The Influence of Communications Infrastructure on Agricultural Growth

by

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(Abstract)

Increased access to communications infrastructure is theorized to influence both the productiveness of the agricultural sector and the direction of technical change. The purpose of this thesis is to empirically examine the effects of the level of communications infrastructure on agricultural production and the direction of technical change.

A Cobb-Douglas production function was used to estimate an inter-country production function for fifty developing countries over a fifteen year period, 1970 to 1985. The production function estimates were then used to assess the influence of the communications variables, roads and radios, on the level of agricultural production and the direction of technical change.

Increased levels of radios and roads increased the level of agricultural production in developing countries. Increased levels of radios did not significantly affect technical change. However, increased levels of roads led to an increase in the labor-saving bias associated with research expenditures.

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Somewhere in the midst of time there is completion and then beginning. The endeavors of the past two years bring meaning to the future. This meaning is structured in remembered moments. These moments are ahead, and I am thanking you now.

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Somewhere between my family and friends is Dr. Paxton Marshall whose tireless dedication and wisdom I strive to emulate.

Then there is my family. All my achievements can be attributed to the honor of my

father and mother, sister and brothers. I do not possess words to represent my respect and dedication, but I will always seek to express them.

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Chapter I

Introduction

I.1 Problem Statement

The level and quality of communications infrastructure have been hypothesized to have a significant influence on the development process (Lerner, 1958). The role of communications infrastructure on agricultural development has received relatively little attention but may have a substantial effect on productivity growth and on the types of technologies developed by research institutions.

The communications sector is multifaceted and includes radios, telephones, televisions, roads, and other means of transmitting and receiving information. Roads contain both communications and transportation components. The quality of communications infrastructure, from the farmers' perspective, depends on: (a) the nature of the information transmitted and (b) the ability of farmers to access and implement the information. Farmers in less-developed countries are less likely to have access to modern means of communication than their counterparts in more-developed countries. " It is a striking fact that whereas developing countries represent 75 per cent of the world's population they possess only 10 percent of the world's 600 million telephones, only 18 percent of the radio receivers, and only 12 percent of the TV receivers (Carim, 1985, p.15)." The level of road development is also relatively low in less-developed countries, particularly in Africa. For example, "..for African countries with available data, road densities vary from .01 to .11 kilometers per square kilometer of land area; in Asia those densities range from .35 to .41 (Ahmed and Donovan, 1992) ". Research on communications infrastructure also suggests that within developing countries the limited levels of communications infrastructure are asymmetrically distributed and positively correlated with socio-economic status (Shore, 1980; O'Sullivan, 1980).

Despite low levels of communications infrastructure, international lending for and domestic investment in communications' infrastructure has declined in many developing countries. Ahmed and Donovan (1992) observed that from 1978-88, in many African and Latin American countries, central government expenditures on transport and communications declined relative to total spending. The implications of this decline depend on the relationship between communications infrastructure and sustained increases in economic growth.

Daniel Lerner (1958) examined the impact of media and transportation in facilitating change. He observed the economic growth and social transition that occurred during the 1950s in Balgat, Turkey. Lerner noted that the modernization era in Balgat began with the introduction of radios and the construction of a small dirt road to Ankara. His observations led him to theorize that as modern means of communication replace traditional means, modern ideas and methods are ushered in, and because traditional ideas and methods are no longer reinforced, their use declines. Coinciding with publication of Lerner's work the United Nations General Assembly initiated programs to expand mass media in developing countries.

Everett Rogers (1969) studied Colombian villages and found a high correlation between early adopters of new agricultural techniques and access to mass media (newspapers, magazines, films, radios, and televisions). Surveys of those who adopted new techniques revealed little evidence that a particular medium was directly related to the adoption of a given technique. Hence, Rogers concluded that increased interaction with media influenced the atmosphere within the existing culture that, in turn, increased the likelihood that modern ideas would be accepted, increasing the adoption rate of modern techniques.

Where radio programs have been designed to specifically address farmers' needs, some literature suggests a causal linkage between agricultural technical change and communications infrastructure. For example, a USAID-funded program in Guatemala from 1974-1977 used radio to transmit information to farmers concerning agricultural techniques and modern inputs. Regions with and without access to the radio signals were studied. These regions were compared on the basis of reported agricultural practices which included land preparation; seed choices; insecticide, herbicide, and fertilizer use; treatment of crop residues; storage practices; and credit use. Areas with radio access were found to achieve relatively large gains in improved agricultural practices compared to areas without radio broadcasts (Hornik, 1988).

Farmers may not always be able to capture and process the information provided by radio. An example of farmers having poor price-information, despite intensive media coverage, can be found in Maritim's study of maize marketing in Kenya (1982). In 1976/77, only 67% of producers knew the prevailing level of government prices despite the fact that these prices were announced regularly on the radio, in daily newspapers, and in government circulars. In fact, among different regions of the country, the percentage of farmers aware of government prices varied, ranging from 81% to 50%. Furthermore, Maritim found that only 56% of farmers were aware of local market prices before bringing their produce to market. Two possible explanations for these results are that: (a) these farmers have inadequate access to communication (few radio receivers, poor distribution of newspapers, inadequate travel to and from the market), and (b) farmers are unable to understand or process information.

Transportation infrastructure facilitates increases in the flow of information and reduces marketing costs. For example, African farmers receive a smaller percentage of final prices, 30-50%, compared to Asian farmers who receive, 70-85%, of final prices. Two-thirds of this difference is due to the high costs of transportation in Africa. (Ahmed and Donovan, 1992)

Despite a general acceptance of communications infrastructure as an important aspect of development, the specific manner by which communications influences the direction of economic growth remains uncertain. Earlier communications theory is criticized for analyzing communications as an independent variable free from the institutional structures which interact to influence the usefulness of communications infrastructure (Shore,1980). Institutions are defined as the rules of the game. Formal institutions are the rules that human beings devise and publicly adhere to. Land distribution patterns reflect a formal, public institution. Private institutions include informal constraints such as conventional codes of behavior, customs, etc. (North, 1990). This study analyzes communications infrastructure in an agricultural setting, taking into consideration the underlying institutional arrangements and the manner by which increased levels of communications infrastructure affect those arrangements.

I.2 Agricultural Development: The Foundation for Economic Growth

In most developing countries, a large percentage of land and labor is devoted to agricultural activities. The agricultural sector must release resources to other sectors of the economy while simultaneously providing for the nutritional needs of a population, providing foreign exchange, and increasing the demand for industrial goods. For most countries, increasing agricultural productivity and farm incomes is essential to achieving sustained economic growth and poverty alleviation.

In Transforming Traditional Agriculture, T.W. Schultz (1964) asserted that low levels of agricultural productivity in developing countries result from a dependency on traditional forms of production and low levels of human capital. This assertion was supported by Hayami and Ruttan (1985) who estimated that three-fourths of the difference in agricultural labor productivity between the developed countries and developing countries may be explained by the use of modern technical inputs, human capital, and conventional inputs. Thus, technical change, involving the introduction and adoption of modern inputs and techniques, is critical for stimulating agricultural productivity and facilitating sustained economic growth.

Modern agricultural techniques often affect the relative use of the principal factors of production (land, labor, and capital). Therefore technical change, involving the adoption of modern inputs, influences both the productivity and the relative use of inputs. Technical change can be considered labor (land) saving when the marginal product of labor (land) falls relative to that of land (labor) holding the factor ratio constant (Hicks, 1932, p.121). Labor-saving technical change is often associated with increased use of mechanical technologies such as tractors. Such technologies generally increase the amount of land that can be cultivated by a laborer. Land-saving technical change is associated with increased use of biological, chemical, and water control investments. These classifications are generalizations that allow researchers to categorize the nature of technical change as labor-biased, land-biased, or neutral.

The 'bias' of technological change is heavily influenced by a country's land and labor endowments. In areas with relatively scarce supplies of labor, labor-saving technologies tend to be generated and adopted, whereas in countries with relative land scarcities, land-saving technologies tend to be generated and adopted (Hayami and Ruttan, 1985).

Despite distinct differences in resource endowments, Japan and the United States achieved similar rates of agricultural growth from 1880 to 1960. However, these parallel rates of growth resulted from the development and adoption of different technologies (Hayami and Ruttan, 1985). Japan developed along a land-saving technology path that resulted in high levels of land productivity. Conversely, the United States increased labor productivity through the adoption of tractors and other mechanical technologies that resulted in larger areas of cultivation per worker. This example illustrates both the potential for multiple paths of technological innovation and the importance of developing technologies that reflect a country's resource endowments in order to achieve high levels of agricultural productivity.

I.3 Technical Change: The Induced Innovation Theory

The tendency for farmers in a particular country to adopt technologies in a manner that saves the scarce resource is explained by Hayami and Ruttan (1975,1985) in the context of induced innovation. This theory describes technical change as an endogenous phenomenon in a dynamic economic system where iterative interactions between product demand, institutions, relative resource scarcity, and relative prices induce institutional and technological change in a direction that facilitates the efficient use of resources.

> "We hypothesize that technical change is guided along an efficient path by price signals in the market...... . Farmers are induced , by shifts in relative prices, to search for technical alternatives that save the increasingly scarce factors of production. They press the public research institutions to develop the technology and also demand that agricultural supply firms supply modern technical inputs that substitute for the more scarce factors" (Hayami and Ruttan 1985, pg. 88).

Several assumptions about the flow of information are implicit in the theory of induced innovations. First, it is assumed that information on current prices is equally accessible to all farmers. Second, it is assumed that farmers have the capacity to communicate their needs to research institutions. Finally, it is assumed that farmers have access to information concerning new technologies.

Unfortunately, in developing countries communications are frequently limited. A lack of communication potentially distorts information flows between farmers and research institutions. This distortion may suppress the rate of technical adoption and/or may result in technical change that does not reflect the needs of the average farmer.

I.4 Transactions Costs and Induced Innovations

High transactions costs may result from a lack of communications infrastructure. "The costliness of information is the key to the costs of transaction, which consist of the costs of measuring the valuable attributes of what is being exchanged and the costs of protecting rights and policing and enforcing agreements (North,1990, p.27)." When information costs are considered, phenomena that appear inefficient may become understandable. For example, in many developing countries, high costs of information have given rise to the popular use of informal credit markets which charge higher interest rates than formal credit markets.

At the micro level, the cost of production includes the cost of transforming inputs into output along with the costs of transacting- defining, protecting, enforcing, and acquiring the rights associated with an input, or final product (North, 1990). Where transactions costs are high, production will tend to be constrained as actors allocate resources to lowering or avoiding transactions costs, or rely on traditional means of production that entail lower transactions costs.

Transactions costs may also cause effective prices to differ among farmers within the agricultural sector. At the farm level, transactions costs may include the cost of gathering information with regard to inputs and final goods as well as costs associated with the costs include the costs of negotiating, monitoring, supervising, coordinating, and enforcing labor contracts (de Janvry, Sadoulet, and Fafchamps, 1987). As a result of transactions costs, cost to the farmer of various inputs (this cost includes the purchase price plus transaction costs) may differ among groups of farmers. If costs to each group vary, the optimal patterns of input use and, hence, demands for different technologies will differ among groups.

When the optimal patterns of input use vary among farmers, the public suppliers of agricultural research may face demands for technologies with different input-saving biases. The direction of public research efforts is especially critical when funding for research is relatively limited.

I.5 Farm Size and Transactions Costs

Different size farms may incur different relative input costs, particularly with regard to labor and land. Large holders incur high costs of organizing and monitoring labor and the effective price of labor to these holders may be greater than that experienced by smaller holders. These differences in labor cost are magnified in developing countries where small holders have a high ratio of family to hired labor.

Where transactions costs create severe disparities in the factor prices faced by large and small farm holders, owners and/or managers of large versus small farms demand different types of technologies. Large holders, as a group, will often organize based on a similarity in needs and relative wealth. If communications infrastructure is distributed asymmetrically, relatively wealthy large holders may organize to effectively lobby public research institutions more persuasively, or at a lower relative cost than smaller, less wealthy farm owners. If large holders are able to collectively influence research priorities, technologies may be developed that reflect the needs of this particular class of farmers, but may not address the needs of the majority of producers.

Research conducted by de Janvry and his colleagues supports the hypothesized relationship between average farm-size, distribution, and technological change: "..a larger average farm size and a more unequal system of land tenure increased the bias toward labor saving technology....(de Janvry, Sadoulet, and Fafchamps, 1987, p.44).[1]" A similar conclusion was also reached in a regional study of the West Central Highlands of Guatemala (O'Sullivan, 1980)

In many developing countries, a large proportion of farmers are small holders whose methods of production and inputs are relatively 'traditional', and their access to information is constrained by a lack of wealth and communication. Therefore, the time and effort necessary to obtain information about modern inputs and techniques may be relatively higher for some farmers than for others. Where transactions costs associated with gathering information are high, the costs to the farmer of new techniques and inputs is relatively higher for small holders than for large holders; therefore, rates of adoption by small holders is likely to be constrained. The relative cost to public institutions of disseminating technologies that reflect the needs of small holders may also be higher. The cost to small holders of organizing and collectively placing pressures on research institutions to develop technologies appropriate to

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[1] The de Janvry study also concluded that larger research budgets tend to favor land-saving technological innovations; "A larger research budget is thus less regressive on the distribution of welfare gains from technological change across farm sizes that a smaller budget (p.44)."

farms of their size may be higher as well.

I.6 The Role of Communications Infrastructure

Earlier discussion highlighted the importance of modern techniques and inputs in increasing agricultural production. These technologies often have implications for factor intensities. Research institutions test, adapt, and develop technologies, and, under limited budgets, must select the types of technologies to be studied. The induced innovation model emphasizes the importance of applied research in developing technologies that reflect farm-level demands. However, where communications between research institutions and farmers are limited, the type of technologies developed may be less suitable for the small holder, as compared to those technologies that would be developed if the research institutions were in closer touch with small holder farmers.

Farmers lacking the means to communicate among themselves and with research institutions may not be able to effectively express their demands. Research institutions, facing high costs of communicating with farmers may be influenced by groups of owners of large farms who are more easily accessed because of their better means of communication and organization.

Communications infrastructure may have a significant influence on the nature of induced technological change. Poor communications infrastructure may (a) cause farmers to inefficiently allocate resources to production activities, (b) constrain the ability of farmers to lobby research institutions and hence affect the type of technologies generated, and (c) influence adoption of new techniques and methods.

Without good communications providing relatively free flows of information, research institutions face higher costs associated with determining needs of operators of small farms. Moreover, public research institutions are susceptible to collective action by wealthier farmers whose demands for technologies may result in research priorities that do not reflect the demands of the majority of farm owners. These effects can result in technological change whose bias is inconsistent with the underlying resource endowments in agriculture.

I.7 Objectives

This study analyzes the relationship between communications infrastructure and agricultural production in developing countries. One aspect of this relationship involves assessing the influence of communications on the type of technologies generated and adopted in the agricultural sector.

The specific objectives of this thesis are to:

1) to examine the effects of communications infrastructure on agricultural production in developing countries, and

2) assess whether countries with relatively good communications infrastructure experience agricultural technical change that better reflects relative resource endowments than countries with relatively poor communications infrastructure.

I.8 Testable Hypotheses

The following specific hypotheses are tested in this thesis:

1) higher levels of communications infrastructure result in higher levels of agricultural production, and

2) higher levels of communications infrastructure influence technical change in agriculture in a direction that is labor using in relatively labor-abundant countries and labor saving in relatively labor-scarce countries.

I.9 Procedures

The procedures used in this thesis to test the above hypotheses are to examine the results of estimating a variable-coefficient inter-country agricultural production function. The model includes output, input, communications, and agricultural research variables for 50 countries with data for 1970, 1975, 1980, and 1985. The model allows for the influence of communications variables on agricultural research. Specific tests are developed to measure the effects of communications on research bias.

I.10 Organization of Thesis

This thesis contains four additional chapters. Chapter two presents the conceptual framework. Chapter three presents a variable-coefficient Cobb-Douglas production function that will analyze the testable hypotheses. Chapter four presents the results of the empirical tests. Chapter five contains a summary of the results, important conclusions, policy implications, and suggestions for additional research.

Chapter II

Conceptual Framework

II.1 Introduction

The purpose of this chapter is to develop a conceptual framework that can be used to analyze the influence of communications infrastructure on public research priorities, technical change, and agricultural production. The next section presents a conceptual framework that introduces a number of components that interact to influence technical change. The last section discusses the measurement of technical change in a manner that is amenable to empirical analysis.

II.2 Conceptual Framework

The definitions and relationships described in the following conceptual framework provide a model that facilitates testing the hypotheses presented in chapter one. This model adds communications infrastructure to previous theoretical models that analyze the role of research in facilitating technical change (de Janvry and Dethier (1985), Piñeiro and Trigo, (1983) and Hayami and Ruttan (1985)). Research objectives are influenced by farmers, researchers, and government policies; together, these groups, form the research institution. Analysis of the influence of communications infrastructure on the type of technologies made available implicitly involves an analysis of institutional change.

An important determinant of technical change in agriculture is the public research agenda. Research priorities influence the types of modern inputs and new techniques developed which, when adopted and applied represent technical change within a country. Two aspects of technical change are technical efficiency and technical bias. The bias of technical change may be categorized as either land- or labor-saving [Sen(1959), Hayami and Ruttan (1985), Binswanger (1974), de Janvry (1987)]. Defining technical change as either land- or labor-saving implies that the relative factor intensity of the 'saved' factor decreases.

Land-saving technologies include chemical inputs, biological inputs, and cultural practices that substitute capital and labor for land. Examples of such technologies include: high-yielding crop varieties, fertilizers, herbicides, insecticides, improved husbandry and soil conservation techniques, water-control investments, and a number of practices that may not demand cash outlay, such as contour plowing, seed selection from own crop, organic fertilizers, and compost piles.

Labor-saving technologies generally substitute capital and land for labor. Such technologies are typified by increased mechanization. Common examples of mechanical technologies include hand hoes and rakes, steel-bottom plows, cultivators, tractors and threshers, tree shakers, and mechanical pickers.

Hayami and Ruttan hypothesized that changes in relative prices lead to demands by farmers that induce public research institutions to supply technologies that save the relatively expensive factor. The price changes are, in part, a function of change in a country's resource endowments of land and labor. Hence, as long as input prices reflect relative resource scarcity, countries are likely to develop along a technical path (either land-saving or labor-saving) that reflects the particular factor endowments of the country (Hayami and Ruttan, 1985).

In the perfect information model of induced innovation, resource scarcity interacts through a market system to determine the relative costs of land and labor to large-farm and small-farm owners. These farmers demand technologies by lobbying their public research system; this lobbying helps determine the research agenda. The ease with which information, generated by research, can be disseminated may be influenced by the quantity of communications infrastructure.

The induced innovation model is illustrated by unit isoquants in Figure 2.1. I1 is an innovations possibility curve that represents the envelope of technologies that exist or could potentially be made available, given the existing state of scientific knowledge. However, because of previous relative prices, researchers have only

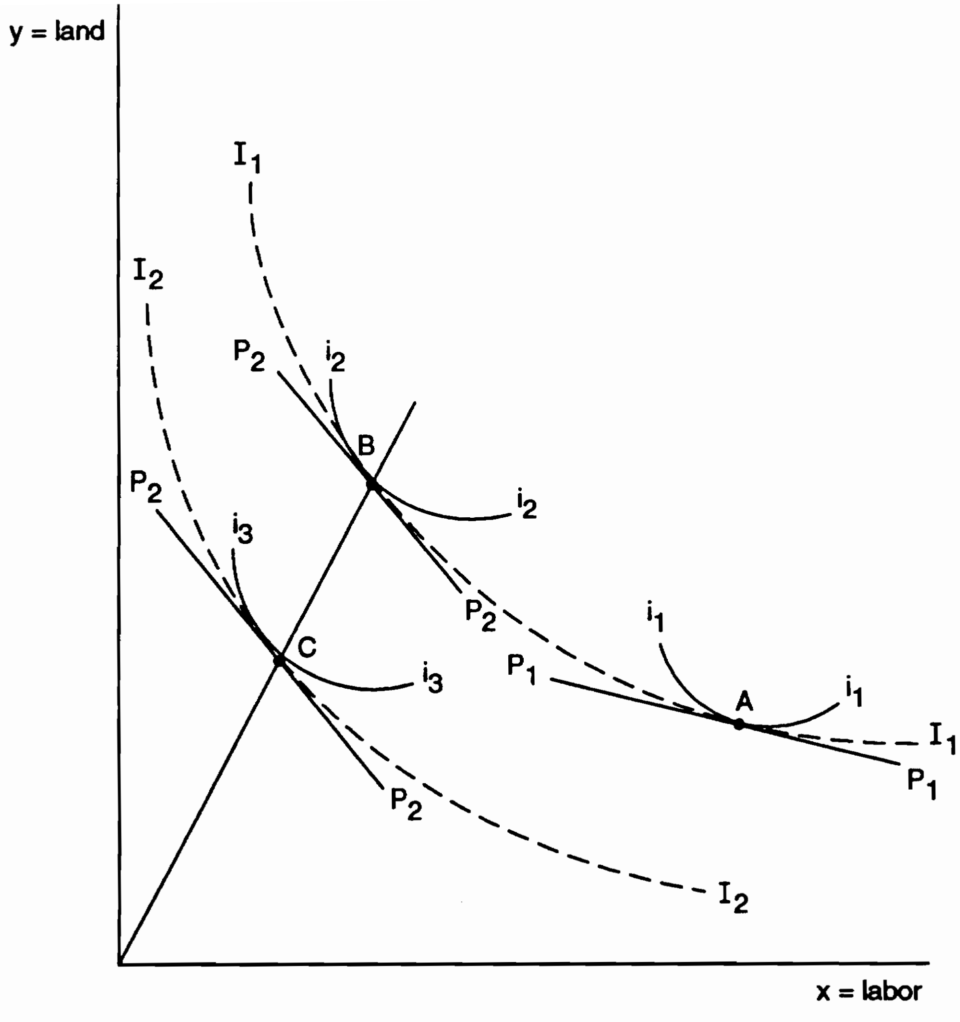

Figure 2.1 Induced Innovations

developed certain technologies on the innovations possibility curve. Movement along the innovations possibility curve is caused by changes in relative prices which induce research institutions to develop and make available to farmers, new technologies. If all farmers face the same input costs (P1), they will operate at point A using technology i1. However, if labor should become relatively more expensive compared to land, causing the price ratio to shift from P1 to P2, farmers will be induced to move to point B on technology i2. These technologies will be developed by the research system and have distinctly different implications in terms of the ratio of factor use (factor intensity); i1 is labor intensive, and i2 is land intensive.

In the short run, changes in prices induce shifts along the current innovations possibility curve. However, in the long run changes in prices induce shifts the innovations possibility curve itself. For example, I2 represents a new innovations possibility curve. Farmers facing prices P2 move from point B to point C, on i3 following the research-induced shift in the innovations possibilities curve. This technical change represents an increase in technical efficiency because farmers are now able to produce the same quantity of output utilizing smaller amounts of inputs.

Changes in technical bias or relative factor intensity result from increases in the relative use of one input relative to another that result from the implementation of new techniques. Technical bias can be defined for land and labor, while holding prices constant as follows:

$$(2.1) \quad \text{Bias} = \frac{\partial(\frac{f_y Y}{f_l L})}{\partial t}$$

where:
f_l = marginal product of labor,
f_y = marginal product of land,
L = quantity of labor , Y = quantity of land,
t = time,
if Bias is > 0, Labor Saving,
If Bias is < 0, Land Saving,
If Bias is = 0, Neutral

Changes in the ratio of marginal products (holding factor shares constant) determine the bias of technical change.

Since John Hicks (1942) argued that rising wages explained the tendency for technical change to be labor-saving, a great deal of theoretical, historical, and empirical analysis has examined the plausibility of the induced innovation theory [(Sen (1959), Kennedy and Thirlwall (1972), Hayami and Ruttan (1985), Binswanger (1977), Kislev (1973), de Janvry et al. (1985)]. Some literature indicates that technical change has not always reflected the relative prices generated by the market. For example, in a historical analysis of factor productivity and growth with regards to Japan, the United States, Germany, France, Denmark, and the United Kingdom Binswanger, Ruttan, et al. (pp 44-72) noted the following relationships:

(1) relative prices of land and labor were inversely related to the relative endowments of land and labor;
(2) variation in land productivity was positively related to the price of land and negatively associated with the price of labor;
(3) differences in the relative scarcity of land and labor did not constrain agricultural productivity;
(4) all countries experienced a strong negative relationship between the price of fertilizer relative to the price of land and fertilizer use per hectare; and;
(5) the relative price of labor to land was positively associated with fertilizer use per hectare.

These observations strongly support induced innovation theory with respect to: the hypothesized relationship between resource endowments and relative prices (1); the hypothesized relationship between the price of land and land productivity (2); the role of different types of technology in stimulating agricultural productivity (3); induced changes in modern techniques (fertilizer) ((4) and (5)).

However, the direction of induced changes in mechanical technology could not be explained by the theory of induced innovations in the aforementioned study. The results indicated a positive relationship between land per worker and the price of land relative to the price of labor. These results are the opposite of what is expected from the model of induced innovation. This outcome led the authors to hypothesize an exogenous labor-saving bias that may be the result of international technology transfers from countries like the United States with historically high land-to-labor ratios.

The market process may not always generate prices/costs that accurately reflect the effective costs to the farmer of employing certain inputs. For example, the cost associated with labor will vary depending on labor-management relations. It is reasonable to assume that small-holding farmers who use family labor would incur lower costs of monitoring labor than large holders who must hire and oversee labor activities. Also, it is consistent with the concept of transactions costs to assume that land purchases become relatively less expensive the larger the land purchase and the wealthier the purchaser. This negative relationship between land holdings or wealth and the cost of buying land stems from information and monitoring costs incurred by credit institutions. Creditors are likely to be more averse to loaning limited funds to small-farm owners, especially where information on the credit history of the farmer is either absent or difficult to obtain and the asset base of the farmer is relatively small. Conversely, information about the credit history of relatively large-farm operators is likely to be less costly to obtain and the land provides an asset base to use as collateral. For these reasons, the cost associated with making loans is expected to become relatively smaller per unit the greater amount of land being purchased.

If farm owners face different effective costs of land and labor depending on the size of their farm, research demands are no longer monolithic. Hence, farmers may undertake collective action (based on farm size) in order to influence research objectives. In de Janvry's and Dethier's (1985) review of collective action, which includes work by Hardin (1982), and Pineiro and Trigo (1984), they concluded that the relative success of collective action depends on certain characteristics. Specifically, greater success in influencing research priorities is expected to be enhanced by: (a) smaller group size (b) increased group homogeneity with regards to origin and goal, and (c) the closer the geographic proximity of group members. These characteristics enable some groups to control 'free riding' better than others, increasing the effectiveness of their demands.

An example where a small group of large-farm owners was able to undertake collective action and influence the public research agenda is witnessed by the progression of technical change is California. A highly concentrated land ownership structure in California has resulted in lobbying that has influenced both state and federal government policies and the state research agenda. The lobbying has ensured a supply of low wage workers and the development of technologies that are labor-saving. From the 1940s on, California's economy has become more diversified, causing wages to rise. Anticipating these wage increases, large-farm owners have sought to influence the research agenda of the University of California. The University has responded with a series of labor-saving technologies including a sugar beet harvester, a corn head for grain combines, and a fig picking machine (Piñeiro and Trigo, 1983). Large-farm owner interests in California may have also influenced federal policies. For example, during WWII, the Bracero program was implemented to ensure a flow of cheap seasonal labor to the California farm sector, a program that lasted until 1965.

Incorporating transactions costs and collective action into the induced innovations model may explain why technical change may not reflect relative scarcity. When the relative resource scarcity of land and labor interacts with transactions costs, different groups of farm owners (based on farm size) will be induced to lobby public research systems in a manner that may result in research priorities that favor one group's needs over those of others. Lobbying costs are influenced by the accessibility to communications infrastructure which may determine the ability of different groups to receive timely information and effectively lobby the public research system. If the research objectives are strongly divergent from those expected given average relative prices and resource scarcity, technical change may be biased along a technical path that does not reflect a country's endowments of land and labor.

Figure 2.2 illustrates a potential technical path that does not reflect average resource scarcity of land and labor. Initially farmers may utilize two distinct technologies i1 and i2, both tangent to the initial innovations possibility curve, I1. The average price

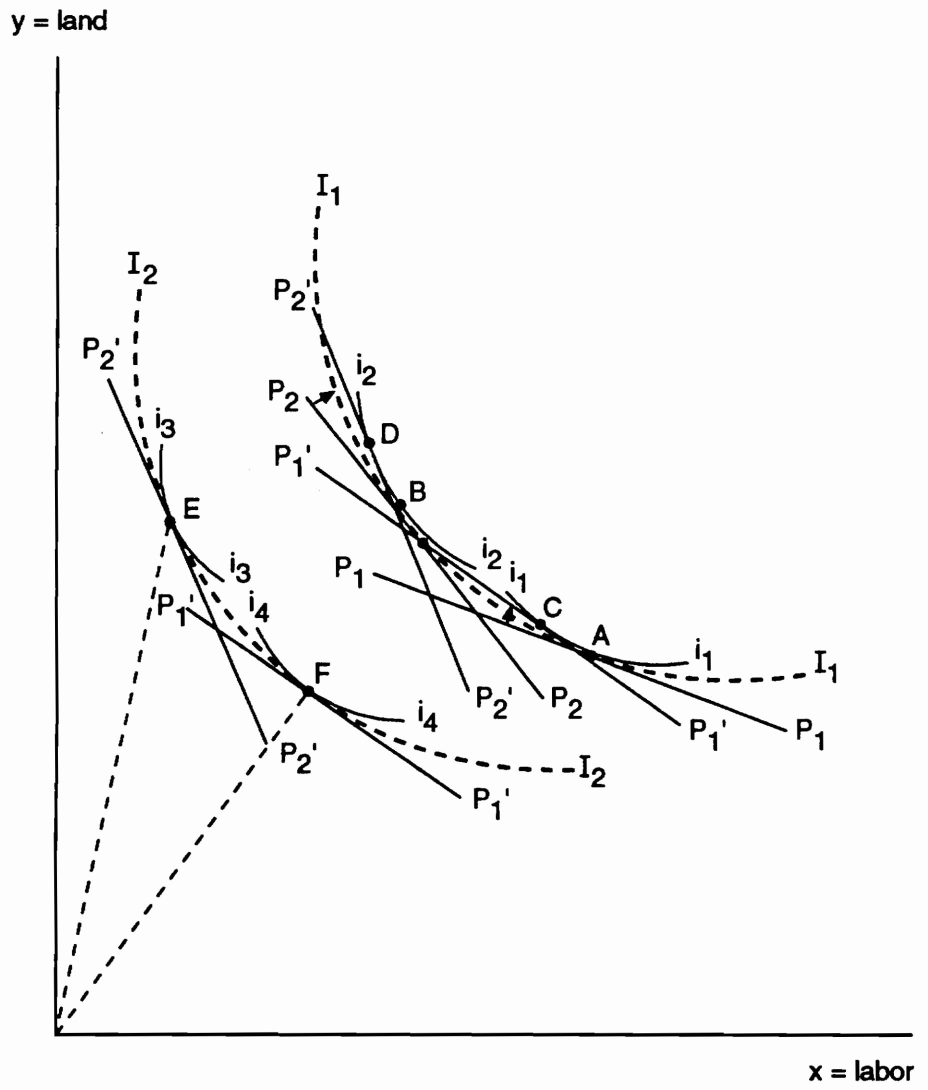

Figure 2.2 Induced Innovations With Collective Action and Transactions Costs

ratio (P1) reflects average resource scarcity and influences where the majority of farmers operate; this is represented by point A, on i1. Assume that large holders employ a distinctly different technology due to farm-level transactions costs, which increase the relative price of labor to land (P2). Hence, large holders operate at point B, utilizing technology i2.

Changes in the relative scarcity of land and labor may induce changes in input costs which in turn cause large- and small-holders to demand new technologies from their research system. For example, assume that labor becomes more scarce causing the relative price of labor to increase to P1' and P2', for average- and large-farm holders respectively. In the short run, large holders will guide production activities along the current technology (i2) to point D. In a similar manner, the average farmer would begin to produce at point C. In the long-run, if large holders are able to influence the research system more effectively than the average farmer, research institutions may allocate energies in a manner that results in the materialization of a technology that is biased towards the needs of large holders. For example, collective action by large holders may induce research institutions to develop i3, on I2 (figure 2.2). Large holders will operate at point E, where P2' is tangent to both i3 and I2. However, i3 is not the optimal technology from the perspective of the average farmer, since they face the price ratio P1'. They prefer I4, which is still on IPC I2, but has not been developed due to the limited research budget.

Increased levels of communications infrastructure are hypothesized to (a) lower the costs to farmers of information about new technologies and, (b) increase the opportunities for a broader base of farmers to influence the public research agenda. Increased participation may influence the types of technologies developed, diffused, and adopted. Hence, in areas with higher levels of communication, technical bias may be more responsive to demands of the average farmer. Increased lobbying of the research institutions by all farms may increase the political and economic incentives to develop technologies which reflect the needs of the average farmer. For example, research institutions may develop technology i4 rather than i3. Technology i4 allows the average farmer to operate at point F; which is the optimal technology for farmers facing the price line illustrated by P1'.

A common method of analyzing changes in the production process is to estimate a production function. A production function can be developed to estimate the innovations possibility curve illustrated in figures 2.1 and 2.2. If the production function is aggregated across all countries, to represent an aggregate technology, the production function may be referred to as a meta-production function. The following section discusses this type of production function.

II.3 Measuring Technical Change

An aggregate production function may be utilized in order to analyze the contributions of various inputs to agricultural production. A country production function may be expressed in the following form:

(2.2) $Y_{it} = F_i(X_{i1t}, X_{i2t}, \ldots\ldots X_{int}, t)$,

Where i indexes individual countries, t represents the time periods, and n is the total number of inputs.

This type of aggregate production function allows the production structure to vary across countries. Lau and Yotopoulous (1989) point out several problems with using this type of production function. One problem is the available data sets may not contain sufficient variation in inputs and outputs. This problem may stem from the fixed nature of certain inputs (i.e. land), and may result in multi-collinearity when inputs such as capital and labor move in the same direction.

The problem of insufficient data variation can be reduced by the use of a meta-production function, defined in its general form as:

(2.3) $Y_{it} = F(X_{i1t} \ldots\ldots, X_{int}, t)$ for all i

F is not subscripted and therefore it is assumed to be the same for all countries. Countries operate at different points on the "meta-production" surface as a result of differences in their economic environments (resource endowments and relative prices). This model,

> "is empirically attractive because it justifies the pooling of data from different countries to estimate the common underlying production function, thus increasing both the ranges of variation of the independent variables and the total number of observations, and thereby reducing the possibility of multi-collinearity, increasing the degree of reliability of the estimated production function and enlarging its domain of applicability (Lau and Yotopoulous, 1989, p.242)".

One important complication that arises when estimating a meta-production function stems from the non-comparability of data. Non-comparability may arise as the result of differences in the definitions, measurements, and qualities of inputs and outputs. Nonetheless, the use of the meta-production function remains an important tool, and its use often generates insights into economic phenomena that commonly occur across countries.

A prominent example of estimating a meta-production function is the work of Kawagoe, Hayami, and Ruttan (KHR, 1985) who estimated a meta-production function using a Cobb-Douglas functional form. Discrete production functions are estimated for 1960, 1970, and 1980. The inputs included labor, land, livestock, fertilizer, machinery, and general and technical education. Countries were partitioned into two groups based on their status as either developing or more developed.

The KHR study found that the production function remained relatively stable between 1960 and 1970, and again between 1970 and 1980. This stability was determined by comparing the estimated elasticities of production between estimated production functions at different points in time. Also, the production functions estimated for developing countries and developed countries differed; developing countries were characterized by constant returns to scale and developed countries were characterized by increasing returns to scale.

The Hayami and Ruttan study (1985) and subsequent research (KHR, 1985; Antle, 1982) made the strong assumption that countries either have the same technology available to them, a new technology could be developed, or an existing technology could be adapted with appropriate investments. That is, inter-country differences in the level of production are captured in the levels of inputs used or in research and education investments. However, these investment effects are disembodied from the conventional inputs, in the sense that they do not account for quality changes in the inputs. The ratio of marginal products of any two inputs was not influenced by the investment variables in the meta-production functions used in the Antle (1982) and Hayami and Ruttan studies (1985).

Technological change embodied (affect the quality of inputs) in the conventional inputs can be accounted for by a variable-coefficient production function. An example of such a model is developed by Mundlak and Hellinghausen (1982). He hypothesized that although all countries have access to the same technology, their choice of technologies differs depending on their economic environments. Certain "state variables" were used to characterize differences in the economic environments. An example of a state variable is a variable that accounts for inter-country differences in land quality. The variable-coefficient production function used by Mundlak and Hellinghausen (1982), allows the parameters of production (Bi) to be influenced by state variables. Thus, the productivity and ratios of marginal products are influenced by the levels of state variables.

Lau and Yotopoulous (1989), re-estimated the KHR function in order to account for country-specific effects. Their working premise is that the meta-production function must account for country-specific effects that may influence the quality of inputs. In order to test for inter-country differences country-specific dummy variables are added to the production function. Their results indicate that the hypothesis that country-specific effects do not influence the production function must be rejected. This supports the use of a production function which allows the productivity of inputs to be influenced by inter-country differences.

Fulginiti and Perrin (1992) specified a Cobb-Douglas meta-production function that embodied technical change using non-conventional inputs to capture changes in the quality and use of the conventional inputs. Their functional form allows for a measure of both the rate and the bias of technical change with respect to certain "technology-changing variables" (similar to Mundlak's state variables). Their model is adapted and presented in the next chapter. The model is used to analyze the role of communications infrastructure on agricultural productivity and the bias of technical change.

Chapter III

Empirical Model

III.1 Introduction

The purpose of this chapter is to develop an empirical model that can be used to estimate an inter-country production function, and to develop tests of the testable hypotheses presented in chapter one. This chapter is divided into four sections. The second section presents the empirical model. A general empirical model is presented and then restricted to a specification that is applied to the data. The third section specifies tests for the hypotheses developed in chapter one. Finally, the fourth section describes the data used in the model.

III.2 The Empirical Model

A meta-production function is utilized in order to analyze the effect of communications infrastructure on technical change in agriculture. The meta-production function is estimated using a variable-coefficient Cobb-Douglas production function. The general model is represented as follows:

(3.1) $$Y_{jk} = A\Pi X_{ijk}^{\beta i} X_{ejk}^{\beta e}$$

j= 1...50 for the countries, k = 1970, 1975, 1980, and 1985, i=1,2 for land and labor, and e= 3...8 for other inputs.

The following specification of the parameters is used to allow changes in technical efficiency and the bias of land and labor to vary according to the levels of communication infrastructure (c), research (τ), and the relative scarcity of land and labor (d).

(3.1a) $\ln A = \alpha_0 + \alpha_1 \tau_{jk} + \mu_{ojk}$
(3.1a1) $\alpha_0 = \zeta_0 + \zeta_1 c_{jk} + \zeta_2 d_j + \zeta_3 c_{jk} d_j$
(3.1a2) $\alpha_1 = \Theta_0 + \Theta_1 c_{jk} + \Theta_2 d_j + \Theta_3 c_{jk} d_j$

(3.1b) $\beta_i = \delta_{io} + \delta_{i1} \tau_{jk} + \mu_{ijk}$
(3.1b1) $\delta_{i0} = \rho_{i0} + \rho_{i1} c_{jk} + \rho_{i2} d_j + \rho_{i3} c_{jk} d_j$
(3.1b2) $\delta_{i1} = \eta_{i0} + \eta_{i1} c_{jk} + \eta_{i2} d_j + \eta_{i3} c_{jk} d_j$

The variables are specified as follows: Y_{jk} = is the value of agriculture gross domestic output for the jth country in the kth year, c_{jk} is a measure of communications, in logs, for the jth country and the kth year, τ_{jk} represents national research expenditures, in logs, for the jth country and the kth year, d is a dummy variable for labor intensity for the jth country, and the X_{jk}'s are conventional inputs for the jth country and the kth year. The μ_{ojk}'s are random variables independent of X and β. The μ_{ijk} is a random variable with a mean of zero.

The objective of the thesis is to analyze the manner in which communications, research, and land-labor scarcity influence technical change through increases in technical efficiency and changes in technical bias. The variable-coefficient model, specified above allows the intercept shifter and the production parameters of land and labor (β_i's) to be functions of the level of c, cd, d, and τ. These variables influence the "state" of technology and are therefore called "state variables".

Communications is hypothesized to lower the information costs associated with gathering information about market prices and available technologies. Therefore higher levels of communication are hypothesized to be associated with higher levels of agricultural production. The level of research expenditures in a country is hypothesized to affect the availability of the most productive technologies. Hence, higher levels of research are hypothesized to increase agricultural productivity. Moreover, increased communications increases interactions between farmers and scientists causing an increase in research productivity. Therefore, communications, research, and communications times research, are included as neutral intercept shifters which influence levels of productivity (see equation 3.1a1).

The coefficients on land and labor (β_i) are specified as functions of the state variables. Thus, the bias of technical change can be analyzed for the two principal agricultural inputs: labor and land. Higher levels of communications are hypothesized to decrease transactions costs associated with adopting new technologies. Increases in the use of modern technologies should result in greater input productivity. Moreover, increased communications promote interactions between farmers and researchers, influencing the level of research productivity and the technical bias with respect to land and labor. More research expenditures are hypothesized to reflect the development of new technologies which also facilitate increases in land and labor productivity.

The bias of technical change is also hypothesized to be influenced by the relative scarcity of land and labor. These relative scarcities influence the types of technologies demanded by farmers and developed by research institutions. Therefore, relative scarcity, represented by the labor-intensity dummy variable, is interacted with the research expenditures variable, and the research times communications variable (see equation 3.1b2).

In order to attain a more parsimonious specification of the model and still be consistent with the research objectives, the coefficients of these variables are restricted to zero. The re-specified empirical model is then used to analyze the data.

Coefficients ζ_2, ζ_3, θ_2, θ_3, which measure Hicks-neutral changes in the level of productivity (see equations 3.1a1 and 3.1a2), are set to zero because they all include the labor-intensity dummy variable. Though this variable is hypothesized to influence the bias of technical change through its interaction with communications and research, these interactions are not hypothesized to affect the level of production, independently of the land and labor inputs. For example, Japan and the United States, despite distinct differences in relative endowments of land and labor, have been able to develop comparable levels of total agricultural productivity; however, the bias of technical change in these two countries has been quite different.

Labor and land times the dummy variable (ρ_{i2}), and labor and land times communications times the dummy variable (ρ_{i3}), are specified to influence the bias of technical change without interacting with research (see equation 3.1b1). Because research expenditures are hypothesized to be the mechanism by which new technologies are developed and made available to farmers, the aforementioned variables are not hypothesized to have a unique influence on technical change. For example, in the absence of research institutions, the relative scarcity of land and labor would not result, or interact with communications, to result in technical change. Instead, farmers would re-allocate activities within the confines of the existing technology. Thus, these variables are deleted from the model.

The changes discussed above are used to restrict the model to the following empirical form:

(3.2) $$Y_{jk} = A\Pi X_{ijk}^{\beta i} X_{ejk}^{\beta e}$$

(3.2a) $$\ln A = \alpha_0 + \alpha_1 \tau_{jk} + \mu_{ojk}$$

(3.2a1) $$\alpha_0 = \zeta_0 + \zeta_1 c_{jk}$$

(3.2a2) $\alpha_1 = \Theta_0 + \Theta_1 c_{jk}$

(3.2b) $\beta_i = \delta_{io} + \delta_{i1}\tau + \mu_{ijk}$
(3.2b1) $\delta_{i0} = \rho_{i0} + \rho_{i1}c_{jk}$
(3.2b2) $\delta_{i1} = \eta_{i0} + \eta_{i1}c_{jk} + \eta_{i2}d + \eta_{i3}c_{jk}d$

The model can be expressed in log form as follows:

(3.3) $$\ln Y_{jk} = \zeta_0 + \zeta_1 c_{jk} + \Theta_0\tau_{jk} + \Theta_1 c_{jk}\tau_{jk} + \Sigma_i(\rho_{i0}\ln X_{ijk} + \rho_{i1}c_{jk}\ln X_{ijk} + \eta_{i0}\tau_{jk}\ln X_{ijk} + \eta_{i1}c_{jk}\tau_{jk}\ln X_{ijk} + \eta_{i2}d\tau_{jk}\ln X_{ijk} + \eta_{i3}c_{jk}d\tau_{jk}\ln X_{ijk} + \mu_{ijk}\ln X_{ijk}) + \beta_e\ln X_{ejk} + \mu_{ojk}$$

III.3 Hypothesis Tests

The first testable hypothesis asserts that higher levels of communications infrastructure increase agricultural productivity in developing countries. The second testable hypothesis postulates that higher levels of communications infrastructure help guide research activities in a direction that results in technical bias that saves the relatively scarce input. In order to test these hypotheses a number of statistical tests are developed to assess the significance of the communications, research, and dummy variables in the model. In addition, tests of significance of the combinations of variables that reflect the bias associated with research expenditures, and communications' influence on this bias. These tests are collectively referred to as tests of the research hypotheses, and are as follows:

(H1) H_o: $\zeta_1 = \Theta_1 = \rho_{11} = \rho_{21} = \eta_{11} = \eta_{21} = \eta_{13} = \eta_{23} = 0.$

If the null is accepted the coefficients associated with the communications variables are jointly considered statistically non-significant. Hence, communications does not increase the explanatory power of the model. If the null hypothesis is rejected, the elasticity of production for communications may be developed. The elasticity of production is defined for any input X and output Y as follows:

$$(3.4) \qquad \psi_x = \frac{\partial Y}{\partial X}\frac{X}{Y}$$

Using equation (3.3) the elasticity of production for communications is defined as:

$$(3.5) \qquad \psi_c = [\zeta_1 + \theta_1\tau + \Sigma_i(\rho_{i1}\ln X_i + \eta_{i1}\tau\ln X_i + \eta_{i3}d\tau\ln X_i)],$$

In a similar manner, using equation (3.3) the elasticity of production with respect to research is also be defined:

$$(3.6) \qquad \psi_\tau = [\theta_0 + \theta_1 c + \Sigma_i(\eta_{i0}\ln X_i + \eta_{i1}c\ln X_i + \eta_{i2}d\ln X_i + \eta_{i3}cd\ln X_i)].$$

The bias induced by research expenditures is defined as the change in the log of the ratio of marginal products with respect to τ (Fulginiti and Perrin, 1993). This definition is expressed below:

(3.7) $$B_{n,i,\tau} = \frac{\partial(\ln\partial Y/\partial X_n - \ln\partial Y/\partial X_i)}{\partial\tau} \quad .$$

Using equation (3.3), the research bias for the empirical model (3.3) is developed:

(3.8) $$B_{1,2,\tau} = \frac{[\eta_{10}+\eta_{11}c+\eta_{12}d+\eta_{13}cd]}{[\rho_{10}+\rho_{11}c+\eta_{10}\tau+\eta_{11}c\tau+\eta_{12}d\tau+\eta_{13}cd\tau+\mu_1]_a} - \frac{[\eta_{20}+\eta_{21}c+\eta_{22}d+\eta_{23}cd]}{[\rho_{20}+\rho_{21}c+\eta_{20}\tau+\eta_{21}c\tau+\eta_{22}d\tau+\eta_{23}cd\tau+\mu_2]_b} \quad .$$

If the bias is positive, research leads to land-saving technical change; if negative, research leads to labor-saving technical change.

The following two tests are developed to assess whether the research bias is non neutral (i.e. equation 3.8 = 0).

(H2) H_o: $\eta_{10}=\eta_{11}=\eta_{12}=\eta_{13}=\eta_{20}=\eta_{21}=\eta_{22}=\eta_{23}=0$.

In this case, both numerators of equation 3.8 will equal zero and research bias will equal zero.

(H3) H_o: $\eta_{10}-\eta_{20}=\eta_{11}-\eta_{21}=\eta_{12}-\eta_{22}=\eta_{13}-\eta_{23}=\rho_{10}-\rho_{20}=\rho_{11}-\rho_{21}=0$.

In this case the first term in equation (3.8) equals the second term and the difference between them (the bias of research) equals zero.

Rejection of the null for both tests of research bias (H2 and H3) provides statistical evidence that the research variable, τ, has a non-neutral influence on technical bias. the direction and magnitude of this influence can then be determined using equation (3.8).

Using equation (3.8), the influence of communications on the technical bias associated with research expenditures can be developed:

(3.9)
$$\frac{\partial B_{1,2,\tau}}{\partial c} = [\frac{([\eta_{11}+\eta_{13}d])([*]_a)-(\rho_{11}+\eta_{11}\tau+\eta_{13}d\tau)([\eta_{10}+\eta_{11}c+\eta_{12}d+\eta_{13}cd])}{([*]_a)^2} - \frac{([\eta_{21}+\eta_{23}d])([*]_b)-(\rho_{21}+\eta_{21}\tau+\eta_{23}d\tau)([\eta_{20}+\eta_{21}c+\eta_{22}d+\eta_{23}cd])}{([*]_b)^2} .$$

$[*]_a$ = , $[\rho_{10}+\rho_{11}c+\eta_{10}\tau+\eta_{11}c\tau+\eta_{12}d\tau+\eta_{13}cd\tau+\mu_1]_a$

$[*]_b$ = , $[\rho_{20}+\rho_{21}c+\eta_{20}\tau+\eta_{21}c\tau+\eta_{22}d\tau+\eta_{23}cd\tau+\mu_2]_b$

A positive value for $\partial\beta_{1,2,\tau}/\partial c$ implies that increased levels of communications impart a land-saving tendency for research bias; if negative, an increase in communications has a labor-saving influence on the research bias; if zero, the effect of communications on the bias of research is zero. A statistical test is developed to determine whether the influence of communications on research is non-neutral:

(H4) H_o: $\eta_{11}=\eta_{13}=\rho_{11}=\eta_{21}=\eta_{23}=\rho_{21}=0$.

Failure to reject H4 means that the numerator of the $\partial\beta_{1,2,\tau}/\partial c$, equation (3.8), is not significantly different from zero. Hence, communications would not influence the bias of research. Rejection of the null hypothesis gives a statistical basis for the estimation of the effect of communications on research bias (equation 3.9).

Before countries, grouped on the basis of relative labor intensity, can be compared, a statistical test is developed to determine whether the coefficients associated with the dummy variable are jointly significant. This test is:

(H5) H_0: $\eta_{12} = \eta_{22} = \eta_{13} = \eta_{23} = 0$.

Failure to reject the null means that he dummy variables are not considered to be statistically significant. Rejection of this test gives a statistical basis for estimating the research effect on bias for labor-intense versus labor-scarce countries. The sign of the derivative $\partial\beta_{1,2,\tau}/\partial c$ can then be compared for labor-intensive (d=1), and relatively less labor-intensive (d=0) countries.

III.4 Definition of the Variables and Sources of the Data

The variables and their sources are defined in table 3.1. A complete listing of the data is provided in appendix A. Fifty countries are analyzed over a sixteen year period using observations for 1970, 1975, 1980, and 1985. No country in the data set has a 1989 per capita GNP above 2,320 dollars (World Bank, 1992).

The output variable, agriculture gross domestic product (AGGDP), was measured in local currency units and deflated to 1980 currency units using country- specific implicit GDP deflators and then converted to an "international" dollar using 1980 purchasing power parity indices obtained from Summers and Heston (Norton, Ortiz, and Pardey, 1992). This variable provides a measure of the aggregate agricultural production for each country.

Two different types of communications infrastructure were examined: roads and radios. Roads facilitate interpersonal means of communication and transport which

Table 3.1- Variables and Sources

Variable	Definitions and sources [a]
AGGDP:	Agriculture Gross Domestic Output for country i at year t; for i = 1,....,50, and t= 1970, 1975, 1985. Calculations by Philip G. Pardey. Sources: International Monetary Fund, The World Bank, and United Nations.
Roads:	Total kilometers of roads per 100 sq.km of total area for country i at year t; for i = 1,....,50 and t = 1 observation. Sources: Central Intelligence Agency (1990), Europa Publications (various years), and The Economist (1989).
Radios:	The number of receivers per 1000 inhabitants for country i at year t; for i = 1,....,50 and t = 1970, 1975, 1980, 1985. Source: Unesco Statistical Yearbook (various years). Missing values interpolated.
Research:	Estimate of actual public expenditures on agricultural research; for country i at year t; for i = 1,....,50 and t = 1970, 1975, 1980, 1985. Source: Pardey and Roseboom, 1989. Missing values interpolated and extrapolated. Research was also lagged five years.
Dummy variable[b]:	The dummy variable = 1, if countries have an average land to labor above 192 per 1000 hectares of agricultural land. The dummy variable = 0, if the ratio is below 192. Average ratios (1970,1975,1980). Source: See labor and land below.
Labor:	Economically active population in agriculture; for country i at time t; for i = 1,....,50 and t = 1970, 1975, 1980, and 1985. Source: FAO Agrostat Database.
Land:	Total agricultural land in hectares (thousands); for country i at time t; for i= 1,....,50 and t = 1970, 1975, 1980, and 1985. Source: FAO Production Yearbooks (various years).
Livestock:	Number of livestock in equivalent units; for country i at time t; for i= 1,....,50 and t = 1970, 1975, 1980, and 1985. Source: FAO Production Yearbooks (various years).
Fertilizer:	Total fertilizer consumption in 1000 metric tons; for country i at time t; for i = 1,....,50 and t = 1970, 1975, 1980, and 1985. Source: FAO Fertilizer Yearbooks (various years). Missing values interpolated.
Land quality:	Land quality index; for country i at time t; for i = 1,....,50 and t = 1970, 1975, 1980, and 1985. Source: Peterson and Pardey (1989).
Machinery:	Proxies from total average horsepower, for country i at time t; for i = 1,....,50, and t = 1970, 1975, 1980, and 1985. Sources: FAO Production Yearbooks (various years). Hayami and Ruttan (1985).
Primary and secondary education:	The number of pupils enrolled in primary and secondary schooling for country i at time t. For i = 1,...., 50 and t = 1970, 1975, 1980, and 1985. Source: Unesco Statistical Yearbook (various years).
Post high-school education:	The number of pupils enrolled in post high-school education in country i at time t. For i = 1,....,50 and t = 1970, 1975, 1980, 1985. Source: Unesco Statistical Yearbook (various years). Missing values interpolated.

[a] All data had been previously collected and used in a study by Norton, Ortiz, and Pardey (1992), except the roads variable gathered by Deborah Wagner (Ph.D. student at VPI, Agricultural Economics); and the radios, fertilizer, and dummy variables which were collected or constructed by Brady J. Deaton, Jr.

[b] Labor-intensive countries include: Ethiopia, Zimbabwe, Fiji, Turkey, Cote d'Ivoire, Ghana, Guatemala, Nigeria, Barbados, Zaire, Pakistan, Malaysia, Malawi, El Salvador, Benin, Kenya, Liberia, Mauritius, India, Philippines, Indonesia, Sri Lanka, Nepal, Rwanda, Bangladesh, and Egypt. Relatively less labor-intensive countries include: Botswana, Argentina, Uruguay, Paraguay, Bolivia, Zambia, Venezuela, Chile, Sudan, Peru, Mexico, Colombia, Costa Rica, Morocco, Jordan, Swaziland, Panama, Senegal, Ecuador, Cameroon, Tanzania, Cyprus, Niger, and the Dominican Republic.

reduce both information and transportation cost. Radios represent media infrastructure which may increase the accessibility to information. Both of these variables are hypothesized to have a positive influence on agricultural output and are expected to affect the bias of technical change in a manner that saves the relatively scarce input.

Other variables might have been used to measure inter-country differences in the level of communications infrastructure. For example, both the number of telephones and the circulation of newspapers are potential measures of communications infrastructure. However, both of these variables are likely to be heavily influenced by a country's level of urbanization. Since the purpose of this thesis is to analyze the role of communications in facilitating agricultural production, which typically occurs in rural areas, telephone and newspaper variables were not included in the empirical analysis.

The research variable accounts for the level of actual public expenditures on agricultural research in a given country. The research data are compiled in local currency units, deflated to 1980 currency, and finally, converted into purchasing power parities in millions of U.S. dollars. Research was included as current expenditures in one model and as expenditures lagged five years in another. Lagged research was included to reflect the fact that research takes time to complete and adoption of the product of research occurs with a lag.

The dummy variable is incorporated in the model to reflect relative resource endowments of land and labor. The variable is 1 if the average (for 1970,1975, and 1980) land to labor ratio is above 192 laborers per 1000 hectares of agricultural land. The variable is zero if the average land to labor ratio is below 192. This point (192) represents a middle point over a fairly continuous labor/land relationship for the 50 countries in the data set.

Labor and land variables represent the economically active population in agriculture and total agricultural land. Land and labor are two important inputs in agricultural production. A quality of land variable is included to capture inter-country differences in agriculture production that result from inter-country differences in the quality of land.

The education variables- primary and secondary education, and post-high school education- are included in the model to capture inter-country differences in the ability of farmers to understand, adopt, and implement new technologies. These variables are hypothesized to increase the level of agricultural output.

A livestock variable is included to measure inter-country differences in levels of investment associated with animal use. The livestock variable was measured in cattle equivalents.

The fertilizer and machinery variables reflect the use of modern inputs within a country. The fertilizer variable measures total fertilizer use for all countries in 1000 metric tons. The variable includes nitrogenous, phosphate, and potash fertilizers. The machinery variable represents the number of tractors weighted by a time-varying weight of average tractor horsepower; where weights represent a linear interpolation and extrapolation of Hayami and Ruttan's (1985) 1970 and 1980 estimates of 35 hp and 40hp, respectively. Both these variables represent the use of modern inputs and capital investments.

The next chapter discusses the estimation procedures and results. Four different models are used to estimate a meta-production function, using the restricted form developed in this chapter (see equation 3.3).

Chapter IV

Estimation Results

IV.1 Introduction

The meta-production function developed in chapter three is estimated using Ordinary Least Squares (OLS) procedures. In order to keep the model manageable and reduce collinear relationships between the independent variables, radios and roads were included in separate models. Four separate models are estimated. The first, model 1, uses the radio variable as a measure of communications infrastructure. Model 2, is estimated using the roads variable as a measure of communications infrastructure. Models 1 and 2 are estimated using a research variable constructed using current research expenditures. Models 3 and 4 are identical to models 1 and 2, respectively, except that research expenditures are lagged five years.

This chapter presents the estimated coefficients for all models. This presentation is followed by a brief discussion of the statistical adequacy of the models. Then, the results of the tests that assess the statistical significance of communications variables, dummy variables representing labor-intensity, the variables affecting the measures of research-induced bias of labor and land, and the variables that measure the influence of communications on this bias, are presented and discussed. Next, production elasticities for the research expenditure and communications variables are presented and discussed. Then, the research-induced bias effects, and communications' influence on this bias, are presented. Results from this study are compared to previous estimates of inter-country agricultural production functions. Finally, the results are summarized.

IV.2 Production Function Estimates

The estimated production functions for all four model specifications are presented in table 4.1. All models were subjected to misspecification tests to determine whether the models were appropriately specified for OLS estimation. Tests of normality, linearity, and homoskedasticity were conducted. The skewness-kurtosis test (Spanos 1986, pg. 454) was used on the models to determine the validity of the normality assumption. All models failed to reject the normality assumption. A Reset-type test presented in Spanos (1986, pg.461) was used to test for appropriateness of the linear functional form. Finally, a Reset test was used to analyze the assumption of homoskedasticity. This test rejected homoskedasticity in all models. Because of this rejection of homoskedasticity, the standard errors of the estimates were corrected using White's procedure (White, 1980). All the standard errors presented in table 4.1 are corrected standard errors.

The variables that measure livestock, land quality, and post high-school education are

Table 4.1.- Agricultural production function estimates for 50 developing countries

Variable	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]
Intercept	-5.908*	.245	-6.106*	-.819
	(2.204)[i]	(1.40)	(2.10)	(1.35)
Comm[e]	.949*	-.407	.895*	-.286
	(.380)	(.250)	(.359)	(.255)
Res[f]	1.695	-1.78*	1.655	-1.339
	(.958)	(.672)	(1.02)	(.742)
Comm*Res	-.24	.92*	-.222	.809*
	(.200)	(.269)	(.213)	(312)
Labor	.609*	.188*	.571*	.234*
	(.190)	(.078)	(.175)	(.088)
Land	.032	.110	.081	.101
	(.149)	(.084)	(.146)	(.087)
Comm*Labor	-.064*	.065*	-.055*	.063*
	(.026)	(.032)	(.034)	(.034)
Comm*Land	-.014	-.055	-.024	-.067*
	(.031)	(.036)	(.030)	(.034)
Res*Labor	-.080	.203*	-.060	.150
	(.118)	(.085)	(.121)	(.087)
Res*Land	-.065	-.116	-.098	-.088
	(.162)	(.080)	(.169)	(.081)
Comm*Res*Labor	.012	-.102*	.009	-.085*
	(.020)	(.037)	(.021)	(.042)
Comm*Res*Land	.011	.061	.0155	.048
	(.026)	(.036)	(.027)	(.039)

Table 4.1.- (Contd.)

Variable	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]
Res*Labor*Dum	-.098 (.128)	.008 (.051)	-.121 (.134)	.027 (.047)
Res*Land*Dum	.160 (.203)	-.038 (.077)	.198 (.214)	-.060 (.077)
Comm*Res*Lab*Dum	.013 (.023)	-.011 (.024)	.016 (.024)	-.024 (.023)
Comm*Res*Land*Dum	-.020 (.038)	.0366 (.036)	-.026 (.040)	.050 (.038)
Livestock	.319* (.060)	.29* (.049)	.323* (.062)	.297* (.052)
Fertilizer	-.002 (.036)	-.003 (.035)	-.007 (.035)	-.019 (.034)
Land Quality	.619* (.122)	.511* (.128)	.659* (.125)	.564* (.139)
Machines	.047 (.029)	.058 (.030)	.063* (.028)	.070* (.030)
Education1[g]	.147 (085)	.079 (.096)	.150 (.087)	.095 (.098)
Education2[h]	.146* (.040)	.193* (.045)	.142* (.041)	.182* (.045)
R^2 adj.(n=200)	.946	.949	.947	.948

[a] Model 1: communications = radios; research = current expenditures.
[b] Model 2: communications = roads; research = current expenditures.
[c] Model 3: communications = radios; research = five-year lag.
[d] Model 4: communications = roads; research = five-year lag.
[e] comm = communications.
[f] res = research.
[g] Education1 = primary and secondary education.
[h] Education2 = post high-school education.
[i] Figures in parentheses are adjusted standard errors (White,1980).
* Significant at the 5% level.

individually statistically significant in all models at the 5% level. The influence of these variables on production was positive, as expected, and the magnitude of the parameter estimates appear relatively consistent between all four models. The machinery variable was positive in all four models but only significant in models 3 and 4. The primary and secondary education variable also had a positive coefficient; however it is not statistically significant in any model.

There was a high degree of collinearity among the state variables, land, and labor. The state variables are the variables used to measure roads, radios, research, and labor-intensity. For many of the interacted variables, the t-statistics were quite low, a likely result of collinearity. Because the specification of the variable-coefficient production function involved a number of interactions between land, labor, research, and roads, overall production elasticities of the state variables, and the land, and labor inputs needed to be calculated. Analyzing the lagged research models reveals that labor had an overall production elasticity of approximately .21 for both models 3 and 4, while land had an overall production elasticity of .02 in model 3 and .10 in model 4. The production elasticities of the state variables are presented after tests for the research hypotheses are presented below. Tests of the research hypotheses were designed to determine the joint significance of the state variables in the model.

IV.3 Tests of The Research Hypotheses

Calculations of the productivity and bias effects can be made for all the state variables. However, calculations are only made for those cases where the state variables were jointly significant. In this study, a p-value below .05 was used as a cut off for rejection of the null. The p-values from the heteroskedasticity corrected F-tests used to analyze the research hypotheses (see section III.3) are presented in table 4.2. The null hypothesis that communications variables are jointly insignificant was rejected (see F1 in table). Similarly, the null hypothesis that research has a neutral influence on technical change was rejected for all models. The hypothesis that communications has a neutral influence on research-induced bias was rejected only for models 2 and 4 (See F4). Tests of the joint significance of the dummy variable on labor-intensity failed to reject the null for all models (see F5). Because the dummy variable was not significant, elasticities of production by labor intensity (low and high) and the influence of labor intensity on the bias of research were not calculated.

Following the results of the significance tests of the research hypotheses, calculations of communication production elasticities and the direction bias associated with research (research-induced bias) were made for all four models. However, the results of these significance tests indicated that only models 2 and 4 could be used

Table 4.2.- P-values from tests of the research hypotheses.[a]

F test #	Model 1[b]	Model 2[c]	Model 3[d]	Model 4[e]
F1[f]	.041	.000	.033	.001
F2[g]	.038	.000	.041	.000
F3[h]	.000	.001	.000	.001
F4[i]	.076	.004	.086	.012
F5[j]	.076	.103	.066	.095

[a] P-values adjusted for heteroskedasticity using White's correction test.
[b] Model 1: communications = radios; research = current expenditures.
[c] Model 2: communications = roads; research = current expenditures.
[d] Model 3: communications = radios; research = five-year lag.
[e] Model 4: communications = roads; research = five-year lag.
[g] Test the significance of communications in the model.
[g]&[h] Tests the significance of non-neutral change in research-induced bias.
[i] Tests the significance of communications non-neutral influence on research-induced bias.
[j] Tests the significance of the labor-intensive dummy variables.

Actual Tests (see equations 3.8 and 3.9) :

$$F1\text{: } H_o\text{: } \zeta_1 = \theta_1 = \rho_{11} = \rho_{21} = \eta_{11} = \eta_{21} = \eta_{13} = \eta_{23} = 0 \ .$$

$$F2\text{: } H_o\text{: } \eta_{10} = \eta_{11} = \eta_{12} = \eta_{13} = \eta_{20} = \eta_{21} = \eta_{22} = \eta_{23} = 0 \ .$$

$$F3\text{: } H_o\text{: } \eta_{10} - \eta_{20} = \eta_{11} - \eta_{21} = \eta_{12} - \eta_{22} = \eta_{13} - \eta_{23} = \rho_{10} - \rho_{20} = \rho_{11} - \rho_{21} = 0 \ .$$

$$F4\text{: } H_o\text{: } \eta_{11} = \eta_{13} = \rho_{11} = \eta_{21} = \eta_{23} = \rho_{21} = 0 \ .$$

$$F5\text{: } H_o\text{: } \eta_{12} = \eta_{22} = \eta_{13} = \eta_{23} = 0 \ .$$

to estimate the influence of communications on research-induced bias. Because the labor-intensity dummy variable was found to be non-significant, its productivity and bias effects were not calculated.

IV.4 Production Elasticities for Roads and Research Expenditures

The production elasticities for roads and research are presented in table 4.3. The positive production elasticities for both the radios and roads variables confirm the first hypothesis of this study: higher levels of communication infrastructure increase agricultural production. For example, using model 3, the production elasticity for radios indicates that a 10 percent increase in the number of radio receivers per 1000 people increases agricultural production by .43 percent. Similarly, a 10 percent increase in the kilometers of road per 100 square kilometers of land results in a .95 percent increase in the level of output. The production elasticity of roads is smaller in model 4, which uses a lagged research expenditure variable, than in model 2, which uses a research expenditure variable constructed using current research expenditures. This result indicates that the production elasticity of roads may be overestimated by a model that uses current research expenditures as a measure of the research variable.

The elasticity of production with regards to research expenditures, estimated at the

Table 4.3.- Estimated production elasticities for roads and research expenditures.[a]

Variable	Model 1[b]	Model 2[c]	Model 3[d]	Model 4[e]
Communications	.0413	.175	.043	.088
Research	.094	.185	.093	.095

[a] Elasticities calculated for all fifty countries at variable means.
[b] Model 1: communications = radios; research = current expenditures.
[c] Model 2: communications = roads; research = current expenditures.
[d] Model 3: communications = radios; research = five-year lag.
[e] Model 4: communications = roads; research = five-year lag.

variable means, is also positive. Increases in research expenditures result in higher agricultural production. For models 1,3, and 4, a 10 percent increase in the level of research expenditures results in a .9 percent increase in agricultural production.

IV.5 Research-Induced Bias and the Influence of Communications

The effect of research on the labor- and land-saving bias is presented in table 4.4 In addition, the effect of changes in the communications variable on the research-induced bias are presented. In all models, the research-induced bias was labor-saving. Tests of the research hypothesis failed to reject the null hypothesis at the 5% level that radios had an influence on the research-induced bias. Therefore, only models 2 and 4 using the roads variable, were used to calculate this influence. In both models 2 and 4, the roads variable reinforces research induced labor-saving bias. Hence, increases in the kilometers of road per 100 square kilometers are associated with an increased labor-saving bias of research.

IV.6 Comparisons With Previous Estimates

The estimated production elasticities of the current study are compared with previous studies that used intercountry agricultural production functions in table 4.5. Specific comparisons are made for the traditional inputs as well as infrastructure and research

Table 4.4.- Research-induced technical bias and communications' influence on this bias.[a]

Variable	Model 1[b]	Model 2[c]	Model 3[d]	Model 4[e]
Research	-1.93	-.877	-1.8	-1.23
Commmunications	------	-1.51	-----	-1.18

[a]Research Bias is defined as:

$$B_{n,i,\tau} = \frac{\partial(\ln\partial Y/\partial X_n - \ln\partial Y/\partial X_i)}{\partial\tau}$$

Communications' influence on research bias is defined as $\partial\beta_{1,2,\tau}/\partial c$ estimated at the input means; τ is the research expenditure variable.

[b] Model 1: communications = radios; research = current expenditures.
[c] Model 2: communications = roads; research = current expenditures.
[d] Model 3: communications = radios; research = five-year lag.
[e] Model 4: communications = roads; research = five-year lag.

Table 4.5.- Comparisons of estimated production elasticities with those in previous studies.

	Source:						
	Evenson-Kislev (1975)	Antle (1982)	Mundlak-Hellinghausen (1982)	Hayami-Ruttan (1985)	Fulginiti-Perrin (1993)	This[a] Study (1993)	
Number of countries included	36	47	58	43	18	50	
Period of estimation	1955,60,65	1965	1960-63	1960,70,80	1961-85	1970,75,80,85	
Estimation method	OLS	OLS	OLS	OLS	OLS	OLS	
Input						Model3	Model4
Labor	.20	.40	.49	.50	.25	.21	.21
Land	.10	.08	.21	.03	.25	.02	.10
Livestock	.35	.25	.02	.30	.17	.32	.30
Fertilizer	.1	.13	.11	.15	.18	-.007	-.02
Machinery	.1		.08	.06	.21	.063	.07
Infrastructure[b]		.19				.04	.08
Research	.1				-.02	.09	.09

Source: Hayami and Ruttan (1985), Antle (1982), Mundlak and Helinghausen (1982), Fulginiti and Perrin (1993).
OlS represent ordinary least squares.
Mundlack-Hellinghausen, Fulginiti-Perrin, and current study employ variable-coefficient models.
[a] Model 3: communications = radios; research = five-year lag; Model 4: communications = roads; research = five-year lag.
[b] Antle study uses a communication and transportation variable. Current study uses a roads and radio variable in separate estimations.

variables using model 3 and 4. These models are used for comparison with other studies because the use of a lagged research variable is consistent with the measurement of research in previous studies. This study's estimates of the overall production elasticity for labor were smaller than the average of previous estimates.

However, the estimates were very close to that of Fulginiti and Perrin, who also used a variable coefficient model. The estimates of the land elasticities were lower than the average of previous estimates. The estimates of the output elasticity for livestock were also higher than the average of past estimates. The estimates of the fertilizer elasticity were below past estimates, and the sign was negative, although the variable was not statistically significant. The estimates of machinery were consistent with past estimates.

The elasticity estimates for infrastructure in models 3 and 4 were smaller than those calculated in Antle's (1982) study. Antle's communications variable included measures of communication and transportation expenditures. This thesis estimated the effects of roads and radios in separate models in order to reduce the number of independent variables in each model. The production elasticity for infrastructure in model 3 was approximately half of that in model 4, indicating that increased roads have a greater impact on agricultural production than do radios. The estimate of the production elasticity for agricultural research in models 3 and 4 were higher than that of Fulginiti and Perrin (1993), but very close to that of Evenson and Kislev (table 4.5). Differences in this study's estimates and those of previous studies are likely to reflect data differences that result from definition, time periods, and countries used.

IV.7 Summary of the Results

The production elasticities of the traditional inputs were, with the exception of fertilizer, positive as expected. Moreover, in all models, except for machinery, fertilizer, and primary-secondary education, these variables were statistically significant at the 5% level. The state variables- research, radios, and roads- were also jointly significant at that level with positive overall elasticities of production. Increases in the research variable were associated with labor-saving technical change in all four models. The results of the research hypotheses indicated that only models 2 and 4 could be used to analyze the influence of communications on non-neutral changes in the research-induced bias. Radios had no statistically significant influence on this bias. The test of this influence indicated that higher levels of roads were associated with increased labor-saving technical change. Comparisons were not made between countries with relatively higher labor-intensity and those with lower levels of labor-intensity because this variable was found to be non-significant at the 5% level. The estimates of the elasticities of production for the traditional inputs, research, and communications were reasonably consistent with previous studies. The following chapter discusses the implications of these findings.

Chapter V

Summary and Conclusions

V.1 Introduction

This chapter summarizes the major objectives and results of this study. Then, the conclusions are drawn, based on those results. Finally, policy implications are discussed and recommendations for future studies are made.

V.2 Summary of Objectives and Results

The theoretical role of communications infrastructure in facilitating growth in agricultural production is widely accepted. However, studies empirically verifying the importance of such infrastructure are sparse. This study set out to identify the importance of communications in facilitating increases in agricultural production. Communications were hypothesized to lower transactions costs associated with acquiring information, increase the efficient use of current technologies, and improve the capacity to adopt new technologies. Increased levels of communications were postulated to influence the research agenda by improving and expanding all farmers' interactions with the agricultural research system. Hence, increased levels of communications were hypothesized to be associated with research-induced technical change that saved the relatively scarcest resource, land or labor.

A variable-coefficient Cobb-Douglas meta-production function was specified in a manner that allowed changes in the production coefficients of land and labor to be influenced by levels of 'state variables'. The state variables in this study included radios, roads, research expenditures, and the relative labor intensity. The production function was estimated using time series cross-sectional data for 50 countries.

Both radios and roads had positive production elasticities. This result confirms the first testable hypothesis: higher levels of communication increase the level of agricultural production. On average, the roads variable had a greater impact on agricultural production than radios. The second testable hypothesis was: increases in communications influence technical change in agriculture in a direction that saves the relatively scarcest resource, land or labor. This second hypothesis was neither confirmed nor rejected by this study. The results indicate the following: (a) increased expenditures on research lead to technical change that is labor-saving; (b) increased numbers of radios per habitant does not affect the direction of the research-induced bias; (c) increased levels of roads significantly affect the bias associated with research; and increases in the levels of roads are associated with an increase in the labor-saving bias associated with higher levels of research expenditures; and (d) relative land/labor intensity in a country's agricultural sector does not have a significant effect either on agricultural production, or on the bias of research.

V.3 Conclusions

The major conclusions of this thesis are as follows. First, radios and roads increase the level of agricultural production in developing countries. This influence may be caused by the effect that communications infrastructure has on reducing information costs, and, in the case or roads, reducing transportation costs. Second, radios do not significantly affect the interactions between farmers and researchers in a manner that influences the bias of research-induced technical change. Finally, roads do significantly influence the types of technologies developed; this influence increases the already labor-saving bias of research.

One plausible explanation for radios' inability to influence the bias associated with research is the nature of the media. Radios are typically characterized by one-directional flows of information from the broadcaster to the receiver, or, in this study, farmers. Therefore, radios do not provide a feedback mechanism which enable farmers to interact with researchers. On the other hand, road infrastructure does facilitates two-way communication. Hence, the results of this study which indicate that increases in roads are associated with changes in the bias that results from research.

Increases in the levels of roads were associated with an increase in the labor-saving bias caused by increased research expenditures. Increased levels of roads are likely to be associated with higher rates of rural to urban migration. Hence, wages or expectations concerning the changes in wages, may increase. This increase might induce farmers to increase lobbying pressure on the research institution to develop labor-saving technologies.

Because the dummy variable, specified to represent differences in relative labor intensity, was not significant in any of the models, the role of communications in guiding technical change along a growth path that differs according to relative labor intensity could not be assessed. The lack of statistical significance of the labor-intensity dummy variable may stem from the inability of relative labor to land ratios to accurately represent factor prices. Without price information on land and labor it is difficult to assess the degree of scarcity of land and labor. For example, a country with a relatively high ratio of labor to land was assumed in this study to face lower labor to land price ratios than a country with a relatively lower labor to land ratio. However, the organization of labor in one country may lead to higher wages or expected higher wages than that suggested by relative scarcity. Other factors could influence factor prices also; land to labor ratios are probably poor proxies for these prices. Where factor prices are greatly influenced by phenomena other than relative scarcity, technical change will be induced by relative prices of land and labor which may not reflect changes expected from relative land to labor ratios.

A second explanation of why the labor-intensity dummy variable was non-significant may be that the induced innovation phenomena is not a good explanation of inter-country differences in technical change in developing countries. Research institutions and markets in these countries may be less responsive to changes in relative resource scarcity than those in developed countries.

V.4 Policy Implications

Increasing the accessibility of radios and road infrastructure facilitates increases in agricultural production. Increasing the information content towards the targeted needs of farmers is likely to augment the influence of radios on agricultural production. Increased levels of access to radios decrease the costs of acquiring information. Increased use of radios may not decrease the costs of collective lobbying and, therefore, may not influence the types of technologies developed by researchers. Because of this, information transmitted via radios may need to address organizational issues (i.e. town meetings, the location of extension groups) which facilitate collective action and promote increased interactions between farmers and researchers. In summary the distribution and the information content of radios should be carefully targeted, to ensure that farmers receive, understand, and are able to implement the information.

Higher levels of road infrastructure also encourage increases in agricultural production. Road infrastructure may facilitate interactions between groups in different locations. Hence, policy makers should carefully consider where future roads are located. For example, roads might be designed to connect rural farmers with each other, in order to promote collective lobbying among farmers and stimulate interpersonal means of information exchange.

V.5 Suggestions for Future Research

An important conceptual issue, indirectly touched upon in the current study, involves the need for institutional change. One formal institution of theoretical importance to this thesis is the size and distribution of farm holdings within a country. A great deal of literature, discussed in chapters 1 and 2, asserted that the greater the inequity in farm distribution, the greater the tendency for labor-saving bias. Analyzing the influence of communications on the land inequality-induced bias would be informative. Such a study might shed light on which farmers have access to and can implement the benefits of communications infrastructure. Unfortunately, data on the distribution of farm holdings is difficult to obtain for many developing countries. Hence, this study did not include a farm distribution variable.

Future studies may compare differences in the roles of communications infrastructure on agricultural production in countries with privately-owned media infrastructure and those with publicly-owned infrastructure. Although roads are almost universally publicly owned, radio message content may vary by the structure of ownership. Such a study requires more information on ownership of the communications systems in developing countries. Inferences from such a study might indicate what types of ownership structure increase the productive impact of radios.

At the micro level, studies that analyze the content of media are needed. Before the exact nature of media infrastructure's impact on aggregate production can be assessed, some definition of message quality. For example, it may be that radios should be weighted differently across different countries, regions, or localities, depending on the quality of message disseminated through communications infrastructure. Such studies are important to determine: (a) how communications infrastructure affects certain areas (i.e. rural or urban), and (b) lend support or criticism of aggregate studies which implicitly impose the same quality specification on the communications variable.

The current study indicated that roads have an impact on production levels, and an influence on the research-induced bias of technical change. Such a result indicates that roads facilitate some level of interaction between farmers and the research institutions. However, it is difficult to distinguish the overall productivity effects of roads between the communication and transportation components of road infrastructure. Studies should be initiated to analyze road infrastructure's influence on an economy, monitoring both the communications and transportation effects.

Finally, the distribution of radios and roads in a particular country may have a profound influence on increases in agricultural production and the types of technologies adopted. For example, radios may or not be as accessible to small farm holders as they are to owners of large farms. The location of road infrastructure is likely to be important. Farmers with access to roads will face lower transportation costs and are likely to have greater contact with researchers.

In the final analysis, the role of communications infrastructure in agricultural production is determined by the farmers who have access to it, the information that is transmitted, and the ability of farmers to influence and transform that information into their agricultural practices. This study suggest that communications plays a positive role in agricultural production; understanding why, requires detailed micro analysis.

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Appendix- Data Included in the Production Function Model

Definition of variables:

Research =	res
Agricultural gross domestic output =	aggdp
Primary and secondary education =	educ1
Post high-school education =	educ2
Fertilizer =	fert
Labor =	labor
Livestock =	ls
Machinery =	mach
Land quality =	lq
Land =	land
Year =	year
roads =	roads
radios =	radios

For a complete definition of variables and sources see Table 3.1 (p.46).

Table A.1- Data for year of 1970.

COUNTRY	RES	aggdp	educ1	educ2	fert	labor	ls	mech	lq	land	year	roads	radios
ARGENTINA	66.60	8839276.00	4362769	274634	87.036	1495400.00	48825800.00	6300000	52.00	177133	1970.00	7.72	376.00
BANGLADESH	34.60	18965118.46	6979624	117603	143.2	16700900.00	24787210.00	45500	171.00	9697	1970.00	4.66	15.00
BARBADOS	1.30	92155.02	58317	763	5.7	16400.00	36820.00	14525	134.00	37	1970.00	381.86	372.00
BENIN	5.09	524079.18	196029	311	5.7	1175100.00	828920.00	2730	115.00	2194	1970.00	6.73	31.00
BOLIVIA	4.60	1015192.34	768754	35250	1.545	736100.00	3882270.00	40250	58.00	30544	1970.00	3.78	93.00
BOTSWANA	1.60	216654.17	88199	250	1.7	203000.00	1523230.00	56000	34.00	44928	1970.00	2.31	32.00
CAMEROON	2.90	1316586.70	999695	2690	20.255	2587900.00	2215720.00	1540	105.00	14678	1970.00	11.12	25.00
CHILE	19.56	2746974.93	2341249	78430	152.817	686300.00	4032120.00	1067500	97.00	16829	1970.00	10.55	148.00
COLOMBIA	46.70	8373630.74	4036107	85560	144.384	2446600.00	18502770.00	975520	92.00	35346	1970.00	7.20	107.00
COSTARICA	3.00	943127.00	410446	15473	49.365	225800.00	1380050.00	192500	101.00	2125	1970.00	56.08	75.00
CYPRUS	2.06	306153.90	111465	698	27.447	99000.00	204470.00	216370	78.00	526	1970.00	97.03	150.00
DOMINICANREPU	2.00	1494458.25	899655	23546	37.881	633400.00	1650280.00	147000	116.00	3334	1970.00	35.39	150.00
ECUADOR	8.76	1782402.00	1233210	38692	34.098	949400.00	2976910.00	98000	106.00	5331	1970.00	13.07	281.00
EGYPT	22.00	5822883.10	5243153	233304	372.893	4765200.00	5578150.00	612500	93.00	2812	1970.00	9.04	133.00
ELSALVADOR	3.00	1379526.33	619616	9515	64.987	662200.00	1248340.00	71750	117.00	1266	1970.00	58.62	163.00
ETHIOPIA	3.52	5197321.41	790590	4543	5.3	12236800.00	31848920.00	42000	64.00	59441	1970.00	3.59	20.00
FIJI	2.00	290956.96	138883	442	5.947	79100.00	147450.00	43750	138.00	293	1970.00	23.51	400.00
GHANA	7.30	3096276.03	1519137	5426	3.343	2008600.00	1184050.00	94500	102.00	6173	1970.00	12.30	82.00
GUATEMALA	2.00	2236236.60	581165	15609	46.312	972900.00	1772620.00	110250	127.00	2808	1970.00	15.97	42.00
INDIA	204.00	115373564.14	77159745	1761800	2177.307	160622000.00	211612020.00	2205000	155.00	180593	1970.00	52.27	9.50
INDONESIA	50.00	26103391.80	17330095	248220	240.193	30261600.00	11107710.00	297500	155.00	31587	1970.00	11.99	21.00
IVORYCOAST	21.00	2259206.07	572579	4381	21.196	2104200.00	589320.00	49420	109.00	6472	1970.00	17.30	14.00
JORDAN	1.30	305202.70	375231	4518	2.727	162300.00	324170.00	96530	38.00	1174	1970.00	6.14	200.00
KENYA	20.91	2102879.51	1563619	7795	49.5	4198700.00	8121320.00	229250	69.00	6021	1970.00	9.61	20.00
LIBERIA	0.44	145157.72	137016	1109	2.3	433900.00	91160.00	5600	122.00	604	1970.00	5.62	143.00
MALAWI	3.80	507089.26	374288	980	10.999	1957900.00	575520.00	29750	90.00	4097	1970.00	12.98	23.00
MALAYSIA	30.00	4933978.59	2293639	17386	192.973	1986900.00	1148450.00	162120	170.00	4209	1970.00	15.14	55.00
MAURITIUS	4.45	125881.33	194371	1975	21.996	87800.00	55070.00	9905	174.00	112	1970.00	98.16	100.00
MEXICO	12.20	17947383.18	10832632	247637	537.721	6390800.00	36754270.00	3220000	78.00	97243	1970.00	11.13	109.00
MOROCCO	10.00	3295110.99	1474157	620	87.8	2333100.00	7431020.00	542500	49.00	20167	1970.00	12.92	61.00
NEPAL	7.00	4392649.90	505439	20000	5.359	4813300.00	9193920.00	12530	123.00	4099	1970.00	4.61	5.00
NIGER	2.40	842585.77	95593	300	0.123	2238800.00	5259620.00	560	39.00	12702	1970.00	2.21	35.00
NIGERIA	50.00	19601108.31	3872392	15560	6.894	16771000.00	14094320.00	33250	121.00	50489	1970.00	11.86	22.00
PAKISTAN	9.22	16228011.89	5455365	114980	283.206	11375700.00	31798310.00	350000	87.00	24516	1970.00	14.14	44.00
PANAMA	1.00	388519.41	347732	9403	21	213900.00	1187340.00	59500	103.00	1713	1970.00	12.76	140.00
PARAGUAY	1.00	906791.34	479956	8172	9.001	390100.00	5374270.00	77000	78.00	16303	1970.00	2.85	60.00
PERU	20.70	3570607.91	2887283	126234	84.3	1820700.00	6988300.00	384160	81.00	30286	1970.00	5.29	132.00
PHILIPPINES	36.32	10637415.43	8688364	651514	201.152	7525800.00	8037020.00	189000	166.00	8198	1970.00	52.93	40.00
RWANDA	1.30	600806.47	429318	571	0.2	1842700.00	671620.00	630	91.00	1505	1970.00	48.38	8.00
SENEGAL	15.33	840055.15	322329	4962	7.915	1579400.00	2804020.00	17150	69.00	10690	1970.00	7.81	60.00
SRILANKA	14.71	3484013.72	2612750	10000	105.1	2402800.00	2163990.00	280000	175.00	2498	1970.00	235.44	25.00
SUDAN	12.15	3667592.03	958246	14308	33.007	3600600.00	17407420.00	147000	50.00	67719	1970.00	2.02	60.00
SWAZILAND	0.65	86012.65	77493	139	6.023	160600.00	507210.00	43050	91.00	1385	1970.00	16.03	71.00
TANZANIA	14.38	2115819.45	901154	2027	15	6485600.00	11633060.00	192500	68.00	39703	1970.00	9.24	11.00
TURKEY	48.00	15707019.25	6320705	169793	43.075	11361300.00	20761790.00	3654000	76.00	37747	1970.00	7.67	70.00
URUGUAY	2.00	1179546.37	528396	30000	69.278	206100.00	9408670.00	889000	72.00	15020	1970.00	6.91	356.00
VENEZUELA	44.00	3576106.00	2194826	100767	59.47	798100.00	8188260.00	672000	78.00	20388	1970.00	11.40	361.00
ZAIRE	6.20	2292373.02	3336329	12363	4.7	6863500.00	1167120.00	37170	102.00	15251	1970.00	6.39	32.00
ZAMBIA	2.30	486052.80	750852	1433	36.199	1121900.00	1353720.00	94500	64.00	39775	1970.00	5.04	18.00
ZIMBABWE	11.33	656137.31	841948	500	127	1738600.00	3515580.00	595000	61.00	7400.00	1970.00	22.19	27.00

Table A.1- Data for year of 1975.

COUNTRY	RES	aggdp	educ1	educ2	fert	labor	ls	mach	lq	land	year	roads	radios
ARGENTINA	63.60	10042941.28	4814238	596736	60.00	1435300.00	55608000.00	7050000	52	176147	1975.00	7.72	380.00
BANGLADESH	34.60	20127463.42	10792676	158604	215.00	17615300.00	23387040.00	131250	174	9631	1975.00	4.66	20.00
BARBADOS	1.90	73710.30	61909	2000	4.00	15000.00	40120.00	18000	132	37	1975.00	381.86	400.00
BENIN	4.90	530620.40	307308	1900	2.00	1202700.00	832520.00	3300	115	2208	1975.00	6.73	49.00
BOLIVIA	3.60	1324774.89	989442	49850	3.00	770400.00	4631480.00	28463	58	29919	1975.00	3.78	235.00
BOTSWANA	1.41	185665.70	130579	289	2.00	217000.00	1794120.00	69375	34	44800	1975.00	2.31	76.00
CAMEROON	2.90	1681059.13	1266712	6130	13.00	2564400.00	2756620.00	10500	105	15107	1975.00	11.12	31.00
CHILE	19.56	2966390.32	2747909	149647	99.00	655900.00	4344520.00	1050000	95	17156	1975.00	10.55	164.00
COLOMBIA	46.79	10311413.53	5281811	176098	215.00	2594100.00	22005220.00	907013	91	35154	1975.00	7.20	121.00
COSTARICA	4.00	1107741.31	472841	33239	66.00	233200.00	1645220.00	211875	100	2573	1975.00	56.08	77.00
CYPRUS	2.20	227427.93	105975	602	15.00	88700.00	195950.00	367500	77	519	1975.00	97.03	200.00
DOMINICANREPU	2.70	1800111.67	1119942	41352	73.00	672900.00	2168310.00	105000	109	3470	1975.00	35.39	156.00
ECUADOR	22.00	2192472.13	1599857	170173	33.00	951000.00	3643390.00	225000	104	6111	1975.00	13.07	285.00
EGYPT	26.40	7532165.88	6289089	408235	501.00	4902300.00	5887310.00	806250	92	2411	1975.00	9.04	141.00
ELSALVADOR	3.90	1756363.87	811191	28281	94.00	675900.00	1043640.00	108750	118	1321	1975.00	58.62	266.00
ETHIOPIA	5.90	5106139.47	1315215	6474	31.00	13109100.00	32270420.00	135000	63	58727	1975.00	3.59	29.00
FIJI	2.60	328276.50	165516	1653	12.00	87800.00	192890.00	53625	137	294	1975.00	23.51	450.00
GHANA	4.58	2770319.00	1712738	8022	25.00	2177300.00	1297450.00	120000	102	6188	1975.00	12.30	108.00
GUATEMALA	6.86	3011954.42	726359	22881	55.00	1048400.00	2281220.00	138750	122	3061	1975.00	15.97	44.00
INDIA	279.00	134718068.98	89298688	4615992	2509.00	172236800.00	220436420.00	8537550	155	179784	1975.00	52.27	17.80
INDONESIA	76.70	31238054.17	21346697	278200	489.00	31202500.00	10771110.00	393750	156	31254	1975.00	11.99	37.00
IVORYCOAST	25.00	2810555.71	792189	7174	38.00	2234000.00	748920.00	82500	113	6828	1975.00	17.30	44.00
JORDAN	1.89	373263.77	550198	11873	6.00	120500.00	362430.00	140550	38	1171	1975.00	6.14	250.00
KENYA	26.50	2417368.93	3122124	11351	44.00	4883600.00	7536220.00	225488	69	5975	1975.00	9.61	29.00
LIBERIA	0.85	175719.44	191972	2404	5.00	482800.00	105610.00	9375	120	606	1975.00	5.62	167.00
MALAWI	3.44	641814.56	658506	1153	15.00	2072100.00	711720.00	36375	90	4117	1975.00	12.98	33.00
MALAYSIA	86.06	7772558.46	1940254	36246	248.00	2125300.00	1393140.00	272625	169	4295	1975.00	15.14	115.00
MAURITIUS	4.30	148381.28	215686	1321	24.00	86800.00	64670.00	11250	172	113	1975.00	98.16	150.00
MEXICO	63.38	20816897.17	14400387	562056	1073.00	7226000.00	40062520.00	3750000	81	96482	1975.00	11.13	115.00
MOROCCO	16.88	3190138.50	2033820	1921	166.00	2398900.00	7111820.00	750000	49	20011	1975.00	12.92	81.00
NEPAL	9.52	5053708.77	824340	23504	12.00	5213400.00	9871920.00	16875	129	4070	1975.00	4.61	9.00
NIGER	1.85	670602.74	156644	541	1.00	2400400.00	3589920.00	2550	38	13037	1975.00	2.21	40.00
NIGERIA	85.00	17300076.87	6805081	44964	54.00	19046800.00	13688820.00	281250	119	50649	1975.00	11.86	74.00
PAKISTAN	35.39	17973908.19	7172052	127932	554.00	12468200.00	28401540.00	1339275	88	24956	1975.00	14.14	54.00
PANAMA	1.02	412756.77	472826	26289	25.00	211900.00	1323410.00	138750	102	1713	1975.00	12.76	149.00
PARAGUAY	1.35	1291915.92	527673	18302	1.00	446100.00	4731670.00	101250	78	17361	1975.00	2.85	67.00
PERU	21.17	3448164.53	3654114	195641	104.00	1976600.00	7011210.00	468750	75	30154	1975.00	5.29	135.00
PHILIPPINES	35.20	13196363.16	9888986	769749	227.00	8430000.00	9735490.00	453750	167	8723	1975.00	52.93	42.00
RWANDA	1.40	706709.30	413567	1108	0.60	2119600.00	664550.00	3000	100	1428	1975.00	48.38	15.00
SENEGAL	12.57	934194.59	389685	8213	47.00	1832800.00	2573520.00	13875	69	10872	1975.00	7.81	63.00
SRILANKA	12.19	3747850.87	2455949	15426	72.00	2592500.00	2313680.00	584100	173	2568	1975.00	235.44	51.00
SUDAN	9.60	4301355.38	1451118	21342	95.00	3946500.00	18032920.00	330000	51	67275	1975.00	2.02	72.00
SWAZILAND	0.24	105535.66	106395	1012	9.00	169700.00	552770.00	72563	95	1283	1975.00	16.03	114.00
TANZANIA	18.21	2403207.75	1655394	3064	30.00	7238600.00	12205510.00	251250	68	39562	1975.00	9.24	15.00
TURKEY	68.28	20443139.28	7209844	327082	891.00	11426400.00	20519460.00	9092100	76	37869	1975.00	7.67	100.00
URUGUAY	5.21	1107239.03	509954	32627	47.00	189600.00	11372180.00	1031250	71	14962	1975.00	6.91	530.00
VENEZUELA	45.85	3638581.26	2777551	213542	140.00	815200.00	9023790.00	997500	77	20746	1975.00	11.40	377.00
ZAIRE	6.00	2626682.57	4055979	24853	11.00	7161800.00	1487420.00	46875	102	15362	1975.00	6.39	45.00
ZAMBIA	4.31	590774.50	950258	8403	53.00	1246200.00	1629230.00	153750	63	39463	1975.00	5.04	21.00
ZIMBABWE	14.02	845559.17	932741	2000	147.00	1933300.00	5285980.00	712500	61	7400.00	1975.00	22.19	29.00

Table A.1- Data for year of 1980.

COUNTRY	RES	aggdp	educ1	educ2	fert	labor	ls	mech	lq	land	year	roads	radios
ARGENTINA	86.56	10567208.64	5283893	491473	116.00	1343800.00	52785600.00	6668000	52	178738	1980.00	7.72	420.00
BANGLADESH	77.79	22310561.01	10603075	240181	417.00	18802000.00	30171210.00	164000	175	9729	1980.00	4.66	30.00
BARBADOS	1.81	97607.25	59965	4033	6.00	11600.00	41640.00	22000	131	37	1980.00	381.86	542.00
BENIN	2.84	815056.16	469895	4822	1.00	1246500.00	944020.00	4200	115	2293	1980.00	6.73	66.00
BOLIVIA	4.50	1492833.99	1148960	60000	3.00	807500.00	5873750.00	30000	59	30165	1980.00	3.78	503.00
BOTSWANA	5.23	156592.65	192883	928	1.00	225600.00	2575650.00	86000	34	45696	1980.00	2.31	100.00
CAMEROON	7.06	2185541.32	1613295	11686	36.00	2527900.00	3401320.00	22880	106	15259	1980.00	11.12	88.00
CHILE	25.18	3427195.51	2723768	145497	132.00	619300.00	4597320.00	1384000	94	17530	1980.00	10.55	292.00
COLOMBIA	36.74	12794221.84	5979203	271630	312.00	2736100.00	23436520.00	1136920	92	35670	1980.00	7.20	128.00
COSTARICA	4.13	1211425.68	484504	55593	74.00	239200.00	1972020.00	238000	103	2894	1980.00	56.08	79.00
CYPRUS	3.08	263917.68	96300	1940	15.00	76200.00	228180.00	432000	77	526	1980.00	97.03	259.00
DOMINICANREPU	3.47	2179024.93	1461821	45000	52.00	717800.00	2299730.00	126000	111	3574	1980.00	35.39	162.00
ECUADOR	18.04	2402159.24	2126227	269775	73.00	940400.00	3688720.00	247920	100	7391	1980.00	13.07	289.00
EGYPT	31.82	7989089.89	7591984	715701	664.00	5157900.00	6153740.00	1000000	92	2502	1980.00	9.04	145.00
ELSALVADOR	4.45	1880925.29	907131	16838	60.00	684600.00	1407820.00	132000	134	1341	1980.00	58.62	323.00
ETHIOPIA	9.59	5361225.00	2556993	14368	43.00	14040000.00	32542620.00	158000	63	58825	1980.00	3.59	78.00
FIJI	4.35	396049.25	166102	1814	16.00	95200.00	181570.00	62400	137	300	1980.00	23.51	477.00
GHANA	3.63	3243621.16	2085280	16350	12.00	2430100.00	1370920.00	140000	101	6222	1980.00	12.30	147.00
GUATEMALA	7.65	3522670.03	960016	30000	86.00	1118000.00	1847820.00	160000	120	3166	1980.00	15.97	45.00
INDIA	444.18	141679537.24	102025294	5345580	5231.00	185017000.00	225008020.00	16724640	158	178105	1980.00	52.27	38.00
INDONESIA	122.93	38672599.22	31258868	565501	1173.00	32180000.00	10973770.00	520000	160	32846	1980.00	11.99	99.00
IVORYCOAST	28.00	2560178.92	1263093	19663	53.00	2313800.00	978920.00	124000	115	7084	1980.00	17.30	122.00
JORDAN	1.86	382888.52	720821	36549	14.00	65900.00	504960.00	180800	38	1201	1980.00	6.14	300.00
KENYA	31.82	3028252.59	4354652	12986	62.00	5728900.00	10535820.00	261840	69	6107	1980.00	9.61	32.00
LIBERIA	5.00	220864.01	282054	3789	3.00	539300.00	123710.00	12000	120	610	1980.00	5.62	179.00
MALAWI	4.19	791371.12	828515	3476	33.00	2252600.00	853860.00	48000	90	4240	1980.00	12.98	46.00
MALAYSIA	90.67	9725760.21	3017702	57650	453.00	2219500.00	1434690.00	322000	168	4414	1980.00	15.14	419.00
MAURITIUS	5.00	149261.24	210684	1038	27.00	92500.00	73570.00	13000	172	114	1980.00	98.16	200.00
MEXICO	126.27	25107689.03	19408107	897726	1238.00	8127900.00	42649000.00	4800000	83	98864	1980.00	11.13	130.00
MOROCCO	26.01	4140039.21	2977305	112405	259.00	2594400.00	7487020.00	980000	50	29331	1980.00	12.92	155.00
NEPAL	11.49	4152498.29	1580346	38450	22.00	5707100.00	10500920.00	20800	147	4315	1980.00	4.61	20.00
NIGER	2.75	1045067.91	267716	1435	3.00	2609400.00	4618820.00	7200	40	12805	1980.00	2.21	47.00
NIGERIA	106.12	15109887.84	16105634	150072	174.00	21865600.00	15660720.00	344000	121	52267	1980.00	11.86	87.00
PAKISTAN	48.52	20639279.66	7603410	156558	1080.00	13874800.00	33273440.00	1840000	90	25556	1980.00	14.14	64.00
PANAMA	5.15	464280.54	508795	40369	31.00	208900.00	1484830.00	160000	103	1726	1980.00	12.76	153.00
PARAGUAY	4.11	1738902.23	637796	26915	6.00	508900.00	4967140.00	128000	78	17620	1980.00	2.85	71.00
PERU	8.24	3456525.68	4364491	306353	118.00	2151500.00	6818220.00	556000	74	30868	1980.00	5.29	159.00
PHILIPPINES	28.70	17407973.79	10962167	1276016	334.00	9075700.00	8974000.00	680000	167	9087	1980.00	52.93	43.00
RWANDA	1.60	893430.75	715591	1243	1.00	2478500.00	661340.00	3360	105	1432	1980.00	48.38	29.00
SENEGAL	10.41	791478.87	515352	13560	19.00	2127900.00	3040520.00	18400	69	10909	1980.00	7.81	33.00
SRILANKA	19.49	4628183.02	3348714	42694	165.00	2911600.00	2273060.00	970520	174	2645	1980.00	235.44	98.00
SUDAN	18.12	4281535.65	1848421	28778	81.00	4330500.00	21309420.00	440000	51	68571	1980.00	2.02	187.00
SWAZILAND	0.91	137385.50	135684	1875	20.00	181600.00	585020.00	106000	91	1269	1980.00	16.03	145.00
TANZANIA	21.00	2709219.68	3446359	4000	36.00	8139500.00	11461410.00	744000	69	40509	1980.00	9.24	27.00
TURKEY	45.93	22362952.12	7966607	246183	1456.00	11145500.00	22770440.00	17411240	76	36616	1980.00	7.67	110.00
URUGUAY	4.66	1257403.64	479541	36298	81.00	178400.00	11467280.00	1128000	72	15211	1980.00	6.91	561.00
VENEZUELA	45.80	3914630.83	3380733	307133	241.00	793400.00	10467920.00	1520000	77	21344	1980.00	11.40	397.00
ZAIRE	5.00	2027302.44	5402811	28493	8.00	7460200.00	1566810.00	76000	102	15890	1980.00	6.39	58.00
ZAMBIA	4.48	591203.41	1143957	7541	79.00	1397600.00	1941420.00	184000	63	40402	1980.00	5.04	24.00
ZIMBABWE	17.33	841846.30	1309782	2000	173.00	2169400.00	4406100.00	808000	63	7400.00	1980.00	22.19	33.00

Table A.1- Data for year of 1985.

COUNTRY	RES	aggdp	educ1	educ2	fert	labor	ls	mech	lq	land	year	roads	radios
ARGENTINA	63.68	11837638.38	6389340	846145	155.00	1267000.00	50923200.00	8670000	51	178738	1985.00	7.72	645.00
BANGLADESH	65.10	25563733.96	12045512	436615	541.00	20703900.00	22258110.00	208250	179	9729	1985.00	4.66	40.00
BARBADOS	2.07	89337.94	58856	5227	7.00	10200.00	47720.00	24863	128	37	1985.00	381.86	863.00
BENIN	1.74	829446.73	564814	6818	9.00	1295200.00	1282820.00	4930	112	2293	1985.00	6.73	74.00
BOLIVIA	2.22	1417137.34	1381190	60000	6.00	872900.00	6913950.00	33150	58	30165	1985.00	3.78	587.00
BOTSWANA	6.47	108316.34	256968	1773	1.00	254300.00	2177120.00	91588	33	45696	1985.00	2.31	122.00
CAMEROON	23.78	2608359.70	1962851	17741	57.00	2597100.00	4233720.00	37400	104	15259	1985.00	11.12	123.00
CHILE	28.00	3891699.28	2682985	196937	216.00	614500.00	4294520.00	1459450	91	17530	1985.00	10.55	335.00
COLOMBIA	62.82	13657022.73	5973565	389075	366.00	2834500.00	22827320.00	1228250	90	35670	1985.00	7.20	153.00
COSTARICA	1.50	1348884.92	468070	60288	81.00	245300.00	2212620.00	263500	110	2894	1985.00	56.08	263.00
CYPRUS	4.00	282026.32	95927	2580	18.00	72200.00	241880.00	565930	75	526	1985.00	97.03	289.00
DOMINICANREPU	4.70	2387869.00	1501849	45000	61.00	755300.00	2516830.00	95625	111	3574	1985.00	35.39	164.00
ECUADOR	12.04	2724764.13	2227827	280594	72.00	974600.00	4983020.00	331500	94	7391	1985.00	13.07	295.00
EGYPT	38.33	9453740.17	8551282	873565	864.00	5526400.00	7743000.00	1827500	89	2502	1985.00	9.04	313.00
ELSALVADOR	4.40	1661185.47	968410	57374	85.00	737300.00	1031920.00	144075	131	1341	1985.00	58.62	349.00
ETHIOPIA	13.71	5020623.83	3080897	16030	66.00	14826800.00	32755820.00	165750	62	58825	1985.00	3.59	186.00
FIJI	5.78	403778.73	170413	2299	9.00	97500.00	204610.00	201875	135	300	1985.00	23.51	568.00
GHANA	3.00	3302167.85	2215718	20000	13.00	2625300.00	1540520.00	159375	100	6222	1985.00	12.30	189.00
GUATEMALA	6.81	3424141.91	1154541	40000	95.00	1221400.00	2340920.00	174250	119	3166	1985.00	15.97	61.00
INDIA	471.42	160354176.75	114751900	5500000	8498.00	199765300.00	253452020.00	25830353	156	178105	1985.00	52.27	78.00
INDONESIA	138.59	47135465.01	37355105	980162	1977.00	33521900.00	14950810.00	511403	168	32846	1985.00	11.99	118.00
IVORYCOAST	26.54	2791012.77	1602265	18772	48.00	2453600.00	1057320.00	140250	114	7084	1985.00	17.30	133.00
JORDAN	1.43	436946.34	836656	56253	15.00	62700.00	568710.00	218875	38	1201	1985.00	6.14	400.00
KENYA	20.00	3510040.71	4906588	22157	100.00	6633500.00	8804020.00	297500	68	6107	1985.00	9.61	84.00
LIBERIA	5.15	185719.96	413058	4500	4.00	584000.00	153410.00	13388	118	610	1985.00	5.62	225.00
MALAWI	5.39	944715.85	924302	3884	27.00	2444400.00	952420.00	56525	88	4240	1985.00	12.98	251.00
MALAYSIA	120.00	11376012.28	3490790	93249	509.00	2266200.00	1806690.00	484500	164	4414	1985.00	15.14	731.00
MAURITIUS	5.52	227394.78	210186	794	28.00	98400.00	82870.00	14535	169	114	1985.00	98.16	260.00
MEXICO	109.04	28979209.09	21283509	1071676	1714.00	8656100.00	44433500.00	6672500	80	98864	1985.00	11.13	177.00
MOROCCO	31.72	4190568.09	3408919	126897	299.00	2746000.00	6464420.00	1317500	45	29331	1985.00	12.92	205.00
NEPAL	10.00	4859252.55	2203258	48229	43.00	6345500.00	8873620.00	119850	150	4315	1985.00	4.61	30.00
NIGER	1.64	936361.69	308719	2863	4.00	2861100.00	5228620.00	7225	40	12805	1985.00	2.21	56.00
NIGERIA	78.00	15779074.05	17944694	181945	336.00	24316200.00	16074420.00	437750	120	52267	1985.00	11.86	162.00
PAKISTAN	50.00	24875786.55	8814121	160000	1511.00	15538600.00	36685110.00	6656903	90	25556	1985.00	14.14	97.00
PANAMA	5.72	543980.55	520875	52224	26.00	215000.00	1443930.00	178500	101	1726	1985.00	12.76	184.00
PARAGUAY	12.00	2076822.35	709646	33203	11.00	577400.00	6356560.00	403750	77	17620	1985.00	2.85	165.00
PERU	24.75	4062840.41	5138853	300000	74.00	2315300.00	6843120.00	777750	71	30868	1985.00	5.29	247.00
PHILIPPINES	23.16	19138814.84	12117275	1300000	283.00	9781500.00	7986700.00	828750	165	9087	1985.00	52.93	134.00
RWANDA	2.20	883883.31	776716	1705	1.00	2820500.00	692920.00	3613	105	1432	1985.00	48.38	57.00
SENEGAL	17.30	925253.52	646955	11809	29.00	2304300.00	2617620.00	19550	68	10909	1985.00	7.81	109.00
SRILANKA	24.00	5512748.18	3539096	63460	195.00	3109300.00	2540260.00	1163395	174	2645	1985.00	235.44	167.00
SUDAN	11.19	3779885.11	2106387	35648	93.00	4605900.00	24357520.00	765000	50	68571	1985.00	2.02	253.00
SWAZILAND	4.00	157347.64	164080	1063	8.00	192200.00	561620.00	161500	94	1269	1985.00	16.03	157.00
TANZANIA	16.59	2855542.72	3634710	5000	39.00	9097500.00	12728310.00	788375	67	40509	1985.00	9.24	86.00
TURKEY	55.00	25268293.05	9054825	417225	1482.00	11384800.00	21735600.00	24747368	75	36616	1985.00	7.67	120.00
URUGUAY	3.80	1230140.50	548068	77480	55.00	171400.00	10530280.00	1424600	71	15211	1985.00	6.91	592.00
VENEZUELA	36.00	4256435.49	3604743	381575	408.00	780600.00	11812520.00	1848750	75	21344	1985.00	11.40	425.00
ZAIRE	2.87	2185880.59	6806513	32000	7.00	8012300.00	1787420.00	95625	100	15890	1985.00	6.39	97.00
ZAMBIA	2.24	706254.28	1320242	9000	80.00	1591300.00	2375320.00	186150	61	40402	1985.00	5.04	77.00
ZIMBABWE	19.39	1156176.93	2446922	3177	155.00	2405400.00	4428280.00	862750	63	7400.00	1985.00	22.19	53.00

Table A.2- Research 65-69 Average.

COUNTRY	Research
ARGENTINA	54.02
BANGLADESH	30.00
BARBADOS	1.00
BENIN	5.00
BOLIVIA	3.00
BOTSWANA	0.87
CAMEROON	2.36
CHILE	16.95
COLOMBIA	46.00
COSTARICA	3.00
CYPRUS	1.46
DOMINICANREPU	1.80
ECUADOR	5.88
EGYPT	28.76
ELSALVADOR	2.89
ETHIOPIA	4.22
FIJI	1.50
GHANA	7.32
GUATEMALA	1.90
INDIA	144.86
INDONESIA	40.00
IVORYCOAST	18.00
JORDAN	1.00
KENYA	18.04
LIBERIA	0.44
MALAWI	2.17
MALAYSIA	20.00
MAURITIUS	4.43
MEXICO	10.39
MOROCCO	8.00
NEPAL	3.22
NIGER	2.04
NIGERIA	41.49
PAKISTAN	15.13
PANAMA	0.90
PARAGUAY	0.80
PERU	7.31
PHILIPPINES	23.59
RWANDA	1.19
SENEGAL	11.98
SRILANKA	11.32
SUDAN	13.04
SWAZILAND	0.68
TANZANIA	7.00
TURKEY	18.75
URUGUAY	1.80
VENEZUELA	44.07
ZAIRE	4.93
ZAMBIA	2.49
ZIMBABWE	9.09

VITA

Brady James Deaton, Jr. was born June 3, 1969, the son of Brady James Deaton and Anne S. Deaton. He received his B.A. in Economics from the University of Missouri in May of 1991. In August of 1991 he entered the Virginia Polytechnic Institute and State University, completing degree requirements for a Master of Science Degree in Agricultural Economics in June, 1993. In the summer of 1993 he joined the Peace Corps and went to Lesotho.

Brady James Deaton, Jr.