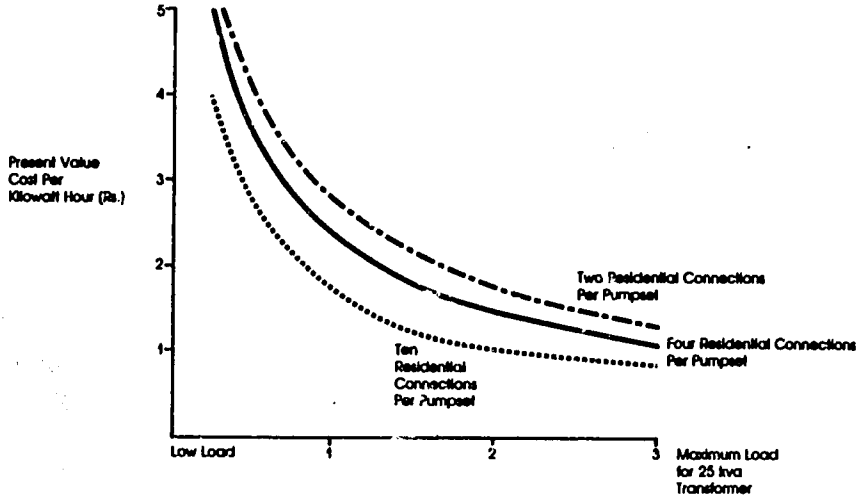
The cost of distributing electricity to each village depends on the length of high tension (11 kilovolt) lines needed (the farther away the village from the distribution substation, the longer the lines), the length of low tension lines needed (the more scattered the users, the longer the lines), and the number and type of connections (see Venkatesan et al., 1983, pp. 70-71). Thus, in order to obtain the total cost of providing electricity to each village, the cost of bringing electricity from the distribution substation to the consumers of a particular village must be added to the average marginal costs of 40 paise per kWh. As indicated in figure 7.2, the cost of distribution to a typical village is three times the cost of generation

and distribution throughout the grid. The reason is that rural consumers generally are geographically dispersed, requiring extensive investments in lines, equipment, and maintenance per customer. For instance, a village with one commercial connection and 30 household, 5 agricultural, and 2 industrial connections on the average would have a yearly electricity use of 18,490 kWh. For this village the 1980 cost per discounted kilowatt hour for 2.75 kilometers of high tension (11 kilovolt) lines (61 paise), 2.75 kilometers of low tension lines (61 paise), and one transformer (15 paise), along with operation and maintenance of the facilities (28 paise), totals Rs. 1.65. The grand total for the long-run marginal cost per kWh is approximately Rs.2.05 paise per kWh. This estimate of the cost of electricity generation and transmission and the full cost of distribution from substations to the village is higher than those calculated in most past studies, but it is consistent with the most recent analysis by the World Bank.

The relationship between density of consumers, load, and cost per kilowatt hour is illustrated in figure 7.3 and table 7.1. The cost per kilowatt hour for the villages in the study ranges from less than one rupee per kilowatt hour in Punjab with extensive connected load to over 5 rupees per kilowatt hour with low load and extensive lines (see table 7.1). These results assume load growth for the first 5 years based on actual connections in the village, but no growth for subsequent years. The cost per kilowatt hour declines to below 2 rupees for villages with an average of one agricultural pumpset per kilometer of high tension lines, assuming 10 household connections per agricultural connection in the village. For individual villages the cost per kilowatt hour depends heavily on the length of high and low tension lines and the village connected load. A general rule of thumb would be at least one or two pumpsets and a significant number of household connections per kilometer of lines is necessary to keep the cost of electricity below 2 rupees per kilowatt hour.

The conservative assumption in table 7.1 that villages would reach maximum levels of connections only after five years probably causes an overestimate of cost per kWh for rural electrification. Therefore, a sensitivity analysis was conducted for two polar villages in order to determine the impact of the growth assumptions. One village from Andhra Pradesh with extremely low load and another from Punjab with a high load were selected and load was assumed to grow for the life

Figure 7.3 Cost per kWh and Density of Consumers. Cost per kWh Declines with More Customers Per Kilometer of Electricity Lines.



Note: The Costs Per kWh Figures are Based on the Long Run Marginal Cost of Electricity Using a 12 Percent Discount Rate and Varying the Number of Pumpsets Per Kilometer of Electricity Lines and Assuming a 25 kva Transformer.

of the project.[6] Reflecting the importance of load on the cost of rural electrification, the cost of electricity for the village of Andhra Pradesh declined from Rs. 8 to Rs. 3, while the decline for the Punjab village was more modest and depended on the assumption of the phasing in of capital cost of the low tension lines. It can be concluded from this sensitivity analysis that the conservative growth estimates for the villages in the study may somewhat overstate future kilowatt hour costs in the long run, especially for the villages with low loads, few connections, and high cost per kWh.

To determine which energy technology is less expensive, the cost of grid-based electrification for pumps and other end uses must be compared with the cost of diesel pumps and that of other alternative energy sources, including diesel, biogas, and wind energy.

Costs of Alternative Decentralized Energy Systems

Alternatives to the central grid include photovoltaics, biogas, mini- hydro, windmills, diesel pumps, and diesel generation. Small-scale diesel electricity generation for individual villages is recommended by Judith Tendler (1979), even though the cost per kilowatt hour generally is higher than for power from the central grid. The attractiveness of diesel autogeneration is that investments can be made in small increments over shorter periods of time, rather than in a lump sum. The technology also is well established and can be satisfactorily managed by villagers; in addition, service does not have to be provided for 24 hours to satisfy village demand for evening lighting. Electricity from small-scale biogas-powered generators is apparently cheaper than diesel autogeneration, but there is a wide range of estimated costs, from 12 cents per kilowatt hour for Sri Lanka (Smith, 1977) to 22 cents for Tanzania (National Academy of Sciences, 1978). The importance of assumptions in the benefit-cost comparisons is illustrated by the fact that in one study comparing cost of central grid with biogas generation, central grid was less costly (Tyner and Adams, 1977), while a similar study with different assumptions (Bhatia, 1979) found that the biogas option for pumping water was less costly than central station electricity.

Research on the cost of wind for generation of electricity and for direct pumping is not at a very advanced stage. Current opinion holds that wind power is an intermediate technology practical only until the central grid or a less expensive alternative is available (Gupta, 1980; National Academy of Sciences, 1978). Likewise, the cost of electricity from photovoltaics is still significantly higher than for central station generation (see Weiss and Pak, 1976, p. 5; National Academy of Sciences, 1978, p. 37). While the cost continues to decline, unless there are some technological breakthroughs, photovoltaics would be applicable only where other energy alternatives are not available. Minihydro generation, however, is cost competitive for regions with favorable hydro resources (see Reddy and Prasad, 1977). The next section delves more specifically into the costs of alternatives compared with central station electricity for the India case study. In order to determine the least cost solution for attaining the benefits of incremental energy supply in an area, the marginal costs of

alternative energy technologies are compared to the marginal costs of rural electrification for the villages in this study.

With the exception of local diesel generation, no one alternative provides all the multiple benefits of central grid rural electrification. Diesel engines can substitute for electric pumps and industrial driveshaft power and also can generate electricity. However, in the absence of costly large diesel generating plants and a local distribution system, three different engines would be necessary for these three applications. Wind power can provide electricity for household use or to directly power pumps, but once again each service would require a different physical system. Photovoltaic systems can produce electricity for all uses, but the cost of these systems is still quite high. Biogas systems can produce methane gas for residential services such as cooking and lighting, but there would be insufficient quantities of dung in most villages for it to be utilized for agricultural pumping. Combinations of these alternative systems could provide all services, but then the costs of all the systems would have to be averaged and compared with the costs of rural electrification.

Energy Technologies That Are Not Competitive

The least viable alternative energy systems, except in extremely isolated regions, are photovoltaic systems, windmills with electricity storage systems, and an experimental solar thermal station (see table 7.2; for details of calculations, see Venkatesan et al., 1983, pp. 34-54).

Power from *vertical axis windmills* is more costly than central grid power, and these windmills are disadvantageous in that they require a wind velocity of at least 12 kilometers per hour as well as special building materials.[7] However, they can be used to generate electricity for small DC applications such as domestic lighting and small agricultural pumpsets. After conversion of energy with AC load through use of an inverter, windmills can also be used for heavy duty applications such as rural industries or for bigger agricultural pumps. The marginal cost per kWh is approximately Rs. 3.27, about one-third more costly than for most villages served by the central grid. These systems are not large enough to provide electricity for a whole

Table 7.2 Net Present Cost Per Kilowatt Hour Equivalent for Central Grid and Alternative Energy Technologies, India, 1980 (Rs. per kWh in 1979/1980 prices)

	Chennapuram	Satulran	Chiagapali
1. Centralized grid supply			
a. Base case (Actual village conditions)	1.85	2.65	2.45
b. 50% increase in energy demand and increase in connected load	1.57	2.20	1.99
c. 100% increase in energy demand and increase in connected load	1.42	1.97	1.76
d. 50% increase in energy demand and no increase in connected load	1.36	n.a.	1.76
e. 100% increase in energy demand and no increase in connected load	1.11	n.a.	1.42
2. Biogas system			
a. Base case (Actual village conditions)	0.96	1.80	2.06
b. 50% increase in energy demand and increase in connected load	1.89	1.77	2.02
c. 100% increase in energy demand and increase in connected load	1.37	1.75	2.00
d. 50% increase in energy demand and no increase in connected load	1.39	n.a.	1.51
e. 100% increase in energy demand and no increase in connected load	1.09	n.a.	1.23
3. Windmill			
a. Horizontal axias (no storage)	0.90	0.90	0.90
b. Vertical axis (electricity storage)	3.27	3.27	3.27
4. Solar thermal (appropriate cost)	62.00	62.00	62.00
5. Photovoltaics (appropriate cost)	21.00	21.00	21.00
6. Isolated diesel (actual village conditions)	3.09	3.42	3.17

Source: Venkatesan and coauthors (1983), Appendix.

Note: n.a. means not available. For isolated diesel system the diesel generations costs are from Smith et al., 1983 and cost of low tension lines was added according to village characteristics.

village or even part of one, so for villages with fairly dense populations this would not be a viable alternative. Yet these wind systems certainly could be applicable in villages with scattered populations, in which landholders live on their farms and not in central villages.

Electricity from *photovoltaics* is even more costly than

that from a windmill system. Photovoltaics currently are used in isolated areas where a reliable supply of electricity is a necessity. Photovoltaic systems were adopted for household lighting on some isolated islands in Fiji, but costs per kilowatt are very high. However, the approximate price of electricity from photovoltaics continues to decline, and it may be a more viable alternative in the future, especially for very isolated areas with minimal energy needs. An experimental *solar thermal* station in Sri Lanka was the most costly system examined. The system uses the sun's energy to generate steam or vapor to drive ordinary turbine generators, with a backup biogas system to continue service when not enough energy is available from the sun. The cost of this system is about 30 times the cost of central station electricity.

Competitive Decentralized Alternative Energy Systems for Commercial Uses

The most attractive decentralized systems are diesel pumps, horizontal axis windmill, and biogas plants.

The *horizontal axis windmills* operate in bore wells to pump water without the intermediate stage of converting the motion to electricity. The cost per unit of energy equivalent to a kWh hour for horizontal axis windmills is 90 paise, compared to approximately Rs. 2.00 for the central grid. While this is the lowest cost for any system, two factors must be considered in comparing the costs: (1) The villages cannot be assured that the windmills, which must have a wind velocity of over 6 kilometers per hour to operate, will in fact be operational to drive the pumps when water is needed the most for irrigation, since these pumps do not include storage batteries. (2) There are no multiple benefits, since the windmills are used exclusively for pumping water. However, although it is not used extensively in India today, wind power remains a viable alternative to electricity for pumping water, especially in regions with wind resources during the right seasons.

The cost of providing electrical energy from *biogas units* is comparable to the cost for central grid, but the cost is somewhat higher than that of the central grid at a certain level of load and energy demand. A biogas unit cannot provide

energy for household lighting, agricultural pumping, and cooking all at the same time, since the load on the system would be too great. The average annual electricity consumption for the three villages in the decentralized energy study by Venkatesan et al., (1983) was 10,647 kWh. Typically, when electrical energy demand is in excess of 15,000 kWh per year, the marginal cost for the centralized grid system is lower than the cost of a biogas system for the three villages. However, when energy demand increases without an increase in connected load, the cost of electricity from biogas units compares favorably with the central grid. Unfortunately, expanding the decentralized system by designing a large biogas system for multipurpose use is of limited practicality because of social and cultural factors and insufficient quantities of dung.[8] Even so, the use of isolated biogas or even diesel systems should be considered when electrical energy demand is relatively low.

Diesel and Electric Power for Agricultural Pumping

Diesel and electric pumps provide approximately the same benefit in supplying water for irrigation and thus improving crop yields. The only exception is for deep tubewells and dugwells, where diesel engines are not practical because access to the pumps would be difficult or impossible. For shallow wells, the cost of diesel engines can be compared with that of electric engines to determine which alternative is the most economical for agricultural pumping. In many project appraisal documents, the cost saving of replacing diesel engines with electric pumps is included in the economic benefits of rural electrification. Although in many cases the economic cost of electricity is less than that of diesel, many of the assumptions in the benefit-cost analyses make comparisons between the findings of studies quite difficult. For instance, a recent report by the Swiss Development Corporation (summarized in Bhatia, 1983) concluded that diesel pumping would be less costly than electricity, while, on the other hand, the Administrative Staff College of India (1980, p. 121) concluded that electricity is less costly than the diesel alternative (for example, diesel pumps combined with diesel autogeneration).

Assuming that electrification projects are multipurpose and electricity is extended for all consumer classes, the long-run marginal cost of electricity for villages ranges between about 1 and 5 rupees per kilowatt hour. A recent World Bank analysis indicates that taking into account the capital and operating cost of diesel engines, electricity must be priced at about Rs. 1.69 per kWh to compete with untaxed diesel, or Rs. 2.11 for taxed diesel. Thus, electricity would be less expensive in densely populated areas, especially those closer to the distribution stations. The greater utilization of existing distribution systems would bring down the cost of electricity per kWh and make it more competitive with the diesel alternative. Just under half of the villages surveyed would have lower kWh cost than taxed diesel, especially in the Punjab, where agricultural pumping is extensive (see table 7.1). On the other hand, diesel would be less expensive in regions distant from the grid or distant from the village transformers, such as those in Andhra Pradesh. Since the subsidized price of electricity for agricultural pumping is Rs .16 per kWh, it is no wonder that electricity is viewed as the least expensive alternative by the farmers.

The assumptions in benefit-cost studies are extremely important in determining the profitability of centralized rural electrification and the alternative energy systems such as diesel pumps and autogeneration. Rural electrification projects are favored in the following assumptions: (1) when 24-hour service is needed, (2) when the project is multipurpose, including agricultural, commercial, industrial, and residential needs, (3) when there are a large number of connections per mile of electric lines, and (4) when the load for the whole system is well managed. The assumptions that favor smaller decentralized service include (1) part-time service (for example, evenings only), (2) single end use, such as irrigation pumping, and (3) low demand for energy. If agriculture is the only end use, electrification is not viable in situations in which farm plots are distant from the central grid. However, if electricity is extended to villages for many different purposes, then the incremental cost of providing electricity for agriculture would be reduced, since the other services would share the fixed costs of extending electrical energy to the village. The complexity of these assumptions makes understandable the different conclusions reached concerning the superiority of central grid electricity or diesel power for agricultural pumping.

Medium-Scale Power Generation. Medium-scale power generation through power sources such as minihydro or small wood-burning generators are another alternative to central generation. Minihydro has been widespread in China, and experimental wood-burning power stations in the Philippines are just coming into operation. In the United States there has been a substantial increase in decentralized generation systems since the enactment of legislation which requires utilities to purchase power from privately and publicly owned medium-sized decentralized generation stations (Flavin, 1986). Decentralized systems based on water, wind, or locally abundant wood resources could be constructed for isolated rural areas and later connected to the central grid systems. However, many present decentralized systems are not compatible with the central grid because of different voltage levels and unstandardized equipment. Thus, standardization of systems design should be a priority for decentralized electricity generation, so that when the central station electricity eventually reaches the more isolated rural areas, the existing system will not have to be completely dismantled and replaced. Decentralized generating units that provide additional energy to the system during peak load periods would be especially attractive. The cost of electricity from medium-sized decentralized generation systems often is competitive with central station generation and should be considered as an alternative when local resources are available.

Revenue-Based Benefits of Electrification

The financial benefits are the revenues paid by customers for electrical service. In most villages surveyed the price of electricity was approximately 16 paise per kWh for agricultural pumping and about 48 paise per kWh for residential, commercial, and industrial uses. As figure 7.2 demonstrates, the marginal cost per kWh, based on the number of connections, is many times higher than the revenues collected by the utilities.[9] It should be remembered that these figures are for one village out of many in a whole scheme, and other villages may have higher or lower long-run marginal costs. It is evident that for the power industry, rural electrification is a

losing proposition unless they recover some of the costs through government or state subsidies or through increased electricity prices. On average, for the village in the example, the utility is losing about Rs. 1.90/kWh for agricultural pumping and Rs. 1.60/kWh for residential electricity, but this depends on the number of connections in the village. In some cases they are losing over 4 rupees per kWh and in others less than a rupee. The drastic difference between the cost and the revenues may well be the reason for the poor reliability and service in rural areas. The utilities are not anxious to further expand or finance rural systems, because every new customer means the utility will lose more money. The utilities receive state and national subsidies for extending distribution facilities to villages, and not much attention is paid to the extensiveness of connections per village.

Before making any judgments on the efficacy of rural electrification programs, it must be determined whether the economic benefits of rural electrification justify the economic costs and under what conditions projects can be profitable or at least incur minimal losses.

Production Benefits

In this analysis, the benefits of electricity for agriculture include additional output per acre, risk reduction for certain crops like cotton, and substitution of higher-value crops (see table 7.3).[19]

For many regions of India, the production benefits of irrigation appear to be substantial. For some farmers, the main benefit is that they are able to switch from groundnut to intensive rice cultivation. But about 100 village acres (twenty pumps) must be affected for the net present value to turn positive (see table 7.3). For additional output of rice and wheat by double or triple cropping, about 50 acres need to be affected by irrigation. When 200 acres are affected, the benefits outweigh the costs by a substantial margin. Finally, in cotton growing regions, rural electrification projects, given current price levels, are economically profitable if only 10 acres are affected. The farmers feel that use of a pumpset is essential because of the possible failure of the monsoons. During critical

Table 7.3 Acres Affected by Electricity and Financial and Economic Net Present Values, India, 1980

Village	Net present value Financial (000 Rs.)	Net present value Economic (000 Rs.)	High tension lines (km)	Low tension lines (km)	Acres affected
Over 100 acres affected					
Sherpur	-1030	+1935	8.28	34.40	850
Jessowal	-230	+511	2.70	6.00	210
Garle Dine	-336	+139	5.00	10.00	176
Dasak	-318	-257	10.80	2.00	190
Groundnut to rice switch (all in Andhra Pradesh)					
Garle Dine	-336	+139	5.00	10.00	176
Krishnagiri	-194	-49	6.25	2.72	52
Chittyala	-82	-9	2.20	1.33	26
Tallagokulapadu	-146	-85	2.06	4.05	26
Gosanipalli	-56	-25	0	2.50	13
Kambalapadu	-122	-115	2.80	2.75	3
Increase in wheat or rice production					
Punjab					
Sherpur	-1030	+1935	8.28	34.40	850
Jessowal	-230	+511	2.70	6.00	210
Khirzabad	+75	+62	1.80	2.00	40
Malapur	-22	+70	1.70	1.60	25
Maharashtra					
Dasak	-318	-257	10.80	2.00	190
Jawali	-189	-177	5.18	3.00	55
Bhatambla	-59	-53	1.40	0.63	15
Deothana	-100	-93	3.00	1.48	10
Sarwargaonagore	-128	-126	2.50	3.40	3
Andhra Pradesh					
Navarasapuram	-116	-60	2.80	2.50	20
Yenuguvani Lanka	-194	-137	1.66	7.81	20
Increase in cotton production					
Dhanora	-198	+235	4.50	4.50	30
Lingi	-151	-50	5.10	2.00	7

Source: Venkatesan (1983).

periods of crop growth, significant drops in precipitation can lead to near total financial ruin for farmers. The consequence is that even in a village with 10 acres of cotton irrigated, the benefits outweigh the costs.

Comparisons between villages in Punjab and Maharashtra indicate that not only is it important for electrification to have an impact on area irrigated, but also on agricultural productivity. Because of the low productivity per acre in

Maharashtra, even for villages with 100 acres irrigated, electrificaion is not as viable a proposition as for the higher productivity villages in Punjab. The villages in Andhra Pradesh with canal irrigation had virtually no pumps or agricultural benefits, confirming that the existence of canal irrigation inhibits growth in the use of groundwater pumps, and the benefits of installing pumps in the region are minimal.

Variations in Village Profitability/Subsidies

The cost of extending electricity to India's villages for the most part is not balanced by revenues received from the project. For all villages, the financial (revenue-based) net present values are negative (see tables 7.3 and 7.4), indicating that prices are kept artificially low and a government subsidy is involved. The variation in the subsidy to the consumers is great, ranging from a negative NPV of Rs. 56,000 to Rs. -1.03 million for the village with the highest subsidy.[11] However, production benefits are in many instances quite substantial, which means that the projects may be economically justified. The wide fluctuation in returns indicates that certain villages benefit more than others. This wide variation in subsidies makes it possible to conduct a sensitivity analysis to determine the characteristics of the villages that require the least or the most subsidies, so that perhaps some priority for extending electricity to villages can be established.

One well-established fact which is confirmed in this study is that the financial viability of rural electrification is improved if the number of customers per mile of high and low tension lines is high. For the five villages that are near the distribution substation, the project's financial subsidies are relatively low. Even the two villages with scattered consumers (extensive low tension lines) required lower subsidies than might be expected (see table 7.4). Less obvious is the fact that the villages under the intensification scheme projects incurred minimum project losses. Villages in the intensification scheme did not incur the cost of additional distribution transformers of high tension lines, because they shared excess capacity with a nearby settlement. Even though financial losses were minimized by these schemes, it should be cautioned that later

Table 7.4 Proximity to Substation and Villages' Net Present Values, India, 1980

Village	Revenue-based net present value (000 Rs.)	V.A.-based net present value (000 Rs.)	High tension line (km)	Low tension line (km)	Domestic connection	Acres affected
Villages near distribution substation						
Bhatambia	-59	-53	1.40	.63	0	15
Khirzabad	+75	+62	1.80	2.00	200	40
Mainpur	-75	+10	1.70	1.60	80	25
Yenguvana Lanka	-194	-137	1.66	7.81	100	20
Mogalu	-126	-126	1.53	4.88	138	0
Villages sharing distribution transformers						
Gosanipani	-56	-25	0	2.50	9	13
Manegaon	-20	-20	0	1.00	28	0

Source: Venkatesan (1983).

growth of consumer demand for electricity actually may cost the project more in the long run because of the greater use of low tension lines and later addition of new transformers. Thus, the financial viability of the scheme is greatly affected by the physical layout of the distribution system and the village connection load (connections per kilometer of lines), and cost savings could be great if low tension lines were initially installed only for significant sized loads, although the distribution systems should be designed in anticipation of expanding rural demand for electricity (see Sen Gupta, 1984; Munasinghe and Warford, 1982).

Another factor affecting a system's financial viability is the price of electricity. As indicated, the price of electricity for agriculture is one-third the price for households. As a consequence, the villages with high numbers of agricultural connections are more costly for the utilities, even though the economic returns for society can be quite attractive (see table 7.3).[12] For instance, the village with over 100 acres of land irrigated by electric pumps has relatively high project financial losses, but this is more than compensated for by the production benefits. The sensitivity of the financial net present values to village load and electricity prices is illustrated in table 7.5. In general, the project financial net present value is less negative with increased prices and higher sales per village.

Social Benefits

The social benefits have already been discussed in previous chapters. Generally they cannot be monetized and entered into benefit-cost analysis, but they include higher quality of rural life, more reading by children, greater impact on women and children than men, and the use of new appliances in the home. Other benefits often ascribed to rural electrification but not found to be directly associated with rural electrification in the research include diminished rural to urban migration and reduction of birth rates. Rural/urban migration is more related to availability of jobs and education than to rural electrification. The emergence of growing towns and service centers is more likely than a retention of population in small villages or communities. The only negative bene-

Table 7.5 Relationship Between Financial Value, Change in Price, and Change in Electricity Load, India, 1980

Total village kilowatt hour sales (approximate)	Cost per kWh	Financial present value of electricity for village: Price of Rs. .16 for agriculture & Rs. .45 for others (Rs. 000)[1]	Price of Rs. .32 for agriculture & Rs. .90 for others (Rs. 000)	Price of Rs. .50 for agriculture & Rs. 1.00 for others (Rs. 000)	Price of Rs. 1/kWh for all consumers (Rs. 000)
10,000	2.62	-107	-90	-84	-76
15,000	1.90	-108	-85	-76	-62
20,000	1.60	-110	-80	-68	-48

Note: Discount rate is 12 percent.

[1]For this column, the marginal cost of energy in the distribution system is lower than the price, so greater kWh use means greater financial losses.

fits of rural electrification include an adverse effect on rural equity, especially early in the programs. These benefits are very difficult to quantify in monetary terms, but should be included in social benefits of rural electrification.

SUMMARY AND CONCLUSIONS

Rural electrification programs should be considered as a part of an overall commercial energy strategy which does not compete with programs for enhancing supplies or conservation of traditional fuels. The general trend is that as societies develop, traditional fuels decline as a percentage of total energy use, since new uses are found for commercial energy. Central grid rural electrification must compete with diesel, kerosene, and commercial renewable fuels. At present, the most competitive alternative to central station generation is diesel for pumping water, biogas for generating electricity, and direct wind for pumping. For regions with the necessary resource endowments, minihydro and small wood-fueled stations, although not examined in detail in this analysis, appear to be low-cost alternatives to complement electricity generated from central stations. Conservation of existing energy without diminishing rural productivity also should be seriously considered for improving energy costs, since this avoids expensive investments in plant and distribution facilities and alleviates the power shortages that exist in many developing nations. Many alternative energy systems can be advantageous in providing commercial energy for rural areas that are distant from the electricity distribution substations and for villages which have very low electrical energy needs.

Considering the alternative projects reviewed in this chapter, rural electrification generally is less expensive than photovoltaics, wind power with battery storage, and an experimental solar thermal project. Diesel engines and biogas generation of electricity can be cost competitive with central grid rural electrification, depending on the location of villages and pumpsets with respect to the distribution network. However, large scale biogas plants are not always feasible in India because of social and cultural constraints, including the fact that most village cattle are owned by large farmers. Wind

energy also may only be appropriate in a few regions, and at present there are not many windmills used for pump irrigation. Nevertheless, villages with very low electricity needs may well benefit from the development of alternatives such as biogas. For some regions a combination of electric pumps close to the distribution system and diesel engines distant from the grid may be the least costly energy alternative for agricultural use.

The central factors affecting the financial and economic feasibility of rural electrification schemes include load management and development, the layout of the distribution system, the extent of economic benefits resulting from the projects, and the price of electricity. Load development and management are important in several respects. A greater electricity consumption per mile of line will mean a lower unit cost of providing electrical service to rural areas because of the better use of fixed investments. Placing distribution transformers and lines in rural areas and using them only two or three months per year for agricultural pumping means that the hardware is underutilized for most of the year. The development of multiple uses for electricity in rural areas would be highly desirable from the viewpoint of central grid electrification. For instance, residential electricity use occurs the year round, but mostly during the evening hours. Agricultural processing and water lifting loads take place during different periods of the year, but the load occurs mostly during the daytime. Many commercial establishments are open year round and draw small amounts of electricity during the day and the evening. By coordinating the use of electricity for different end uses, the load factors can be improved and the cost of electricity per kilowatt hour can be substantially reduced.

The layout of the distribution system is very important for the overall cost of electricity for rural areas. Not only are distribution lines themselves very expensive, but longer lines mean greater technical loss of electricity within the system. In many cases the planning of the distribution network is viewed as putting the hardware in place. However, to minimize the cost of the system, before planning the layout of the distribution system the potential connected loads for agriculture, industry, and residential use should be assessed. Perhaps even a minimum number of connections or load levels need to be established firmly prior to extending lines and placing transformers in electric rural communities. To be competitive on a cost basis with diesel, about one electric pumpset is necessary

for every kilometer of distribution lines. In regions where such densities of electric pumpsets can be achieved, the economic benefits of irrigation for the farmers and society are substantial. Due to the capital costs involved in distribution systems, advance planning in many cases can considerably lower line costs and electricity losses, with virtually no impact on quality of rural service.

The social benefits of rural electrification in most cases have not been adequately factored into the benefit-cost evaluations, primarily because they are hard to quantify in monetary terms. In many cases the justifications for a particular rural electrification project are based on social and regional equity considerations or on rural-urban differences in the quality of life. The value of social benefits is assumed to be part of the judgment by rural consumers on whether they should adopt a household electrical connection. But prices are set with a variety of directives in mind, so financial returns really do not reflect the willingness to pay. Social benefits are undervalued in most project assessments.

In summary, the least cost energy alternative for the same level of rural service probably is the best method for evaluating the viability of rural electrification. Such an approach broadens the evaluation to define *the most appropriate rural energy strategy for specific communities or regions.* In general, an improved knowledge of present and predicted future energy use is necessary before it can be safely assumed that rural electrification projects are the most economical way to meet specific rural energy needs. Under the right conditions, rural electrification can be one of the least cost energy alternatives for socioeconomic development, but sparsely populated regions with little potential for productive use are the wrong sites. The right ones include regions with favorable load potential, both rich and poor agricultural regions with underutilized groundwater resources, and areas with relatively high levels of income.

NOTES

1. For a discussion of reasons why long-run marginal costs are appropriate guidelines in developing countries, see Munasinghe and Warford (1982) and Turvey and Anderson (1977).

2 .In this study, the revenue based (financial) net present value is defined as the difference between the net present value of cost of service and the net present revenues collected by the electricity industry, giving some guide as to project profitability. The (economic) value added is defined as the difference between net present value of cost of service and the sum of net present value of project revenues (willingness to pay) and for agriculture the incremental value of production (minus project revenues) yielded by the project.

3. Costs and benefits by consumer categories often are calculated for electrification projects, and this is a valid approach. But given that all consumer classes within a village are the same distance from the grid and that the major expense in rural electrification is the distribution system, more research needs to be conducted on connecting different types of villages.

4. When incremental agricultural production is included as an output, the project revenues are not included as benefits, since this would be double counting of benefits.

5. The marginal cost is based on the cost the project will incur in meeting the incremental demand for electricity caused by the project. In assessing the first type of cost, the increased supply of electricity is assumed to be met by thermal power stations. This is a tenable assumption for three reasons: most of present demand is met by thermal stations; there are locational constraints on meeting additional demand from hydro sources; and the government plans to expand thermal capacity. The cost is derived by calculating the cost streams for the thirty-year life of a typical project, adjusting the cost streams to 1980 values by using a 12 percent discount rate, and dividing the total value by the discounted number of kWh to be produced in the project. As load curves in India at present are typically flat, peak and off-peak considerations in marginal cost calculations are not of great importance and have been ignored here.

6. For the Andhra Pradesh village, the number of connections reached after 30 years of electric service was 80 households, 5 commercial, 2 industrial, and 20 agricultural connections. For the Punjab, with already high load, the growth rate assumed was much lower. Assumptions were also made concerning the extent of low tension lines necessary to reach the additional consumers.

7. For the alternative technologies, insofar as possible the same assumptions were utilized in making comparisons between costs. Many of the studies on costs of alternative technologies have different assumptions, making comparisons between costs somewhat difficult.

8. The amount of dung available in most villages would be sufficient to produce power for lighting and agricultural pumping, but not for cooking or for heavy industrial uses. Providing electrical energy of 10,560 kWh/year would require 281,600 cubic feet of gas per year, or 772 cubic feet per day. This is about 117 kg of dung per day for the village. In determining the cost it is assumed that this dung is provided free, which may not be a reasonable assumption. This represents approximately one truckload of dung per week. Expanding consumption beyond these levels would increase the price of dung and require additional expenditures.

9. The financial return has been calculated by discounting capital costs for the distribution system over 5 years, assuming constant operation and maintenance costs from 5 to 35 years, and no growth of energy use after the first 5 years of service. These figures are conservative in estimating possible demand growth. However, the further growth of electricity use would only marginally affect the long-run marginal cost.

10. It was assumed that there is no growth in agricultural connections after 5 years of electrical service, which would make incremental productivity estimates conservative. In the cost-benefit study it was assumed that the incremental value in productivity is from a state of nonirrigated agriculture using hybrid seeds and fertilizer. (Current output value minus without-case output value minus pumpset costs minus the difference between value of fertilizer cost and manure cost and the difference in labor costs.) The approach is based on the assumption that nonirrigated traditional agriculture would continue in the absence of the project. When production benefits are included, the revenue is not included as a benefit.

11. Because the price of electricity for agriculture is one-third the price of residential electricity, in some cases the villages with the worst financial viability have the best economic returns.

12. Agricultural pumpsets not only involve extensive high and low tension lines because they are widely dispersed in the fields, but also the price is kept low by the government to encourage the productive use of electricity. In many cases, however, the economic benefits of irrigation outweigh the consumer subsidies involved in the projects.

8
Evolution of the Public Policy Debate

Rural electrification is a very important component of energy strategies for developing nations. The recent criticism of rural electrification has helped to focus attention both on the previous assumption that electrification has a positive impact on rural development and on the policy issues involving the most appropriate energy strategies for socioeconomic growth. As is usually the case in such controversies, the situation turns out not to be black or white; in some cases the criticisms of rural electrification are justified, while in other cases they are not. Portraying rural electrification as a universal solution to rural energy and development problems certainly is incorrect. But, on the other hand, the position that electricity projects contribute virtually nothing to development is equally fallacious. This research has found that rural electrification has had more of an impact than was anticipated at the beginning of the research. Nevertheless, central grid distribution of electricity is not always the least cost energy alternative for rural development. Electricity is obviously not the only energy program which should be considered for all situations in developing nations, yet it certainly is an important component for rural energy development.

ELECTRICITY FOR RURAL DEVELOPMENT

The evaluation and resolution of the policy issues in the rural electrification controversy have involved assessing improvements in rural productivity, determining the social

benefits, and weighing the economic benefits and costs. In the beginning of the research, several important questions were advanced concerning the efficacy of rural electrification projects. Many of these questions have been answered in the research, although in the process new questions have been raised. This section summarizes the findings discussed in the previous chapters.

Agricultural Productivity

The Indian policy for utilizing electricity in rural development has led to greater agricultural impact there than in Colombia or Indonesia. Agricultural development definitely is enhanced by rural electrification in India. In addition, India has in place an aggressive agricultural development program, including the dissemination of hybrid seeds, fertilizers, and other agricultural inputs. Complementary credit programs have also been beneficial. In Indonesia there were no similar credit programs that would aid farmers in obtaining agricultural pumpsets.

The way in which rural electrification has had an impact on agricultural development in India is through irrigation pumps and new agricultural technologies. In India the price of electricity for agricultural pumping is subsidized heavily, demonstrating the government's commitment to rural development but also causing problems of cost recovery for the utilities.

The impact of rural electrification has occurred through the following causal chain: electricity lines are extended from the central grid to villages. With access to electricity, farmers replace diesel engines or purchase new electric powered pumpsets; this does not take place immediately but is a slow and continuous process. As more pumpsets are added in the village, a higher percentage of village farmland is irrigated. Irrigation is associated both with high cropping intensity - farming land for more than one season - and the use of agricultural inputs such as hybrid seeds, fertilizers, and pesticides. Growing a second crop increases income for the farmer and requires more agricultural labor for land preparation and utilization. As a consequence, the benefits of irriga-

tion go both to the farmers and to the agricultural laborers. The improvements in irrigation, cropping intensity, and use of agricultural innovations lead directly to higher agricultural productivity.

This model of how rural electrification relates to agricultural productivity must be qualified by the knowledge that some regions benefit more than others and diesel pumps have about the same consequences as electric pumpsets. The areas that benefit the most from rural electrification are not the relatively rich, traditionally irrigated rice regions with heavy rainfall, but rather are the dryer and, in many cases, poorer parts of India with sufficient but relatively untapped groundwater sources for irrigation. The potential for such irrigation in India still remains underutilized. The more wealthy wheat growing regions also have benefited substantially from rural electrification. Interestingly, the traditional forms of irrigation - such as persian wells and tanks - are not associated with improvements in agricultural innovations or higher crop yields. Also, the growth of pumps is slowest in the regions with extensive canal irrigation systems. One conclusion, therefore, is that rural electrification helps improve regional levels of equity through the development of farm-level irrigation.

India's effort to improve rural development through electrification has been successful, but there has been no parallel impact in Indonesia and Colombia. One of the reasons for the lack of impact in Indonesia is that the survey was completed in a traditionally irrigated, rice growing region. Even in India, the rate of growth of electric pumps for irrigation is low in such regions. Also, the past and, to a lesser extent, the present price of diesel fuel is heavily subsidized in Indonesia, diminishing the attractiveness of electric pumps for farmers. In Colombia the farming systems are not as intense as in Asia and the growing seasons are somewhat shorter. Consequently there is a limited demand for water lifting in Colombia as compared to Asia, but there is still scope for irrigation beyond current levels in the country. Some parts of Colombia could probably benefit from a more extensive agricultural development program that would feature irrigation, fertilizers and hybrid seeds. Colombia also is reliant on export plantation crops, and electricity is used in the coffee region for lighting and coffee processing activities.

Small-Scale Industry and Commerce

Businesses in rural areas of India, Colombia and Indonesia typically include small commercial shops, grain mills, sawmills, and brickmakers. In all three countries rural electrification has stimulated additional productivity, either through improvements in existing industries or by encouraging the development of new businesses. Rural industries using electricity in India, which most typically are grain mills, have greater labor productivity, have lower fuel cost as a percent of total costs, employ more workers, and are larger than industries without electricity. Virtually all industries in India have adopted electricity when it was available within their first year of operation. In Colombia the benefits of electricity for rural businesses were lighting, refrigeration, and a few driveshaft power applications. In Indonesia, because of the low price of diesel fuel and high connection charges, very few businesses used electricity for driveshaft power. However, because of electric lighting and refrigeration, businesses stayed open for longer periods of time, employees worked longer, and productivity improved. The general consensus is that electricity was beneficial for businesses in all three countries.

Electricity is just one of the important inputs that help in the development of rural industries. The other complementary conditions include access to good rural markets, adequate credit, and the entrepreneurial skills of business leaders. Extending electricity to regions without paying attention to these other conditions will lead to lower than average growth of rural businesses. Without sufficient markets for their goods and services, businesses have a difficult time continuing operations. Credit may be necessary for start-up capital and for expansion of existing industries. Perhaps because these complementary conditions are not present in all rural areas, the anticipated growth of industries in rural areas with electricity is still somewhat slow. However, the areas without electricity have an even worse record of business development. Thus, the conclusion is that electrification is an important condition for the development of rural businesses, but an explosion of industry and commerce should not be expected.

Social Impact and Equity

The social impact of rural electrification was greater than anticipated. Many studies had reported that electrification resulted only in a few light bulbs being used in the most wealthy households. However, this research found this presumption to be widely off the mark. Electricity was used for both lighting and appliances. In fact, there was greater than expected appliance use for rural households, especially in Colombia. In Colombia a very high percentage of households with electricity possessed television sets, some households were even cooking with electricity, and others had refrigerators. The appliance ownership resulted in a change in evening social patterns, in which persons tended to spend more time watching television and less time visiting and engaged in productive activities. However, children were able to study more in households with electricity, and this was true for both India and Colombia. In India a higher than expected number of households purchased fans, which is important for the quality of life in a hot climate. Supporting this notion, the households with electricity in India reported that they had a generally higher quality of life than those living in households without electricity, and this was especially true for the middle income groups.

Migration and education are affected by rural electrification in different ways. As indicated, electric lights are superior in quality to kerosene lamps and make it easier for children to study during the evening. On average, even among households at the same level of income, those with electricity also have higher levels of education, so the attractiveness of electric lights may be responsible for the strong association between literacy/education and rural electrification.

Contrary to the expectations of most analysts, migration may increase as a consequence of rural electrification. Many advocates of rural electrification have expected that rural-urban migration would be reduced by improving the quality of life in the countryside. In fact, the villages in India with electricity seem to have more migration from the villages to urban centers than those without electricity. However, this finding is consistent with expectations that rural development should be accompanied by more rather than less migration, as young people would be expected to seek opportunities beyond the

farm, moving for education and jobs. But as job opportunities increase in rural communities, then a significant amount of in migration probably would take place. The Colombia results indicate significant migration for employment there, especially into the coffee region, which also happens to have higher levels of electrification. But people also tend to stay longer in regions with electricity, a finding that supports the notion that electricity stems out-migration.

The impact of rural electrification on inequality is negative over the short run but tends to improve over the long term. When electricity is first extended to rural communities, the more wealthy households have the money and influence to obtain a connection before anyone else. Thus, the wealthy households have access to the considerable benefits made possible by electricity, while poor households are left out. Television, fans, radios, and lights all can improve the rural quality of life of those who can afford electricity. As time passes, however, more and more households are able to adopt electricity, and the programs become much more equitable. One immediate positive impact on a country is that rural electrification typically benefits women and children more than men, since men spend less time in the home.

Rural electrification has not caused greater land concentration or rural poverty in India. Large farmers are not buying out smaller farmers who cannot afford to make investments in pumps and new technologies. Electrification appears to be neutral with regard to farm size, although there may be some consolidation of land parcels to take advantage of electric or diesel pumps. This neutral impact may be the result of the land ceiling laws that discourage large farmers from acquiring new land. Also, rural electrification does not appear to be a cause of rural poverty. If anything, rural electrification may help lessen the percentage of people in villages living below the poverty line, probably through the additional employment of agricultural labor. Over the long term the socioeconomic benefits of rural electrification probably outweigh the short-term negative equity impact.

Costs and Benefits

Almost all rural electrification schemes involve financial subsidies. The size of the subsidies is dependent on the population density of the village, the agricultural acreage affected by electric pumps, the expected adoption rate of electricity, and regional factors such as climate and level of development. In some cases the economic benefits of additional agricultural and industrial production balance the extensive financial subsidies necessary for rural electrification projects. In other words, the overall benefit to the society is greater than the cost. However, even if the economic and social benefits are greater, the cost recovery by the power industry is very low, and they require large loans or grants from the government to maintain service. The restricted financial viability of rural electrification may be one reason why power industries consider rural service a low priority. As a consequence, the reliability of service in rural areas may suffer.

Several alternative energy technologies are cost competitive with central station rural electrification. The most attractive decentralized systems are horizontal axis windmills for direct pumping of water and biogas plants for residential electricity service. The horizontal axis windmill is the least costly method of pumping water for irrigation. One must keep in mind, however, that unlike other energy devices, a horizontal axis windmill does not generate electricity that can be used for multiple purposes. In addition, there are many locations in which there is not enough wind during the right seasons to make this system a viable alternative.

The cost of providing electrical energy from biogas units is quite comparable to the cost of the central grid. Unfortunately, the potential for larger biogas systems for multipurpose usage is limited, both because of social and cultural factors and because the quantity of dung available in most villages is insufficient. Even so, the use of biogas plants may be considered when the anticipated demand for energy is relatively low. Distance of a village from the central grid electricity distribution stations is a key factor in determining whether the decentralized alternatives are viable solutions for rural energy development. Small diesel irrigation pumps are also cost competitive with electric pumps for many locations.

ELECTRICITY AND RURAL ENERGY USE

The oil crisis of the 1970s convinced many policy makers in developing nations that a prudent policy would be to substitute electricity for oil, in order to reduce the reliance on imported oil. In both oil crises, shortages in both the developed and the developing countries were followed by abrupt rises in the price of oil. These oil "shocks" caused many countries to develop alternative resources such as coal or hydro for electricity. Even the United States passed laws encouraging the use of renewable energy and discouraging electricity generation with oil. Oil obviously will continue to play a major role in the economies of developing nations, but the development of their own commercial energy resources essentially means more emphasis on electricity from other sources, energy conservation, and renewable resources. In India, for instance, the rural electrification program began to concentrate on substituting coal generated electricity for diesel for irrigation pumping. With the recent decline in oil prices the situation is changing somewhat, but past experience makes many countries cautious about overreliance on oil.

The pricing of diesel fuel and electricity does affect their adoption and use in the rural economy. In the oil subsidizing countries of Ecuador and Indonesia, for instance, there is very little motivation for substituting electricity for oil for driveshaft power. On the other hand, in the electricity subsidizing countries like India, electricity is substituted for oil in agricultural pumping and rural industrial applications. The one exception is lighting, for which electricity is the preferred choice in all countries. Although oil and electricity compete with one another for some end uses, they also are complementary in others. Farmers with small, scattered plots may prefer the portability of a diesel engine. Electricity is not yet practical for transportation or plowing. Nevertheless, the fact that oil importing nations have been attempting to substitute electricity for oil underscores the vulnerability that many have felt after the quick and dramatic increases in the price of oil during the last two decades.

Diesel fuel is heavily taxed in India. The policy of subsidizing electricity while taxing diesel, even though the costs to society are about the same, raises questions concerning pricing and fiscal policies. However, the questions must be examined

in a larger context than just diesel versus electric pumps. Lowering the tax on diesel fuel would encourage greater consumption of diesel, not only for pumping - for which electricity is an alternative - but also for transport and other uses for which there are no easy alternatives. The result would be greater levels of oil imports. In addition, the production of electricity in India benefits the Indian economy more than importing oil does, since greater employment results from coal mining and constructing and maintaining the generation and distribution facilities. Also, as has been indicated, there are social benefits to the society that are not measured in the cost-benefit analysis. Finally, other technologies for producing electricity that may be competitive with the central grid include microhydro, diesel and wood-fired steam, but their cost competitiveness depends on local resources and proximity to the central grid.

Other Energy Programs

Commercial fuels must be placed in the context of overall energy use patterns. Electricity and petroleum-based products account for only a small fraction of total rural energy use, even in villages that have electricity. The use of commercial fuels and traditional energy sources may be complementary rather than competing. For instance, lighting, cooking and heating are the most energy-intensive activities in rural areas. Except in some countries in Latin America, very few people use electricity for cooking. In rural areas people typically rely on traditional fuels such as wood, dung, and agricultural waste. The consequence is that electricity as a percentage of overall energy use appears to be insignificant, limited to lighting, appliances, and some driveshaft applications. However, the impact of electricity on rural households probably is greater than its percentage of total energy use, since electricity or other commercial energy use may involve new energy-using activities that improve rural productivity or quality of life.

Many developing countries are experiencing deforestation and subsequent wood fuel shortages, and some analysts see electricity as one possibility for helping take pressure off the world's forests. However, as electricity is not used extensively

for cooking in these countries, the prospect of substituting electricity for wood fuels is remote. Even kerosene, which is commonly used in urban regions for cooking, has found only limited use for lighting in many rural areas, probably because of the convenient access to renewable fuels including wood, agricultural wastes, and dung. More viable programs for taking pressure off the forests would include growing fuelwood locally and conservation through improved stoves. Still, social forestry and traditional energy conservation programs do not compete with, but rather complement, rural electrification programs. In the case of limited funds for energy development programs, regional energy needs should be considered in order to determine the greatest energy priority.

Electricity and oil are more competitive, since kerosene and diesel fuel can both be used for lighting and driveshaft power. Recently, many have questioned the typically large subsidies for electricity in combination with heavy taxes on petroleum products. Only in the oil-producing developing countries, such as Ecuador, Mexico, or Indonesia, is oil subsidized. The question policy makers in developing nations face is whether substituting electricity for imported oil is important enough that producing electricity at about equal the present cost to the society is worth the long-run benefits, which would include lessening the impact of a future oil price rise. This question is especially relevant in the context of recent declines in the oil price.

In defining rural energy priorities policy makers should be concerned not only with current rural energy problems but also with future rural development potential. Choosing the most appropriate energy strategy for rural areas in developing nations depends on factors such as the extent of fuelwood scarcity, the existence of indigenous oil supplies, the potential for energy conservation, and local renewable energy resources. Rural electrification probably should not be considered for extremely poor countries with severe fuelwood problems. In these societies, power programs should concentrate on the more densely populated cities and small towns. Social forestry and fuelwood programs and improving the efficiency of stoves are more appropriate responses to deforestation and wood energy shortages in most developing nations. However, such programs cannot lift water for irrigation or improve incomes, though they may improve rural productivity. Programs for preserving and improving traditional rural energy sources are not in con-

flict with electrification programs, which are based on new energy-using activities and realizing long-term development potential.

Energy conservation is an important factor in rural electrification programs. Many developing nations have shortages of electricity which are not expected to disappear in the near future. Without reserve capacity, customers experience blackouts or brownouts at times of peak demand. Likewise, most developing countries are adding costly power stations and distribution systems, and this is likely to continue in the foreseeable future. Since the construction of new plants and new distribution facilities is extremely costly, conservation of electricity in the rural electrification system would be highly desirable.

Electricity conservation for rural areas does not mean cutting back on productive and essential uses of electricity. Good design of rural distribution systems is extremely important for reducing power loss in the system. One estimate for a less developed rural area was that for every 2 kWh of electricity produced one was lost in the rural distribution system. Long low-tension lines or lines that are too small for their loads needlessly waste energy. Thus, diesel engines should be considered as a viable alternative to electric pumps in regions that are distant from the distribution system and in systems that involve significant energy losses. Planning the distribution systems probably has not been given enough priority in rural electrification programs. Since the distribution systems for rural areas account for almost half the electricity investments, the programs should be designed to match expected current demand and provide flexibility to meet future demand.

Medium-scale power generation through power sources such as minihydro or small wood-burning generators are another alternative to central generation. Minihydro power has long been widespread in China, and experimental wood burning power stations in the Philippines are just coming into operation. In the United States there has been a substantial increase in decentralized generation systems since the enactment of legislation requiring utilities to purchase power from privately and publicly owned medium-sized decentralized generation stations. Decentralized systems based on water, wind, or local abundant wood resources could be constructed for isolated rural areas and later connected to the central grid systems. However, many present decentralized systems are not

compatible with the central grid because of different voltage levels and unstandardized equipment. Thus, standardization of system design should be a priority for decentralized electricity generation, so that when the central station electricity eventually reaches the more isolated rural areas, the existing system will not have to be completely dismantled and replaced. Decentralized generating units which would provide additional energy to the system during peak load periods would be especially attractive. The cost of generating electricity from medium-sized decentralized systems often is competitive with central station generation, so they should be considered as an alternative when local resources are available.

Electricity and Other Energy Prices

The adoption and use of electricity depends on relative prices, the level of rural income, the extent of power use, and the relative convenience of different fuels. Large energy users are more likely to substitute one fuel for another because of price. The studies in India and Indonesia demonstrate that the effects of this can sometimes be dramatic, depending on the relative price advantage of one fuel over another. India is an oil importing nation that subsidizes electricity and taxes diesel heavily, while Indonesia is an oil exporting country that subsidizes diesel fuel. In India the policy of encouraging electricity use has resulted in the substitution of coal or hydropower for oil. By contrast, in Indonesia there has been no major switch to electricity for pumping water or for driveshaft power in small-scale industry. Thus, the relative pricing of electricity for large power uses does have an impact on the mix of commercial fuels in the rural energy economy.

Many small appliances really cannot be powered by any fuel other than electricity. In such a situation the relative energy prices would have little impact on interfuel substitution. Such appliances include sewing machines, radios, televisions, fans, and perhaps even small refrigerators. Also, because the energy used for these appliances is rather small compared to the purchase cost of the appliance, the adoption of these energy using appliances is probably constrained more by low rural incomes and the inability to afford the appliance rather

than the price of electricity. Although extremely high electricity prices probably would discourage purchase of such appliances, the most important factor for appliances that use relatively little electricity is the purchase price of the appliance itself.

Convenience is an important factor in determining whether electricity is substituted for competing fuels. Electric lights generally are substituted immediately for other lighting sources such as kerosene or candles. Likewise, households with electricity tend to purchase electric irons rather than those heated by charcoal or coal. New sewing machines bought by households with electricity are more likely to be electric rather than run by a foot treadle. For such low or intermittent uses of electricity the additional expense of electricity is a rather small consideration, even for households with low incomes. On the other hand, the convenience of using electricity for cooking may well be outweighed by the cost of the electricity. Wood and kerosene stoves still retain their popularity for cooking because they are less expensive, and even kerosene is not used extensively for cooking in rural areas, partly because of the cost but also because of periodic scarcity of this fuel in the rural areas.

When energy prices are taxed or subsidized, this will affect the commercial fuel growth rate and profile of rural energy use. Generally, all things being equal, the price of all fuels should be at the long run marginal cost to produce, import, and distribute the fuels. In this way the consumer can make a choice of energy use based on the real value of the fuel to society. However, governments encourage or discourage energy use for many reasons, such as limiting reliance on foreign sources of energy, making distribution of energy more equitable, generating regional employment through energy development, and indirectly holding down consumer prices by subsidizing energy for agriculture or industry. Nevertheless, one of the most important considerations for having adequate electricity prices is that the power industry must be able to provide reliable long-term electricity service, which may not be possible if they constantly have to rely on government subsidies and other outside sources of financing.

Conclusion

Rural electrification programs should be considered as part of an overall commercial energy strategy which does not compete with programs for enhancing supplies and conservation of traditional fuels. However, as societies develop, traditional fuels tend to decline as a percentage of total energy use, since new uses are found for commercial energy. Central grid rural electrification must compete with diesel, kerosene, and commercial renewable fuels. At present, the most competitive alternatives to central station generation are diesel for pumping water, biogas for generating electricity, and direct wind for pumping. Although not examined in detail in this analysis, minihydro and small wood-fueled stations appear to be low-cost alternatives which can complement electricity generated from central stations. Conservation of existing energy without diminishing rural productivity also should be seriously considered for improving energy costs, since this avoids expensive investments in plant and distribution facilities and helps to alleviate the power shortages that exist in many developing nations. Many alternative energy systems can be advantageous in providing commercial energy for rural areas that are distant from the electricity distribution substations and for villages which have very low electrical energy needs.

POLICY ASSESSMENT

Several lessons have been learned concerning the role of rural electrification in development. Because electricity is a multiple use energy, providing lighting and many forms of driveshaft power, government policy plays an important role in shaping rural electrification. In general, the greater mix of end uses powered by electricity leads to greater impact for rural areas, so very narrowly focused projects should be avoided. The ambitious goal of attempting to spread electricity across a whole nation too fast and too soon may lead to severe financial strains on the power industry and may hinder such programs in the long run. Electricity programs are very costly, and huge financial losses are possible, but they can be avoided

by adequate pricing policies complemented by careful load development and management. The extension of electricity to villages should follow a predetermined list of development priorities, as electricity by itself can never be expected to have a significant impact on development. Rural electrification should be evaluated as a part of the larger context of socioeconomic development should be evaluated in forward-looking energy planning rather than from a static perspective of current rural energy use.

Rural electrification is a capital-intensive investment. If developing nations are not careful, its tremendous costs and operating subsidies can take capital away from other much needed development programs. Long-term reliable electric service can be assured if financial subsidies are minimized by concentrating on villages with significant loads and planning to minimize the length of high and low tension lines. In villages with adequate load per kilometer of lines, electricity will be less costly per unit of energy and also a greater impact on the community. Assuring financial health of the power industry will mean that the expansion of the system can later be accomplished without severe strains on the reliability of rural electrification service.

Not surprisingly, the villages that have demonstrated most significant load growth are those with large populations. For residential electricity, conditions conducive to load growth include larger population, high literacy rates, greater access to roads, adequate credit availability, and high agricultural income. Although this would suggest that perhaps only the most well developed villages should receive priority, many poor villages have also benefited substantially from rural electrification, especially those with adequate groundwater for irrigation. Since there is little demand for agricultural pumpsets in the rice growing regions, in these regions residential service probably should receive the highest priority. For rural businesses, as might be expected, markets, credit, and rural literacy were associated with growth of electricity use. The fact that literacy is related to household, business, and agricultural load growth shows that education and rural electrification are very complementary programs.

These guidelines so far sound rather conventional; extend electricity first to the most developed villages with the greatest pent-up demand for electricity. But the real challenge of rural electrification programs is to identify the less devel-

oped villages or regions where electricity will provide a development stimulus, in conjunction with other rural development programs. The profitability of rural electrification schemes is sensitive to the length of high tension lines, the productive impact, and the development of village load. Conventional project appraisals typically ignore these regional variations in predicting response to electrification. This research has revealed that in dry villages with significant irrigation potential electrification can generate significant economic benefits, especially in villages close to the distribution network. Poor villages with dense population centers can be more economically provided with electricity than villages with dispersed settlement patterns. In many cases the complementary programs that could be extended to poorer villages to improve electrification project response would include such programs as credit and education. However, it should be realized that not all villages can develop into market towns and many will remain essentially agricultural in character.

The energy policy for villages distant from the central grid and with poor load prospects should be carefully appraised to determine whether electrification or an alternative energy program is the least cost alternative. Installation of electric pumps distant from a grid when diesel pumps would be less costly is probably a waste of national resources. When it will not result in a significant number of connections, extending costly electricity distribution facilities to villages should be avoided. For instance, in many areas diesel engines in combination with biogas or diesel electricity generation would be a less costly alternative than central grid electricity. For the smaller villages, minimum load requirements should be established before the village is considered for connection with the central grid. Yet these villages should not be ignored in energy planning just because they may be uneconomical for connection with the central grid; rather, alternative programs should be established to provide for similar levels of energy service or for more pressing energy problems. For instance, woodfuel energy programs also may be a priority for villages with severe deforestation problems.

The financial viability of rural electrification is sensitive to costs, load growth, and the price of electricity. Village selection procedures should figure more prominently in economic appraisal reports. Some programs may even require the more wealthy villages to defray some of the initial capital

costs of providing transformers and high tension lines to the other villages. The price of electricity should reflect the long run marginal cost, since this would help utilities maintain the financial resources necessary to provide reliable service. Finally, costs in the system can be minimized by the careful placement of transformers and laying of high and low tension lines.

Government programs are very influential in determining the outcome of rural electrification programs. In most cases governments create incentives and disincentives by setting prices and establishing priority categories of consumers. Many past programs have become overly concerned with either residential or agricultural use of electricity. In some programs productive uses of electricity garner little attention, while in others they are stressed so heavily that household consumers cannot obtain a connection from the utility. One of the primary advantages of electricity is that it is a very flexible form of energy that can be utilized economically for productive, residential, and commercial uses. Not all villages will have need for all end uses, and programs must be flexible enough to adapt to local conditions and to encourage the multiple use of electricity whenever possible. Electricity has the unusual quality of being centrally produced, but having an impact that decentralizes productivity, information, and social amenities.

Rural electrification affects rural life through improving economic production and enhancing the quality of rural life. It has the most impact in regions where it can be used for multiple purposes, including agriculture, industry, commerce, and households. Social benefits are very important, but during the initial stages they will only be available to those with relatively high incomes. Economic activity can be enhanced by electricity, but only under the right conditions. A program aimed only at households will contribute little toward raising rural incomes, and one with a narrow focus on economic production will not improve the rural quality of life. Ideally, rural electrification programs should improve rural incomes, literacy, and quality of life.

CONCLUSION

Rural electrification programs should be evaluated from the perspective of the present and future energy needs of the village, the least cost alternative for providing these energy needs, and long-term impact on socioeconomic development. Rural electrification programs are based on well established technologies and management procedures, but many other energy technologies also are well established and should be considered as an alternative to or a complement of the central grid. The ideal energy mix and end use patterns for the village economy should be established in order to determine whether rural electrification or other energy programs are best suited to meet these needs. In addition, policies should be forward-looking rather than based on current energy use patterns. In many cases current energy use patterns reflect the low level of rural development, and to build an energy program around current patterns would be to assume that there will be no future socioeconomic growth.

Rural electrification certainly has not lived up to the rosy picture painted by its most ardent advocates, nor has it been as dismal a project as contended by the critics. The optimistic picture painted by the advocates has been blurred by benefits that never materialized, poor service resulting in brownouts and blackouts, and the inability of the poor to adopt electricity. On the other hand, the pessimistic scenario is contradicted by the substantial socioeconomic benefits from many programs, increased educational opportunities made possible by lighting, and greater productivity in commerce and industry.

If this is true, then should developing countries have rural electrification programs? Electrification certainly is not a magical force which will stimulate development in all circumstances. Several misconceptions concerning what rural electrification will accomplish need to be dispelled. Rural electrification will not play a significant role in stemming migration; in fact the reverse may be true, since more migration seems to occur in regions with electricity. Rural electrification by itself will not act as a stimulus to development without supporting programs or favorable socioeconomic conditions. Electricity is not the primary energy used in villages with electricity; rather, traditional fuels dominate rural energy use including wood, dung, and agricultural waste, along with human and animal

energy. Birth rates appear to be unrelated to rural electrification. Electricity is not likely to be used for cooking in most rural areas, although Latin America is somewhat of an exception to this rule. Finally, electricity is not always cheaper than the alternatives, since in many remote villages the extension of electricity can be quite costly.

Although it is not a magical force, electricity does provide basic energy important for rural development in many situations. It is instrumental for expanding agricultural pumping and driveshaft power in villages close to the grid and with the proper complementary conditions. Electricity and education are mutually reinforcing programs, since electric lights make reading in the evening much easier. In general, rural electrification is equitably applied across classes over the long term, although for the short term the distribution may be skewed. Both small and large farmers appear to benefit from rural electrification programs with a significant focus on agricultural development, and electrification shows some correlations with use of agricultural innovations. Rural electrification programs that stress the multiple uses of electricity can have a broad impact on social and economic development. The quality of life is improved for households with electricity. The number of households adopting electricity continues to grow for years after a village receives electricity, reinforcing the argument for evaluating these programs from a long-term perspective. Electricity makes possible some new uses of energy, including household appliances such as fans and televisions. Rural electrification programs which stress the multiple uses of electricity can have a broad impact on social and economic development.

Thus, the changes are cumulative and beneficial. While rural electrification is not the answer to all energy problems. it does bring new energy uses to the village which would not have existed without the program. Programs which manage to limit costs, improve connection rates, and keep prices relatively unsubsidized should be able to make a significant contribution to rural development. Rural electrification's variable impact on rural life implies that its positive effects may be determined more by government policies and unique regional characteristics than by the technology itself. Significant social and economic development can occur with rural electrification, but opportunities for even more productive uses may be constrained by the lack of complementary programs or conditions.

Appendix A

RESEARCH PROCEDURE

The surveys in India, Colombia, and Indonesia involved the sampling of households, communities, and rural businesses. Information was gathered through a variety of research techniques, including household interviews, reviewing village records, interviews with village leaders, and obtaining data from rural industries. Several factors were important in designing the research project. Since the communities in the project had to have a wide range of experience with electricity, some of the communities selected had had electricity for 20 years or more while others had never had it. The sample also had to have diverse levels of development if generalizations were to be applicable to both developed and less developed communities. Similarly, the households in the survey ideally should include high income households without electricity and poor households with electricity, as well as wealthy households with electricity and poor households without electricity. This ruled out a strictly random sample procedure.

SELECTING THE COMMUNITIES

In India and Colombia the villages for the study were chosen by a combination of purposive and random selection procedures. As mentioned above, communities with varied histories of electrification were selected, ranging from long to short to none at all. Likewise, the regions were selected for varying levels of development.[1] As indicated in table A.1, both samples have a wide range of time of electrification and level of socioeconomic development. In India 80 percent of the sample villages had electricity and in Colombia 79 percent. On average, the villages in India had had electricity for 12.6 years; in Colombia the average was 11.4 years.

Table A.1 Sample Village Electrification and Level of Development, India and Colombia, 1980

Level of development	Time of village electrification				
	Without electricity	1975-1980	1965-1974	1965 or before	Total
A. India					
Level 1[a]	4	5	13	12	34
Level 2	12	2	12	7	33
Level 3	7	6	12	9	33
Level 4	6	5	12	9	32
Level 5	29	17	49	37	132
B. Colombia					
Level 1[a]	3	3	4	5	15
Level 2	4	0	2	9	15
Level 3	5	2	3	5	15
Level 4	4	3	4	4	15
Level 5	16	8	13	23	60

Source: India Survey, 1980; Colombia Survey, 1980.

Note: India village level of development based on crop yields; Colombia level of development based on a factor score of infrastructure variables.

[a]This is the highest level.

For India, the study selected 132 villages in twelve districts in four states in India. The states of Andhra Pradesh, Maharashtra, Punjab, and West Bengal represent the diversity of India in terms of social, cultural, and geoclimatic conditions and levels of socioeconomic development. These states are located in southern, western, northern and eastern India, respectively. Together they account for 27 percent of India's population and 22 percent of India's geographical area. The choice of three of the states was dictated by the decision to replicate many of the questions in a 1966 study on agricultural innovations in India's villages (see Fliegel et al., 1968).2 To broaden the sample, it was decided to add the Punjab to the 1966 sample of states in order to include a wheat-growing region with a high level of agricultural development and rural electrification. The sampling of the villages in the Punjab was modeled after the procedure followed in the 1966 study in order to avoid any bias that might result from altering sampling designs.

The decision to resurvey the villages in the 1966 study made possible an over-time or longitudinal analysis (see Barnes and Binswanger, 1986). Most rural electrification studies in the past have been cross-sectional analyses. The resurvey of the 1966 villages improved the study's ability to deal with the crucial question of whether rural electrification is the cause of important changes in village socioeconomic development. While the causality question is one that can never be answered with complete satisfaction, this research offers a significant opportunity to examine the change in rural villages in India during a fifteen year time period. During the 1966-1981 period 57 percent of the villages gained access to electricity for the first time.

The 132 sample villages are fairly representative of India, although they are somewhat above average in population size and level of development. Also, the percentage of villages in the sample with electricity is far greater than the national average, but this was deliberately caused by the village selection procedure. The Colombia study followed a different sampling strategy but in many ways was similar to the India study. Sixty Colombian communities were selected from three different regions. Data were available for all of the municipalities in each region on socioeconomic variables such as average income, percent of literacy, percent of households with sewers and water lines, and commercial energy use. For these variables a

scale was created to measure a municipality's general level of development.[3] Using the scale, the following average values were obtained for each region in the study:

Level of Development of Manufacturing (Scale 3)

Region	Mean	Range
Coffee	0.925	1.57 to -1.41
Central	0.217	1.72 to -2.11
North Coast	-1.139	0.01 to -2.03

The coffee region is the most advanced in terms of level of socioeconomic development and the North Coast is the least developed, but the variance of the municipalities within the zones is large. The municipalities were purposely chosen according to their level of socioeconomic development.[4]

FIELDWORK

The fieldwork in India was conducted during the period March to May 1981 for three states - Andhra Pradesh, Maharashtra, and Punjab - and in April to June 1981 for the fourth state, West Bengal. All the field work was coordinated by Indian researchers. Four teams of experienced economic investigators, each guided by senior field supervisors of Operations Research Group, an India research/marketing team, conducted the fieldwork in the four states. The actual interviews were preceded by intensive briefing and pilot interviews in at least three villages that were not in the final sample. At that time adjustments were made in both interviewing techniques and individual questions in the research schedules. The actual interviews commenced only after the quality of the work and the interteam consistency of the pilot results met project standards. The field teams received extensive printed field instructions and maps. In addition, some basic data from the 1971 census were provided to the field investigators, so that broad cross-checks with certain critical indicators were possible. On completion of the field work, review sessions were held, and all village level schedules and a random sample of village leader and household schedules were reexamined with the field supervisor.

The fieldwork in Colombia was completed during June and July 1981. Three teams of interviewers were formed for each region. In total there were fifteen persons involved in the fieldwork, including one supervisor and four field investigators per region, all of whom were from Colombia. The interviewers received an introductory course from Instituto SER, a Colombian research institute, covering the data collection instruments and the contents of each research schedule. The introductory course clarified the general purpose of the study and resolved questions and doubts about specific survey procedures. Next, pilot interviews were conducted to familiarize the staff with the research instruments. In the process of these trial interviews each interviewer was given an instruction manual containing detailed rules regarding the expectations of and materials required by Instituto SER. The supervisors and interviewers were professionals with extensive experience in this type of work, including psychologists, sociologists, economists, and social workers.

The data for Indonesia study were collected through a series of surveys conducted between October 1980 and February 1981 in Central Java, Indonesia. The survey area consisted of villages and sections of villages in which electricity had been made available one and one-half years previously by a rural electrification project. Survey instruments were designed to obtain quantitative information regarding impacts which were directly attributable to electrification. In accordance with characteristics of the area and research interest in productive uses, conditions related to off-farm income-generating activities were examined with particular rigor.

The major survey of the area with electricity in Indonesia utilized a census of the village businesses and a random sample of households with and without electricity. Responses from all of the businesses with electricity, representing 94 percent of the business population, are included in the present analysis. Data on home enterprises were gathered in the course of the household survey. Interviews were also conducted with National Electric Company officials, government and bank officials, and village leaders. Participant observation of the villages was conducted for five months.

THE INDIA, COLOMBIA, AND INDONESIA SURVEYS

The India and Colombia surveys assume that benefits for the community, households, and industries can be very different. As a consequence, different types of surveys were administered in the communities in order to measure the different benefits. The survey included a variety of research instruments to collect information on households, industries, and agriculture. As indicated, the survey was somewhat different for Indonesia, so the Indonesia procedures are reported in the last section.

Village Information

Village-level information for India and Colombia was obtained by examining village or community records, by structured interviews with village leaders, and from data collected by the utilities (for details, see table A.2). Questions were asked on everything from crop yields to the number of young men migrating from the community. The leader survey provided fairly reliable information on aspects of the community not published in the official statistics, and in many instances the leaders' responses acted as an independent check on the reliability of the official data. On the basis of the village records and the leader survey in India, the data obtained from the State Electricity Board of West Bengal was deemed unreliable, since the information did not correspond to the data from the village survey, and it was dropped from the study. Similarly, in Colombia the utility data also were at variance with the survey results and so were not used in any analysis.

In India the village level information was obtained using three research schedules: the village information schedule, the village leader schedule, and an electricity board schedule. Much of the data for the village information schedule was acquired from the village block or official records, and other data were obtained from sources such as the village

Table A.2 Number of Interviews by Type of Research Instrument, India and Colombia, 1981

Research schedule	Number of interviews			
	India		Colombia	
	Goal	Achieved	Goal	Achieved
1. Village information	132	132	60	60
2. Village leader	528	518	240	211
3. Electricity board	132	90	n.a.	n.a.
4. Household	720	631	632	608
5. Industry/Commerce	214 (Total census)	134	No goal; part of household survey	136

Source: India Survey, 1980; Colombia Survey, 1980.

Note: n.a. means not applicable.

Panchayat president, the village-level workers, and the state electricity board (for details, see table A.2).

Respondents were selected on the basis of their leadership roles in the community. Four different types of leaders were selected for the village leader survey: (1) village political leaders, (2) village cooperative leaders, (3) school teachers, and (4) officials of voluntary agencies (for details, Samanta and Sundaram, 1983). If one of these officials was not available, a formal list of alternative leaders was followed to select the alternative. A total of 518 out of the goal of 528 leaders were interviewed for the village leader survey. It was not necessary to make any repeat visits to the communities.

Information on rural Colombian communities was collected from the community surveys, which included materials from available secondary data and community leader interviews. For the Colombia study, the community leaders were those having an affiliation with an institution, such as the mayor or priest, and those with no institutional affiliation but with considerable influence in the community, such as large landowners and civic leaders.

The community research schedule was structured so that objective characteristics of the community, such as the number of businesses and schools, the nearest roads, and the extent of community out-migration, were in a different section than the community leader's opinions on various topics. The latter section of the schedule was administered to four leaders, while only one leader answered questions referring to the more objective characteristics in the community, for it was felt that leader opinion responses would vary substantially more than those on the objective characteristics of the communities. In Colombia the numerical goals for both the community information and leader opinion surveys were achieved (see table A.2). Unfortunately, attempts to collect reliable information from the power industry proved to be unsatisfactory. Attempts at independent verification of the power industry statistics in the sixty villages revealed that the data were completely unreliable.

Household Interviews

Most past studies of the impact of rural electrification on development have concentrated on rural households as the unit of analysis. One difficulty encountered in these studies was that wealthy households are more likely to connect to the central grid than poor households. As a result, income and electricity adoption are highly correlated, and this relationship may cause spurious correlations between electricity adoption and the other socioeconomic variables in the study. In order to control for the bias that would occur in a random sample, it was decided to establish sampling quotas for the India and Colombia projects. The household quotas based on occupation included rich and poor households with and without electricity through a sample stratified by occupation. Controlling for occupation reduced the possibility of spurious correlation between electrification and household's income and between electrification and favorable characteristics associated with income, such as higher educational or lower fertility levels.

In spite of the differences, the occupational distributions of the samples are similar (see table A.3). The household survey in India was administered in a total of thirty-six villages with electricity out of the total sample of 132 villages, including nine villages from each state. Ideally the household interviews should be conducted in control villages without electricity. But previous studies on rural electrification indicate that the differences between the households with no electricity in communities with electricity compared to households with no access to electricity in most cases were very small (see Saunders et al., 1978). The India household sample therefore consists of a stratified random sample of households in villages with electricity. The stratification procedure was to select households with and without electricity in similar occupational categories. Consistent with the goals of the research design, the households without electricity in the more prosperous occupations and the households with electricity in the lower-paid occupations are somewhat over-sampled compared to a normal population distribution.

In Colombia, household interviews were conducted in all sixty rural communities in the study. For the Colombian sample a random sampling procedure for typical occupations within communities satisfied most of the occupational and

Table A.3 Household Interviews by Occupation, India and Colombia, 1980

	India sample						Colombia sample					
	Electrified		Not electrified		Total		Electrified		Not electrified		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Total farmers[1]	132	60.8	90	46.8	222	54.2	78	54.2	84	35.5	163	25.9
Large	45	20.7	24	12.5	69	16.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Medium	45	20.7	35	18.2	80	19.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Small	38	17.5	31	16.1	69	16.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Agricultural worker	26	11.9	41	21.3	67	16.3	82	21.0	72	30.5	156	24.8
Shopkeeper/business	34	15.6	20	10.4	54	13.2	45	11.5	16	6.7	61	9.6
Domestic	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	45	11.5	22	9.3	67	10.7
Service/related	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	47	12.0	10	4.2	57	9.0
Artisans	29	13.3	36	18.7	65	15.8	12	3.0	1	0.4	13	2.0
Professional	0	0	5	2.6	5	1.2	8	2.0	-	-	8	1.2
Others	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	72	18.5	31	13.1	104	16.5
Total	217	100	192	100	409	100	389	100	236	100	629	1002

Source: India Survey, 1980; Colombia Survey, 1980.

Note: n.a. means not applicable. Totals may not equal 100 percent because percentage figures were truncated.

[1]Includes livestock owners and poultry owners in the Colombia sample.

electrification quotas. In contrast to the India study, the Colombian control group of households without electricity is mainly from the communities without access to electricity. But, as can be seen in table A.3, the occupational characteristics of the Colombia household sample are remarkably similar to the distribution in the India sample.[5] The total number of households interviewed was 631, or about 10.5 interviews per community.

Industry and Business

The industry survey for India was a separate research schedule, whereas the survey for Colombia was a series of questions in the household survey. Industry in the India study was defined as all nonhousehold manufacturing, including both food processing industries, such as grain mills, and manufacturing units producing a product for sale. The industrial questionnaire was to be administered to all nonhousehold manufacturing establishments in the total 132 villages, no matter whether the villages had electricity or not. Because of interview refusals for a variety of reasons, the total sample for the industrial schedules was 134 units, or 60 percent of total manufacturing units in all the villages. The respondent for the industrial survey was the owner or senior partner of the manufacturing unit.

The Colombia survey of businesses was limited to those who were interviewed in the household survey. Special quotas were established to include household industries and shops, businesses, or industries outside of the homes in the survey. A total of 136 businesses were surveyed in the sixty villages. In addition, information on the number of rural industries in the community was documented in the community survey.

Indonesia Survey

The survey in Indonesia was somewhat different from the India and Colombia studies. Data for this study were collected in four ways: a village survey, interviews with officials of the National Electric Company, interviews with village leaders, and interviews with government officials at district and subdistrict levels. The village survey was conducted only in the areas of eight villages where electricity had been made available by the Klaten model rural electrification project. The village survey was in fact a series of surveys of households and businesses. A census of all households was first conducted to obtain an initial estimate of household income. Based on those data a stratified random sample of households with and without electricity was drawn in the proportions presented in table A.4. A census of the 131 businesses also was conducted. Since only the very largest businesses were identified by official records, the survey initially identified businesses by using the National Electric Company maps of the village. The maps were then reviewed with village officials, who added businesses that did not appear on the maps, and additional businesses were identified during the course of the survey. Information on home enterprises was collected as part of the household survey.

Table A.4 Samples as Proportion of Total Populations, Indonesia

Population	Sample size	Survey sample (absolute no. in parentheses)	
Electrified households	1748	12.4%	(217)*
Nonelectrified households	484	24.4%	(118)**
Electrified businesses	123	100%	(123)
Manufacturing[1]		37%	(45)
Services[2]		15%	(18)
Agricultural/food[3]		24%	(30)
Commercial[4]		24%	(30)
Other		0%	
Nonelectrified businesses	8	88%	(7)
Manufacturing[1]		38%	(3)
Services[2]		38%	(3)
Agricultural/food[3]		13%	(1)
Commercial[4]		0%	
Other		13%	(1)

Source: Brodman, 1982, p. 8.

*Survey design called for 219 electrified; however, 2 electrified household respondents were unavailable for interview.

**Survey design called for 121 nonelectrified; however, 3 nonelectrified household respondents were unavailable for interview.

[1]Includes makers of furniture (wood or metal) (nonelectrified), tailor made/ready-made clothing (nonelectrified), building materials, ice makers, pottery, bamboo mats, nets, plastic bags; and jewelry and a printing shop.

[2]Includes sawmill (nonelectrified); rice huller (nonelectrified); battery chargers; builder, radio, car, and bicycle repair; tailoring services.

[3]Includes food (bread, tofu, etc.), (nonelectrified); tofu refiner; milk producer; tobacco curing (nonelectrified).

[4]Includes wood store; restaurant/tea shop; general store; private savings and loan company; outlet for purchasing tobacco leaves.

NOTES

1. For India, the level of development is the level of agricultural development for the district. Within each state one district each at high, medium, and low levels of agricultural development was selected. Within these districts talukas and villages were randomly selected. For Colombia, a factor analysis was utilized to create a scale for level of development for municipalities, using such variables as roads, sewage, and level of income. The factor scale was used to rank different regions in terms of their level of socioeconomic development. After the regions were selected, the communities were randomly selected from within the regions.

2. The decision to retain the states, districts, and villages of the 1966 study was made only after careful examination of the distribution of those villages in terms of length of electrification, intensity of electrification, geographic and climatic diversity, cropping diversity, village size, and level of development.

3. The scale is based on principal component factor scores from the factor analysis of the socioeconomic variables for municipalities.

4. States were randomly selected from the three regions, and then municipalities were selected from each state according to the level of socioeconomic development. Finally, the communities were selected from the municipalities, insuring that there would be twenty communities from each of the three selected regions.

5. Farmers, tenants, renters, and agricultural laborers made up over 50 percent of the Colombia sample population but 70.3 percent of the Indian sample. These figures reflect the differences in the number of workers in farming in the two countries. Shopkeepers comprised 9.6 percent of the sample for Colombia and 13.2 percent of the Indian sample.

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