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9. ABSTRACT

The principal objective of this study is to establish the impact of the agroclimatic factors on rice production in the Philippines. Using discriminant analysis, homogeneous regions were delineated on the basis of different sets of agroclimatic variables such as land resource characteristics, agricultural infrastructures, population characteristics, soil types, and rainfall. Farm-level production relationships were estimated from rice production and input data for 2,459 irrigated farms. The functions included the usual farm inputs, a technology variable, and agroclimatic factors as regressors. The scheme of homogeneous regions was employed to generate dummy variables to represent the agroclimatic environment. By locating the farms in the homogeneous groupings, the agroclimatic characteristics could be specified for each observation. The analysis indicates that land and labor resources, as well as agricultural infrastructures, would be the key variables in developing the capacities in the agricultural sector. The results demonstrate the immediate payoffs from pest and disease control in rice. The results reported here also could be utilized to define subregions with homogeneous composite agroclimatic environment in each administrative jurisdiction. Thus programs could be conceived according to a subregion's specific needs.

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THE STRUCTURE OF REGIONAL RICE PRODUCTION IN THE PHILIPPINES

A THESIS

SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL

OF THE UNIVERSITY OF MINNESOTA

By

DONATO BARAQUIA ANTIPORTA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

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ABSTRACT

The Structure of Regional Rice Production in the Philippines

by

DONATO B. ANTIPORTA

A principal objective of the study is to establish the impact of the agroclimatic factors on rice production in the Philippines. Using discriminant analysis, homogeneous regions were delineated. The homogeneous areas are characterized on the basis of different sets of agroclimatic variables such as land resource characteristics, agricultural infrastructures, population characteristics, soil types, and rainfall.

Farm level production relationships were estimated from rice production and input data for 2,459 irrigated farms. The functions included the usual farm inputs, a technology variable, and agroclimatic factors as regressors. The scheme of homogeneous regions was employed to generate dummy variables to represent the agroclimatic environment. By locating the farms in the homogeneous groupings, the agroclimatic characteristics could be specified for each observation.

The regression results presented a strong evidence of the significant influence of agroclimatic factors on rice production. The land input and its quality showed the most dominant effect. Lands with better irrigation and drainage exhibited a superiority in production. The land resource characteristics could explain 5.5 to 20.4 percent variation in regional production.

Labor productivity varied proportionately with the degree of urbanization, literacy rate, and alternative employment opportunities. The estimated partial elasticity of household labor in rice farming was lower in the rural areas. Up to 17.4 percent regional production difference could be attributed solely to differences in labor resource characteristics.

Soil types, monthly rainfall patterns, and agricultural infrastructures were associated with regional differentials in rice production. For irrigated farms, a lighter soil composition appeared favorable to rice production. For the same class of farms, regions with a lower average monthly rainfall have a higher technical efficiency. Regional differentials in farm output up to 23.8 percent, 16.9 percent, and 20.6 percent could be associated separately with soil type, rainfall, and agricultural infrastructures, respectively.

Some factors affecting technical efficiency in rice production are not region specific. The modern varieties have undoubtedly improved production regardless of input levels and traditional practices. The statistical evidence suggests that modern varieties would produce 26.3 percent more than traditional varieties in irrigated farms, holding other things constant. However, the realized benefits fell below the potential because of the negative effects of pests, tungro virus, and other diseases. Production losses were estimated at 11.9 percent for pest and disease problems, and 22.4 percent for tungro virus. Together, such losses would completely negate the advantage of modern over traditional rice varieties.

The analysis indicates that land and labor resources, as well as agricultural infrastructures, would be the key variables in developing the capacities in the agricultural sector. They represent the significant agroclimatic variables amenable to government policies. The results demonstrate the immediate payoffs from pest and disease control in rice. It is necessary to reduce the production risks and losses from pests and diseases to maximize the gains from modern varieties and to stimulate the adoption of inputs, as well as other practices, which fully exploit the available biological technology.

There is a weak congruence between the administrative regions and the homogeneous areas based on agroclimatic characteristics. In view of significant regional differences and their implications on rice production, it would be useful to differentiate agricultural programs for dissimilar areas. The results reported here could be utilized to define subregions with homogeneous composite agroclimatic environment in each administrative jurisdiction. Then, programs may be conceived based on specific needs in the subregions. In this way, there would be a correspondence between the problems and the programs to relieve them.

Affectionately dedicated to my daughter Michelle, to my wife Nenita and to our, as yet, unborn child . . . .

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To a very large extent, I owe the successful completion of my degree program to my wife Nenita, and daughter Michelle. Their presence has given me inspiration and a morale boost. The patience, understanding, and affection of my wife have certainly made my graduate student life very fruitful. I affectionately dedicate this work to my wife, my daughter and to our, as yet, unborn child.

DONATO BARAQUIA ANTIPORTA
March 31, 1976

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CHAPTER I

INTRODUCTION

1.1 Agriculture and the Philippine Economy

Agriculture occupies a central role in the economic growth and development of the Philippines, since primary agricultural commodities comprise about two-fifths of the national output. The Philippine economy exemplifies the potential impact of agriculture on the overall development of a country. The limited off-farm employment opportunities in the rural areas and the generally capital-intensive bias in the growth of the industrial sector emphasize the need for agricultural development. For a long time to come, the agricultural sector will be looked upon as an important source of employment and livelihood for the rural populace.

Failures to develop a responsive agriculture and to build its capacity could seriously impede programs for a total development of an economy. An analysis of sectoral growth in the Philippines underscores the significance of agriculture to the whole economy. Advances in agriculture influence industrial as well as total economic performance. During the years 1950 through 1966 a limited expansion of the agricultural sector and a consequent reliance on manufacturing based on imported rather than on indigenous raw materials did not provide a conducive atmosphere for an accelerated improvement of the Philippine

economy. It was generally agreed that more growth could have been realized had agricultural sector expanded at a faster rate (G. P. Sicat, 1972).

Problems with food supply have great economic and political repercussions. A high rate of population growth brings undesirable effects whenever supply fails to keep adequate pace with growing demand. In particular, frequent food price crises create instability and contribute to the effects of inflation on the welfare of the people.

1.2 Agricultural Development Experience and Its Implications

Experiences during the past decades revealed a limited potency of development policies founded on diffusion models. "Efforts to achieve agricultural development by the direct transfer of foreign technology have been largely unsuccessful. Modern agricultural technology has evolved largely in the developed countries of the temperate zone and is primarily dapted to their ecology and factor endowments. Inadequate ecognition of the location-specific character of agricultural echnology was a major reason for the lack of effectiveness of uch of the technical assistance effort of national and nternational agencies during the 1950's and 1960's." (Y. Hayami nd V. W. Ruttan, 1971, pp. 169-170)

There have been only limited successes in modernizing he traditional agriculture of poor countries and a failure to ustain rapid agricultural advances over a sufficiently long

period of time. Take the case of the new rice varieties in South and Southeast Asia. Dissimilarities in the growing environment contribute to an uneven distribution of the new technology among regions. The rates of adoption of supporting technologies like irrigation and fertilizer vary from one area to another (T. Anden and R. Barker, 1974). In large parts of Asia the new rice remains unsuitable because of the absence of the key requirements for adoption, such as good water control (D. E. Welsch and E. W. Sprague, 1969; R. Barker, 1969). The gains from the adoption of the new seeds and other inputs are substantial; however, "only in a very narrow geographical environment has the growth in yield been so rapid as to establish a higher production trend." (R. Barker, 1973, p. 2)

Differences occur among areas within a country as they do among countries. Agricultural needs vary from region to region due to dissimilarities in resource endowments and constraints to agricultural change. To be effective, the strategy for development should be compatible with resource endowments and agroclimatic characteristics. For example, the rapid growth and progressive structure of Taiwan's agriculture has been based upon the development and rapid adoption of effective technologies. The successful modernization of its agriculture is a product of unified planning, structuring agricultural research, and adaptation of basic research results to particular conditions and needs of well-defined agricultural regions (J. W. Brewster, 1967; M. E. Abel and K. W. Easter, 1971).

These development experiences illustrate some lessons for understanding agricultural change:

(1) Identification of regional differences in the production environment and resource endowments is vital to sharpen the definition and analysis of the problems of agricultural development. It leads to the formulation of better policy instruments that are consistent with regional needs and constraints.

(2) T

rigorously understood and strategies may become ineffective when conceived at a highly aggregative level as, for example, on a national basis. The weakness becomes acute as the heterogeneity of aggregated areas increases.

On the one hand, past lessons from development experiences prove that some amount of disaggregation in analyzing problems is highly desirable. There is ample opportunity to study more basic relationships and to uncover what may turn out as crucial factors, which otherwise could easily get lost in the aggregation process. On the other hand, development planning, by necessity, must deal with a minimum geographic scope wide enough to be relevant in policymaking. In this research, I conceive a methodology which disaggregates the analysis and at the same time relates the findings to a regional dimension big enough for development planning purposes.

1.3 Research Objectives

Previous research in the Philippines tends to concentrate

on optimal resource use. In general, information for capacity building in agriculture and for relieving the constraints to higher agricultural production is scarce, if not nonexistent. The ultimate goal of this research is to identify the factors which explain rice production differences. To move towards accomplishing this final goal I propose to assess the relation between rice production and agroclimatic variables such as labor and land resources, soil, rainfall, and agricultural infrastructure. The study analyzes their fundamental influence on the structure of regional productivity. By understanding geographic variations, I hope to learn about the problems of increasing rice production. The specific objectives of this study are:

1. To delineate homogeneous regions in the Philippines. The study conceives a "region" as a unit made up of provinces,[1] which are not necessarily contiguous but are internally homogeneous with respect to a given set of agroclimatic variables. The scheme of homogeneous agroclimatic regions assures efficient disaggregation. At the same time, the scheme identifies geographic areas for program planning.

2. To characterize regional and provincial profiles. The profile can be used to identify core provinces, those which most typically represent a region. Also, group profiles provide some indication of intraregional differences among provinces.

---

[1]As will be evident later in Chapter II, a province becomes the basic unit of analysis not by design but due to a constraint on the availability of information.

Whereas not all of this information is directly employed in the present analyses, it remains useful for inter- or intraregional comparisons of core provinces.

3. To develop variables to represent the agroclimatic environment. These variables will be included in the productivity analysis to measure regional effects.

4. To map rice productivity and estimate the rice production function which incorporates the usual inputs, technology, and agroclimatic factors. This is an attempt to improve specification and to minimize the biases from omitting external but influential factors. Presumably, a better specification will help identify possible constraints to increasing rice production.

5. To calculate the partial influence of significant factors on rice production. This will demonstrate the relative importance of each factor either in rationalizing production differentials between regions or as a source of output growth.

The choice of rice as a subject of analysis is influenced by its importance as a major food crop in the Philippines, by the continued government emphasis on the rice sector, and also by data availability. However, I could see no difficulty in extending a similar analysis to other crops.

1.4 Organization of the Thesis

The thesis is divisible roughly into two parts. The first portion deals with a delineation of planning regions or homogeneous agroclimatic regions in the Philippines. The second

half consists of an interregional rice productivity analysis to identify the major agroclimatic and other influences in rice production. The production functions include agroclimatic variables as arguments, together with the usual farm inputs. Thus, the latter portion utilizes the results from the first part to measure and specify the agroclimatic environment.

The thesis is presented in four chapters. The remainder of Chapter I outlines the general methodology to establish the linkages between the major parts of the research. It presents the basic theoretical construct for analyzing the contribution of the regional environment to rice production. The readers will discover later that the methodology attempts to make the most out of the limited information that is available. The methodology would combine provincial[2] data on agroclimatic variables and farm level information from a nationwide survey of rice production and inputs. The provincial data are used to construct regions in Chapter II. To specify the regional environment, each sample farm in the regression analysis in Chapter III is located within one of the regional groupings.

Chapter II contains the scheme for defining homogeneous agroclimatic regions in the Philippines. It reviews previous work, sets up, and estimates discriminant models based on provincial level data. The agroclimatic variables are divided into the following sets, namely: rice productivity, land

---

[2]A province is an administrative division immediately below the national level.

characteristics, soil composition, agricultural infrastructures, population characteristics, and first, as well as second, semester rainfall patterns. Chapter II presents and defines the specific variables which fall in each heading. Four regions are delineated for every set of agroclimatic variables and the delineation is independently made for each set of factors. The results of the discriminant analysis would suggest significant environmental differences among the delineated regions in the Philippines.

Chapter III analyzes the impact of agroclimatic factors by mapping provincial rice yields; that is, how rice yields vary across agricultural regions. At the provincial level, the limited information permits only a summary look at the gross relationship between the regional characteristics and the rice production per hectare of a province. The unavailability of farm input data for the provinces severely restricts the interpretation of statistically significant coefficients associated with the regional factors. In addition, Chapter III presents and discusses the regression models estimated from farm survey data on rice production and inputs. To improve the specification, dummy variables are made to represent the regional factors as regressors. The statistical results would show some evidence that the regional environment helps explain rice production differentials.

There is an attempt in Chapter IV to relate the statistical results of discriminant and regression analyses to

development planning and future research. Implications are drawn with regard to the possible sources of rice output growth, the additional analyses which may be desirable to make the results more meaningful for the policymaking process, and the need to build up reliable data bases.

The thesis includes three appendices for other supplementary information. Appendix A contains the coefficients of the discriminant functions used to classify the provinces. Further, the individual provinces are profiled so that they could be compared with each other. Appendix B presents the summary measures of the provincial profiles, such as the posterior probability, for every province, that it belongs to the different regions and a distance statistics which would indicate how closely each province resembles the average regional profiles. Appendix C is a note on the negative elasticity of labor in rice production. It asserts that a negative estimator of labor elasticity would not have resulted from measurement errors.

1.5 The Production Relationship

Production differences may be immediately traceable to an interaction of several phenomena. Consider Figure 1 below which shows production regimes R_1 and R_2. The observed output levels Y_A and Y_B may differ because of underlying production regimes and the use of inputs. R_1 offers a potential advantage BC (at input level X_B). But the observed rice production rises not to the full extent of BC because the lower input level X_A brings an offsetting change CD. Figure 1 clearly shows that

rice production varies according to the response to, as well

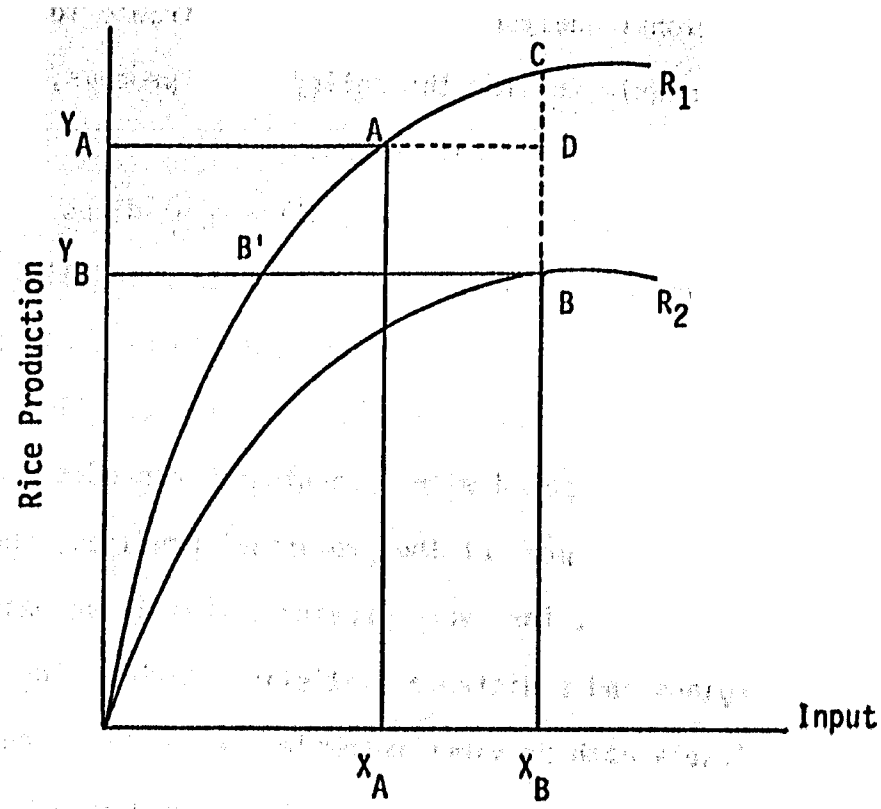

Figure 1. Sources of productivity variations.

as the intensity of farm inputs. The response to farm inputs represents the technical dimension. The question as to what level of input to use, or where on a function to operate, may be considered an allocation problem. The thesis distinguishes between allocative and technical efficiencies in production and tries to concentrate only on the latter. The graph demonstrates the necessity of identifying all relevant response curves before

production differentials or allocation problems could be understood.

The nature of production response is embodied in the set of parameters specific to a function. Since the parameters characterize input-output relationships, they expectedly differ between rice varieties as well as from one environmental setting to another. Modern varieties, the short, stiff-strawed, early maturing, photoperiod-insensitive rice varieties, could have a response curve distinct from that of traditional, indigenous varieties. Therefore, curves R_1 and R_2 could describe either the performance of a biological technology in two distinct environments or of two technologies in the same environment.[3]

The graphical picture in Figure 1 provides a starting point to formalize a model for analyzing rice production. The model should incorporate farm inputs, technology and the environmental variables.

$$Y = f(X_1, X_2, \ldots X_k, T, D_1, D_2, \ldots D_p, \varepsilon) \qquad (1.1)$$

where:

Y is rice production

X_i is an input

---

[3]Let us make explicit the terms "technology" and "environment". In this thesis, technology has a very narrow meaning and is used interchangeably with biological technology or rice variety. Technology refers specifically to two broad types of rice, namely: modern and traditional varieties. Environment encompasses more than the physical surroundings. It is taken to include the physical environment like soil and rainfall, as well as variables that relate to infrastructures, land resource and population characteristics. They shall otherwise be referred to also as agroclimatic variables.

T is a technology variable.

D_i is an environmental variable

ε is a random error term

The production relations in (1.1), appropriately specified, could be capable of distinguishing between productivity differences due to technology from those due to differences in environment. It is important to distinguish between technology and environment in developing appropriate strategies for increasing agricultural output. To determine the influence of the environment on productivity seems to have more long run implications than a purely comparative evaluation of existing technologies. With the current level of technical expertise in the Philippines, it should be possible to generate adaptable rice varieties. Thus, the basic issue is to identify key environmental variables, to calculate their impact and to characterize the kinds of environment for which a technology ought to be generated.

1.6 The External Nature of Agroclimatic Factors

The D variables in (1.1) represent essentially external factors. Often, they are beyond the control of individual producing units. Nevertheless, they can exert a profound influence on rice production. The strategic potential for capacity building in agriculture and the external nature of agroclimatic variables make them a likely subject for public sector activities. Over a sufficient planning horizon, agroclimatic factors can be considered as either fixed or alterable. Environmental modification is presumably difficult

with natural factors like soil and rainfall. But that does not mean than nothing could be done. As regards others, the situation may be alterable as in the case of reproducible factors. For example, the supply of land resources may not be as perfectly inelastic as it might seem at first glance. Undertaking irrigation projects and related improvements could conceivably augment the land resource.

Regardless of the nature of environmental constraints, the appropriate development strategies would involve some investments. As a rule, the investments will be beyond the reach of farmers. The cost associated with changing or improving the resource base is generally too large to be borne individually. In addition, there are substantial externalities associated with such investments and added costs or benefits cannot be internalized. The market could not be relied upon to allocate costs and benefits or determine the price for the goods generated by agricultural investments. The public good nature of irrigation or drainage structures could be one example. Each farmer benefits from the facilities which may be available to other farmers without necessarily diminishing the gains derived by current users. Furthermore, some operations are better accomplished by group as opposed to individual efforts. Coordinated or collective action often brings greater effectiveness. This is often true with regard to pest and disease control measures.

1.7 The Conceptual and Practical Issues

Some conceptual and practical issues stand in the way of a direct estimation of (1.1). There are virtually no precedents to help define the environmental variables. The D variables are not known to begin with. To account for them means: first to hypothesize which factors are possibly relevant; then, to develop measures to be able to include them in a quantitative model and finally, to test their significance.

Rice production function studies have previously been undertaken in the Philippines.[4] But they provide little help since only production inputs are normally included. Most studies have been confined within specific locations. To locate comparative experiments, for example, reveals a tacit admission of outside influence. The experimentor is only trying to correct for external factors. Alternatively, a location effect might have been included. In both cases, the external variables on the basis of which the observations are standardized are usually not necessarily made explicit. The effects might have been measured without characterizing the underlying causal agents. At least, there seems to be some difficulties in making generalizations from such effects.

Some research by experiment stations, notably the International Rice Research Institute, recognized the critica importance of the environmental aspects of rice production.

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[4]See, for example, L. J. Atkinson and D. E. Kunkel, 1974, and D. B. Antiporta and R. D. Torres, 1972.

Efforts have been directed at analyzing how solar radiation, soil texture, and water situations condition rice production. It is also encouraging to see that experiments are beginning to be performed at the farm level and at a level of management and cultural practices within the reach of farmers. For operational or logistic reasons, the studies have been limited in scope and treatment. Consequently, the regional impace of agroclimatic variables have not been rigorously investigated. The findings from intensive studies might have been significant, but for policymaking purposes their implications might become limited by the inability to extend and generalize the results.

Of course, another problem would be that there could be no assurance that all relevant external factors have been adequately considered. This would be so when these factors are analyzed one at a time and more so, when there is not even a notion as to what factors the investigator should standardize for in the observations. This deficiency is serious as demonstrated below. Suppose that the relationship in (1.1) is a linear model as follows:

$$Y = X\beta + D\Gamma + \varepsilon \qquad (1.2)$$

where:

Y is a matrix of $n \times 1$ observations

X is a matrix of $n \times k$ inputs

D is a matrix of $n \times p$ environmental factors

β is a matrix of $k \times 1$ parameters

Γ is a matrix of $p \times 1$ parameters

ε is a matrix of $n \times 1$ random error terms with a zero mean; that is, $E(\varepsilon) = 0$.

Equation (1.2) is assumed to define a true production relationship where rice output depends on a set of inputs and the environmental factors.

Assume further that one estimates the following regression:

$$Y = X\hat{\beta} + \hat{U} \tag{1.3}$$

That means the true β in (1.2) are estimated using only the matrix of production inputs such that:

$$\hat{\beta} = (X'X)^{-1}X'Y \tag{1.4}$$

Equation (1.3) represents the situation where the environmental variables are completely left out. The expected value of (1.4) is:

$$E(\hat{\beta}) = \beta + \rho\Gamma \tag{1.5}$$

where is a $k \times p$ matrix of parameters associated with:[5]

$$D = X\rho + \eta \tag{1.6}$$

This proves that to estimate (1.2) using (1.3), in general, generates biases in the estimators for the included variables. For instance, the expected value of the estimated coefficient of X_i:

$$E(\hat{\beta}_i) = \beta_i \sum_{j=1}^{p} \rho_{ij}\Gamma_j \tag{1.7}$$

Perhaps, the failure to isolate or estimate the matrix is even a more elementary deficiency if in fact the environmental variables are important. The Γ matrix would indicate the set

---

[5]Strictly speaking, the direction of the causal relations between X and D would be the reverse of what (1.6) implies.

of possible development instruments in which policymakers and planners would be most interested. From (1,7):

$$E(\hat{\beta}_i) = \beta_i \text{ if and only if } \sum_{j=i}^{\rho} \rho_{ij} \Gamma_j = 0$$

The exclusion of D variables would impart no bias on under three conditions:

A. X_i is totally unrelated with all the excluded variables; that is, $\rho_{ij} = 0$ for every j.

B. The excluded variables are totally irrelevant; that is, $\Gamma_j = 0$ for all j.

C. The components of the bias are exactly compensating.

For most production inputs, case A seems to be the exception rather than the rule. Previous development experiences provide some reasons to believe that case B probably represents a very strong assumption. The third situation could be ruled out as fortuitous.

For biases to be present, it is not necessary that the whole set of D variables be excluded. As long as a subset remains out of the estimating equation, there is likely to be omitted variable bias. However, as more environmental factors are included, the probability of leaving out the major or relevant variables presumably diminishes. In other words, the situation approaches similar but less restrictive conditions as in cases A and B above.

The agroclimatic variables are reported, at best, only at provincial levels. But the number of provinces is small

time series data, the degrees of freedom might be insufficient. Even with a few degrees of freedom, one could expect relatively large standard errors. Neither is a time series available. Indeed, the bigger problem is the nonexistence of time series data for X_i's at the provincial level and for most agroclimatic variables. To complicate matters, there are strong reasons to anticipate very high collinearity, specially among the agroclimatic variables. The desirable properties of the estimators would remain but the standard errors of estimate increase further and make the test of individual coefficients unreliable in judging the importance of each variable.[6]

To establish the relevance of agroclimatic variables, as well as to improve the reliability of the estimates, requires more information than is available at the provincial level. The data base could be expanded cross-sectionally for farm inputs and partially for agroclimatic variables. But it would be necessary to characterize every observation with respect to each important environmental factor. For some agroclimatic variables, for example, weather variables, farm level measurements would need tremendous amount of resources. Considering that the focus of development planning is usually regional, the investment to generate agroclimatic information at the farm level may not be practical. At the same time, the exclusion of such variables

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[6]Multicollinearity would pose no problem to the estimates of combined effects of collinear variables. Individual coefficients possibly may be separated through mixed estimation; however, prior restrictions need to be placed on some coefficients. Unfortunately, no such outside information is available.

could guarantee biases in the estimation

1.8 A Workable Methodology

It is not possible to estimate (1.1) for provincial units because of insufficient number of observations and the unavailability of input information. Neither would an estimate of (1.1) be possible nor meaningful from purely survey information because the survey would not include agroclimatic data for each farm. The implication is quite clear. It appears necessary to blend the available information sets and estimate (1.1) at the farm level and use the provincial information to incorporate the agroclimatic variables. The provincial data may be used to construct regions. Since the sample farms could be located within one of the regions, the agroclimatic environment could be specified for every observation. It is also necessary to build a mechanism for projecting the analytical results to a regional dimension because of the nature of agroclimatic variables and the needs of development planning.

I propose to apply the technique of discriminant analysis to classify provinces into distinct agroclimatic regions. The ability to characterize the homogeneous groups and to distinguish between them hopefully insures that the observations can be characterized without unnecessary disaggregation. Further, samples may be drawn from provinces with contrasting agroclimatic characteristics. Consequently, the influence of agroclimatic variables on the regional variations in rice productivity may be operationally quantifiable. Alternatively, farm level

observations could be standardized with respect to agroclimatic environment. It becomes possible to incorporate the environment effects or hold them constant, and know what were held constant, when evaluating, for example, alternative rice technologies. The regional scheme of homogeneous provinces could also help to minimize the biases in the estimates of productivity coefficients for the farm inputs. In short, the distribution of provinces into agroclimatic regions would permit me to develop measures for the D variables when estimating (1.1) and to designate rice planning regions.

CHAPTER II

DELINEATING AGROCLIMATIC REGIONS

This chapter presents the specific technique employed in defining homogeneous areas in the Philippines. Homogeneous regions are delineated, based separately on land resource variables, agricultural infrastructures, population characteristics, physical environment such as soil texture and rainfall pattern, and rice productivity from 1970 to 1974. The information about these agroclimatic variables is available only at a provincial level, consequently, a province becomes the basic unit of analysis, even though one would expect some internal variability in a province. However, the principle inherent in the method of regionalization could be applied to smaller units if the constraint on the availability of information is relaxed.

2.1 Review of Literature

The concept involved in defining homogeneous regions is not a new one. Regional studies in the past invariably involved schemes of defining regions according to kinds of homogeneity criterions. A region has always been conceived as a grouping of small spatial units homogeneous with respect to geophysical characteristics, or as having political boundaries such as being under the same administrative jurisdiction of some government machinery, or as being functionally dependent upon the same

commercial nucleus or urban center for trade or other economic activities (J.R. Meyer, 1967). The choice of a classification scheme is governed by the objectives of the study and the data situation. The choice will depend partly on how heavily one weighs the relative advantages of using a method that can utilize existing published data or of adopting a new method of classification even though it requires collecting new data. The same way of delimiting regions may not be appropriate where the purposes of agricultural planning differs (A.T. Mosher, 1973).

There are several approaches to regionalization. In the Philippines, development areas have been delimited along administrative lines based on contiguous political subdivisions The areas may not coincide with a grouping according to variables relevant to agricultural productivity. But regionalization by political boundaries may have other goals, namely, cultivating leadership at subnational levels and administrative convenience in carrying out policy decision. After all, the stream of benefits inherent in a good program flows out mainly through an effective implementation by established political institutions.[2]

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[1] Various legislations created 17 regional development entities from 1961 through 1966. Seven are on operating status (J.M. Lawas, 1973).

[2] This is an empirical consideration which does not interfere with the theoretical framework. A regionalization scheme can cross administrative boundaries as they bear no consequence in the analysis of productivity problems, except in determining the size of the primary unit of observation for which statistics are available.

Type-of-farming area is another approach in delineating regions for agricultural planning and management (K.W. Easter, 1972; K. Kanungo and J.S. Sarma, 1973). This method serves to bring out regional disparities in productivity within crop zones and to identify regions with common production problems. When programs are nationally directed and are commodity oriented, the type-of-farming criterion is appropriate for regionalization.[3]

Alternatively, agricultural regions can be defined by using agroclimatic zoning (M.E. Abel and K.W. Easter, 1971; K.W. Easter, 1972). The rationale behind the technique is that agricultural regions and their needs, rather than farm commodities, form the basic component of regional planning. The Abel-Easter model appears consistent with the premise that increasing agricultural capacity, together with maximizing output from existing capacity, is a viable long-term strategy for agricultural growth. It is also consistent with the recognition that a dynamic modern agriculture is achieved locality by locality and district by district (A.T. Mosher, 1973).

To the extent that climatic and environmental influences set a geographical pattern of production, the type-of-farming approach overlaps the agroclimatic zoning method. However, the

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[3]For example, the approach is useful in the national coordination of rice and corn programs in terms of locating areas where yield and other problems exist.

former is inadequate for separating regional productivity differences which are attributable to reproducible factors. The latter is a more integrated mechanism as it extends into the identification of specific constraints to productivity and underscores the significance of dealing with the restraints in a sequential manner. But the principle remains to be translated into an operational methodology.

Finally, there is a regionalization based on the degree of immediacy of the future growth potential of areas. Growth potential of an area is gauged according to the presence or absence of certain factors of agricultural development (A.T. Mosher, 1971). This method operates essentially on the same principle inherent in the Abel-Easter approach insofar as it relates to the issue of capacity building in agriculture and to the temporal dimensions of development planning.

Agroclimatic zoning involves several variables. But handling more than three variables simultaneously to classify observations into regions is quite complicated. The options are using subjective judgements, objective statistical techniques, or both, depending upon the researcher's knowledge of study areas and the availability of quantitative data.

The discriminant model is a device to calculate linear combinations of several attributes such that known groups could be distinctively characterized. It embodies a linear weighting

scheme to allocate observations. Further, the model could be used to estimate the group membership probabilities of the observations. The posterior probability is an assessment as to how each observation comparies with the average characteristics of each group.

Let p be the number of criteria for classification and g the number of groups. The discriminant model is basically a series of g-1 independent mappings from a p into a one-dimensional space, when p is greater than g (W.W. Cooley and P.R. Lohnes, 1962). Suppose two groups are to be distinguished based on attributes X and Y. Let each ellipse in figure 2 include a specified percentage of the members from each group. Line D represents a discriminant function and line C is a decision rule. Its intersection with line D gives a criterion E. Observations with discriminant scores to the left of E are allocated to group A and the rest, to group B.

Discriminant analysis is a classification tool primarily in personnel selection and analysis. It has also been employed to evaluate the development potential of several countries based on a multitude of criteria (I. Adelman and C.T. Morris, 1968). Principal component is another technique widely employed in the literature to reduce the dimension of the analysis. The technique has been applied to construct composite indexes of homogeneity and to stratify regions (E.C. Rhodes, 1937; M.G. Kendall, 1939;

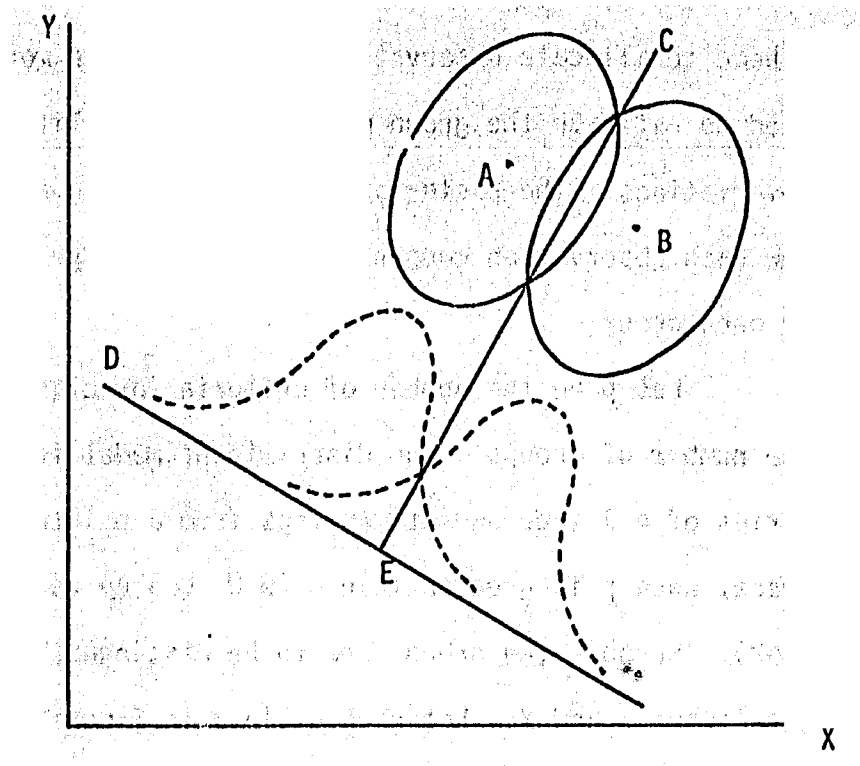

Figure 2. Geometry of discriminant analysis.

M.J. Hagood, et al., 1941; M.J. Hagood, 1943; M.J. Hagood and E.H. Bernert, 1945). Since the 1960's the advent of high speed computers has given impetus to their use in quantitative geography and later in studying patterns of economic development (B.J.L. Berry, 1960; 1961a; 1961b; F.V. Waugh, 1962; B.J.L. Berry, 1965; D.M. Smith, 1968; J.G.M. Hilhorst, 1971; F. Suzuki, not dated). Integration of hierarchical grouping analysis with earlier procedures lent refinements and more precision to regional delineation (J.H. Ward, Jr., 1963; B.J.L. Berry, 1967; N.A. Spence, 1968).

The principal component technique is not without shortcomings. Estimates of factor loadings are susceptible to

biases. The naming of hypothetical factors and their interpretation are not always simple. And there exists the possibility that observations may have identical indexes (and thus end up in the same group) even if they possess contrasting characteristics. Theoretically, these problems can be overcome (H.H. Harman, 1967)

There are some practical difficulties with the principal component method. There are a number of alternative estimation procedures and which one to employ is not, in view of our present objectives, intuitive. Discriminant analysis is more appealing and practical as it is more self-contained. It reduces dimensions and classifies at the same time by finding the set of linear weights which would best separate groups.

2.2 The Discriminant Model

Given a set of observations from a number of distinct groups, each of which is characterized by p measurements with multivariate normal probability density, the likelihood ratio L for any pair of groups i and j is:

$$L = \frac{K \exp\ [-1/2(Z-M_i)'V^{-1}(Z-M_i)]}{K \exp\ [-1/2(Z-M_j)'V^{-1}(Z-M_j)]} \qquad (2.1)$$

here:

V is a p x p matrix of dispersion common to all groups

Z is a p x 1 matrix of attributes

$Z-M_i$ is a p x 1 matrix of deviations of Z from the ith group mean and M_i is a p x 1 vector of means

K is a constant

Simplifying (2.1) further give

$$L = \exp\ [-1/2(Z-M_i)'V^{-1}(Z-M_i) + 1/2(Z-M_j)'V^{-1}(Z-M_j)]$$

$$L = \exp\ [-1/2Z'V^{-1}Z + 1/2M_i'V^{-1}Z + 1/2Z'V^{-1}M_i - 1/2M_i'V^{-1}M_i$$
$$+ 1/2Z'V^{-1}Z - 1/2M_j'V^{-1}Z - 1/2Z'V^{-1}M_j + 1/2M_j'V^{-1}M_j]$$

$$L = \exp\ [Z'V^{-1}(M_i-M_j) - 1/2(M_i+M_j)V^{-1}(M_i-M_j)]$$

$$\ln L = Z'V^{-1}(M_i-M_i) - 1/2(M_i+M_i)V^{-1}(M_i-M_i)$$

$$\ln L = Z'D - 1/2(M_i+M_i)D \tag{2.2}$$

where:

$$D = V^{-1}(M_i-M_j) \tag{2.3}$$

is a p x 1 vector of discriminant function coefficients. It can be shown that D is a vector such that the linear combination Z'D maximizes the ratio of between to within group variances or sum of squares (C.R. Rao, 1952; T.W. Anderson, 1958; W.W. Cooley and P.R. Lohnes, 1962; I. Adelman and C.T. Morris, 1968). In other words, Z'D is the linear discriminant function which could best separate the ith from the ith group.

The discriminant function in (2.2) can alternatively be defined in terms of the parameters of the ith group only. In such cases the function is derived from the likelihood function of the ith group rather than from a likelihood ratio (C.R. Rao, 1952). Thus

$$f_i = K \exp\ [-1/2(Z-M_i)'V^{-1}(Z-M_i)]$$

$$\ln f_i = K' - 1/2(Z-M_i)'V^{-1}(Z-M_i)$$

$$\ln f_i = K' - 1/2Z'V^{-1}Z + Z'V^{-1}M_i - 1/2M_i'V^{-1}M_i$$

$$\ln f_i = K' - 1/2Z'V^{-1}Z + Z'V^{-1}M_i - 1/2M_i'V^{-1}M_i$$

$$\ln f_i = K'' + Z'V^{-1}M_i - 1/2M^{-1}M_i \qquad (2.4)$$

$$\ln f_i = K'' + Z'D - 1/2M_iD \qquad (2.5)$$

$$S_i = \ln f_i - K'' = Z'D - 1/2M_iD \qquad (2.6)$$

where:

$D = V^{-1}M_i$

K, K', K" are some constants.

Classifying provinces on the basis of p characters into, say, four groups is the same as dividing the p dimensional space into four regions R_1, R_2, R_3, and R_4. The expected value of the proportion of wrong classification is minimum for a decision rule such that:

R_1 is defined by $f_1 \geq f_2$, $f_1 \geq f_3$, $f_1 \geq f_4$

R_2 is defined by $f_2 \geq f_1$, $f_2 \geq f_3$, $f_2 \geq f_4$

R_3 is defined by $f_3 \geq f_1$, $f_3 \geq f_2$, $f_3 \geq f_4$

R_4 is defined by $f_4 \geq f_1$, $f_4 \geq f_2$, $f_4 \geq f_3$

assuming that every province is equally likely to be drawn from any group (C.R. Rao, 1952; T.W. Anderson, 1958). The rule is a maximum likelihood rule since a province is assigned to the group for which its likelihood or discriminant score is highest.

Equation (2.6) gives the discriminant functionfor the ith group. It could be utilized together with (2.7) to obtain the group membership probabilities for each observation. Suppose there are g groups. Each observation will then have as many values from equation (2.6) as there are groups. The posterior probability than an observation belongs to the ith group (p_r) could be estimated as:

$$p_r = \frac{\mathrm{Exp}(S_r)}{\sum_{j=1}^{g} \mathrm{Exp}(S_j)} \qquad (2.7)$$

Given the particular set of characteristics for an observation, p_r would indicate the relative probability that it belongs to group r (W.J.Dixon, 1975).

A related alternative measure for comparing observations with group profiles is the square of Mahalanobis distance (D^2). It measures in terms of sum of squares how different say, case k, which is classified in group r from the average values of group 1. Let us represent the matrix of sum of squares within groups as:

$$W = [w_{ij}]$$

of size p x p and with a typical element such as:

$$w_{ij} = \sum_{r=1}^{g} \sum_{k-1}^{n_r} (z_{mki} - m_{ri})(z_{mkj} - m_{rj})$$

where g is the number of groups; n_r is the number of observations in group r; i , as well as j, goes up to p, the number of variables; z_i is a single attribute and m_{ri} is its corresponding average value for group r. The aquare of distance (D^2) statistics for case k in group r from group 1 can be defined as:

$$D^2_{lrk} = (n-g)(Z-M_l)'W^{-1}(Z-M_l)$$

The same relationship can be used to compare observation k with its own group, in which case, l=r.

2.3 Data and Variables

A province is the unit of analysis used here. It is that political subdivision next to the national level. Under the circumstances, a province emerges as the best operational compromise. A province may still be such a large unit that it impinges on the homogeneity of delineated regions. On one hand, villages and towns within a province might possess sufficient variability to cast some doubts on the representativeness of provincial measures. Ideally, the basic analytical unit should be smaller, preferably a municipality if not a village. On the other hand, the information constraint is quite binding. At best, statistics usually are published for provinces but not for smaller units. To summarize characteristics into a provincial value often means less information and less homogeneity within agricultural regions

than is desirable to achieve. But the alternative source of information is quite costly. To generate one's data for villages or municipalities would not be feasible because it is costly. At the same time, it would invariably restrict the geographical scope and would most likely raise the issue of where to start.

To delineate regions, sets of criteria are defined from a natural grouping of several variables described below. The year and the original source of the basic data are in parentheses.

A. Land Resource Characteristics

1. Effective cropping index (1960, Bureau of the Census and Statistics) is a measure of the annual intensity of rice land use and is a ratio of total rice planted to absolute rice hectarage A higher ratio indicates a greater degree of double cropping.

2. Percent rice area (1960, Bureau of the Census and Statistics) shows the relative importance of rice to a province. It is measured here as the proportion of absolute rice hectarage to total arable land planted to temporary crops.

3. Percent rice area irrigated (1960, Bureau of the Censu and Statistics) reflects the extent of effective rice area under irrigation. The index is constructed to indicate land quality of rice areas and, to some extent, the quality of irrigation facilities. If the facilities are serviceable for a longer period in a year, a greater proportion of the effective rice area would be irrigated.

4. Percent land graded over 30° (Bureau of Soils) is intended as a proxy for provincial land topography; it is a ratio of land area which slopes more than 30° to total area of the province.

5. Percent idle land (1960, Bureau of the Census and Statistics) represents idle but arable lands. It indicates the relative availability of the land resource for expansion.

B. Agricultural Infrastructure

1. Loans to agriculture (1970-71, Development Bank of the Philippines, Philippine National Bank, Central Bank of the Philippines) are from agencies which extend financial assistance to agriculture like the Philippine National Bank, the Development Bank of the Philippines, the Agricultural Credit Administration, and the rural banks. Loans to agriculture include only institutional loans. It is the total of the loans extended by the four agencies deflated by arable hectarage to correct for relative size of the province.

2. Road density (1971, Bureau of Public Highways), a supplement to density measure, indicates road quality. A higher value would mean less weather resistant roads or more usable roads during seasons of inclement weather. The residual represents either paved or cemented roads that are likely to be more passable throughout the year.

4. Ratio of 1972 to 1960 irrigated area (National

Irrigation Administration, Agricultural Productivity Commission, and Presidential Arm on Community Development) refers mainly to the rice area serviced by pumps and gravity irrigation systems. With public sector projects for improving infrastructures usually there are other agricultural programs available, such as credit, seed distribution, and extension. This ratio could be regarded as a simplistic proxy for the relative change in government interest in each province over time and for variations in irrigation potential.

5. Rice milling capacity (1971, Rice and Corn Board) is the total provincial daily milling capacity for every 10,000 rice hectares.

6. Warehouse capacity (1971, Rice and Corn Board) is the total provincial storage capability for every hectare of rice.

Provincial statistics on rice milling and warehouse capacities may not accurately differentiate the relative availability of these infrastructures in a province. A mill or warehouse could conceivably extend services to areas beyond the province where it is situated. This will be true if the facilities concentrate near the border between provinces or if the road network is good enough to permit substantial inter-provincial rice flows at minimal cost. Potentially the importance of rice mills and storage capacities is interactive with the transportation infrastructure.

C. Population Characteristics

1. Percent self-employed (1970, Bureau of the Census and Statistics) is the proportion of economically active population, ten years old and over, who do not work for others, private or government.

2. Percent family labor (1970, Bureau of the Census and Statistics) is the proportion of economically active population, ten years old and over, who work for the family and are not paid cash wages.

3. Labor force in agriculture (1970, Bureau of the Census and Statistics) is the percentage of the economically active population, ten years old and over, who depend on the agricultural sector for employment and livelihood.

Labor force includes all ten year olds and over who are either employed or unemployed. Employed persons are those who reported at work or those with a job but not at work. Persons are not counted in the labor force if they are not at work, without job and not wanting work (NEDA, 1975). Labor in 1, 2, and 3 above may not be truly all employed. The classification is primarily based on skill or lack of it and is not contingent on a certain minimum level of employment during the year. It is therefore highly possible to observe a substantial degree of underemployment of those workers classified as employed in the different categories.

4. Percent rural population (1970, Bureau of the Census and Statistics) includes the people who live outside the urban areas.[4] Presumably, the urban-rural population mix affects the pattern of agricultural activities, demand for farm commodities, off-farm employment opportunities, supply of labor to farms, and availability of purchased inputs.

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[4] The Philippine Bureau of the Census and Statistics define urban areas as those characterized by the following:

1) Cities and municipalities with an overall population density of at least 1,000 persons per square kilometer. An exception in Cebu City which is included regardless of population density.

2) Poblaciones or central districts of cities and municipalities with population density of at least 500 persons per square kilometer.

3) Regardless of population size, poblaciones or central districts which possess:

   a) a network of streets either in parallel or right angle patterns

   b) at least six commercial, manufacturing, recreational, and or personal services establishments

   c) at least three of the following: c1) religious service at least once a month in a church or chapel; c2) a public plaza, park or cemetery; c3) trading activities at least once a week in a market place; c4) a public building like a school, a hospital, a puericulture or health center or a library

4) Villages with a population of 1,000 or more which meet the requirements in 3) above and where the occupation of the predominantly non-farming fishing (R.P. Alonzo, 1974).

5. Population density (1970, Bureau of the Census and Statistics) is a measure of the population pressure on land resources. Often, it is associated with economic problems and is an important dimension in the choice of technology for increasing agricultural output.

6. Literacy rate (1970, Bureau of the Census and Statistics) is an index of educational attainment of the population and of the general quality of the labor resource. Literacy is a typical census definition which is a simple classification as to whether one reads and writes or not. It is not based on any functional scale. Quite possibly, literacy rate may affect the effectiveness of government extension programs in agriculture. It is certainly a critical variable for designing or planning government activities in agriculture particularly extension.

7. Annual budget surplus (1965, Bureau of the Census and Statistics) represents the average excess of earnings over expenses for the basic needs of a family. To some extent, it reflects the capability to self-finance other expenditures. For example, to a farm family the budget surplus is potentially available for financing farm operations.

8. Income tax per capita (1971, Economic Atlas of the Philippines), a major source of revenue to finance public expenditures, indicates the nature of employment activities

and the general economic status of the people. A higher per capita tax income implies more cash employment or greater monetary income.

D. Physical Environmental Factors

1. Soil types (Bureau of Soils) refers to the relative soil composition and includes clay, clay loam, sand, sandy loam, silt loam, loam, and undifferentiated types. This list is not exhaustive. Soil types not common to all provinces are excluded.

2. Rainfall (1950 to 1970, Weather Bureau) is crucial as it relates to water stress. It is one of the climatic variables which is important to agriculture. Another is solar radiation. Unfortunately, weather stations do not monitor solar and provincial data are not available. To some extent, rainfall could serve as an indirect proxy for solar radiation. In particular, there would be an inverse relationship between the two.

E. Rice Productivity

Rice productivity (1970 to 1974, National Food and Agriculture Council) is measured as yield per unit of land. Rice production statistics are published at regional levels by the Bureau of Agricultural Economics. As a rule, this government agency releases no provincial data to the general

public. And data available through other sources would be considered unofficial. From reports of field technicians to the Central Office of the National Food and Agriculture Council (NFAC) provincial estimates of rice yield were compiled. The provincial rice yields published in the Economic Atlas of the Philippines (1972) which were based, as cited, on official statistics were used to validate the compiled data. The correlation between the published yields and the 1971 estimates is high ($r = 0.8825$ for a sample size of 38). On this rests my confidence in using the yield estimates from NFAC for th years 1970 through 1974.

2.4 Estimating Group Parameters

The model for discriminant analysis presumes prior knowledge of either group parameters or sample estimates of group parameters. Classifying new observations becomes a simple task if parameters are known. In terms of figure 2, centroids A and B together with the dispersion around them must be known to enable allocation of additional points to one of the groups. Otherwise, to estimate parameters requires knowledge of group membership beforehand, at least for a subset of observations. Samples for every group must have been identified to estimate group centroid and dispersion. But had I had prior information, discriminant analysis hardly would have been

At the start, no parameters are known nor have I an established grouping. Our observations are practically all new. And there being no discriminant functions for mapping the points, I face two fundamental questions. How does one know the number of distinct groups? What belongs in which group? Before presenting the results, I will first discuss these questions.

Somewhere between one and the total number of provinces lies the appropriate number of groups. One extreme is to treat individual provinces as separate groups. This leads to the maximum homogeneity possible in each group. Usually not every province is justifiably large or different enough for program purposes to attract individualized attention. A contrast is to classify all provinces into one category. At this stage, generalization is at a maximum but significant details are lost. Group homogeneity becomes dubious. And such a simplistic approach would suffer from the dangers of overaggregation. Both extremes would seem quite impractical; however, they serve to illustrate aptly some considerations necessary in choosing the number of groups for my purposes.

There exists a trade-off between internal homogeneity and the number of groups. In the process of grouping, generality could only be gained at the cost of some details. As the members per class increase the grouping diminishes. So does

homogeneity. Homogeneity is important but it could not be made absolute. Bear in mind that in the ultimate analysis the end product aims to cater to the needs of agricultural planning. Thus, for operational utility, I also seek intergroup distinctiveness as well as manageability in the number of groups. Preferably too, the aggregate group size should be relevant enough for policymaking.

To categorize productivity into 3 to 5 regimes is a common practice. For me, the range presents a natural choic with respect to the number of groups. I explain the final decision to settle upon a 4-group model after a discussion of the discrimination procedure. It is suffice to say at this point that a 4-group model is a subjective although not an arbitrary choice.

Next comes the question of estimating group parameters or corollarily how provinces, or some of them, group. The procedure is an iterative one. I relied on 1971 rice yields to define class intervals and to initially allocate the provinces. The procedure results in a grouping for which discriminant functions were computed using all the yearly rice productivity data from 1970 to 1974. For each province there are posterior probabilities of belonging to every group. For some cases, the posterior probability of having come from the group in which they

For others, that is not the case. Based on these posterior probabilities, I reallocated the observations and repeated the cycle of computations. The iterative process terminated when each province recorded the highest posterior probability for the group to which it is assigned.

Of all sets of classification variables, only in the case of productivity did I work with all 3-, 4-, and 5-group discriminant models. To examine how well groups separate under the three options, I resorted to a plot of the first two canonical variates associated with the set of productivity criteria. The procedure is similar to the process of employing a preliminary scatter diagram to choose, for example, a functional form. A better group separateion, as indicated in the plot, was the basis for selecting a 4-group model. The final result of a 4-group productivity classification served as the basis to calculate initial discriminant functions for other sets of criteria. Consequently, the initial distribution of provinces was identical for land, infrastructure, population, soil and rainfall pattern and was congruent, at the same time, with the memberships in rice productivity groups. Intuitively, the initial step attempts to find the discriminating weights for each variable in each set of criteria or the combination which would best characterize distinct productivity groups. As before, iterations were made whenever necessary. The subsequent

steps reviews possible misclassifications in earlier stages; that is, when the posterior probability is higher for a group other than where a case is classified. The final results of the iterations are reported in the following pages.

2.5 Individual Profile

Although a 4-group division of about 34 provinces would seem restrictive, it is not necessarily so. To allay some doubts that certain provinces would not fit very well with others, let us examine table 1. It profiles every province and reveals that not too many observations could be border cases. The D^2 column under rth group shows how different each case is from the mean yearly productivity of the rth group. For example, case #1 in group A is 1.94 units away from group A, 18.90 units from group B, 31.20 units from group C, and 63.95 units from group D. Similarly, case #5 in group B is 29.13 units from group A, 6.43 units from group B, 9.42 units from group C, and 24. 13 units from group D.

The p values have a similar interpretation. p represents the estimated probability that case k under group r belongs to group 1, given the pattern of annual rice yield from 1970 to 1974, as well as the mean values of group 1. That case #1 in group A belongs to group A is almost a certainty as shown by p equals unity. However, case #5 in group B registers only an 82 percent probability for group B and 18 percent for group C.

Table 1. - Individual Profile of Provinces in Relation to the Productivity Groups

Case #[a]	Square of Distance (D^2) from and Posterior Probability (p) for							
	Group A		Group B		Group C		Group D	
	D^2	p	D^2	p	D^2	p	D^2	p
Group A								
1	1.94	1.00	18.90	*	31.20	*	63.95	*
2	5.25	.98	12.63	.02	19.81	*	46.24	*
3	5.92	1.00	25.52	*	35.32	*	72.06	*
4	3.34	1.00	25.64	*	45.94	*	83.23	*
5	1.51	1.00	21.36	*	38.63	*	73.87	*
6	10.31	.95	16.40	.05	35.27	*	71.34	*
7	10.77	1.00	50.49	*	82.58	*	133.75	*
8	1.82	1.00	22.38	*	37.02	*	71.71	*
9	3.76	1.00	41.85	*	65.26	*	111.59	*
Group B								
1	17.42	*	3.49	.93	8.67	.07	29.06	*
2	44.72	*	6.36	.95	12.48	.04	19.89	*
3	23.61	*	3.54	1.00	14.61	*	32.67	*
4	13.40	*	2.67	.96	9.03	.04	29.16	*
5	29.13	*	6.43	.82	9.42	.18	24.13	*
Group C								
1	32.49	*	6.96	.14	3.36	.86	15.82	*
2	33.32	*	3.30	.27	1.33	.72	10.15	.01
3	36.18	*	4.45	.41	3.77	.58	13.41	.01
4	48.11	*	12.59	*	1.61	.90	6.16	.10
5	34.72	*	9.65	.04	3.48	.95	13.02	.01
6	57.09	*	24.62	*	11.84	.86	15.57	.14
7	51.37	*	10.45	.02	2.75	.82	6.00	.16
8	52.92	*	16.13	*	3.58	.55	3.98	.45
9	33.68	*	2.44	.41	1.75	.58	10.61	.01
Group D								
1	103.59	*	35.27	*	20.90	*	6.61	1.00
2	72.51	*	22.17	*	9.85	.03	3.02	.97
3	68.49	*	17.13	*	5.21	.11	1.01	.89
4	105.29	*	37.23	*	19.87	.01	10.75	.99
5	69.32	*	22.34	*	6.47	.09	1.93	.91
6	91.48	*	31.08	*	12.79	*	1.48	1.00
7	67.03	*	21.60	*	5.54	.13	1.80	.87
8	78.03	*	31.38	*	10.43	.06	4.99	.94
9	89.86	*	33.22	*	15.74	.01	6.99	.99
10	76.99	*	25.33	*	11.95	.04	5.59	.96
11	61.74	*	19.95	*	5.52	.46	5.23	.54

*The posterior probability is nil or zero.

[a]The case number corresponds to the province number in Table 4.

Notice the inverse association between D^2 and p. It is logical that points farther away from a group centroid would have smaller posterior probability that they belong to that group.

Table 1 makes it feasible to identify core provinces or those which may picked with some degree of confidence to represent a particular region. The results in table 1 assure that only a few of the provinces would not fit well with others. Further, the table reveals what provinces border which groups. Cases #3, #8, #9 in group C and #11 in group D are definitely poor representatives. The p-values for groups other than where they belong are almost as high. This is probably a good reason to avoid these provinces especially for interregional comparisons. Their similarity with more than one group would not help bring out interregional differences.

With regard to the other sets of criteria, similar tables of the probability and distance statistics are constructed. The interpretation of those figures is identical to our approach above. However, to reduce the repititions, the estimated probability and distance tables for land resources, agricultural infrastructures, population characteristics, soil composition, and rainfall are relegated to the appendix Tables B1 to B6.

2.6 Agroclimatic Regions

2.6.1 Rice productivity. In general, there is no definite yield hierarchy among the groups. No single group consistently

Table 2. - Average Rice Yields of Provinces in Different Productivity Groups, 1970-1974

	GROUP AVERAGE			
	A	B	C	D
	(cavans* per hectare)			
1974	77.56	64.40	76.11	70.27
1973	59.33	69.80	66.00	61.54
1972	68.22	64.20	66.56	63.54
1971	50.22	47.40	58.22	56.18
1970	39.00	51.60	59.33	66.45

*A cavan is a volume measure equivalent to 44 kilograms of rough rice.

Table 3. - Matrix of F Statistics for the Hypothesis of no Difference Between a Pair of Vectors of Group Means for the Yearly Rice Yields

	Group A	Group B	Group C
Group B	11.79*		
Group C	30.02*	3.54	
Group D	65.12*	13.40*	5.84*

*Significant at 1% level; the critical F value at 5 and 26 degrees of freedom is 3.818 at 1% level and is 2.587 at 5% level.

Table 4. - Distribution of Provinces Among the Productivity Groups

Group A	Group B	Group C	Group D
1. Antique	1. Davao	1. Batangas	1. Aklan
2. Bohol	2. Cagayan	2. Camarines Norte	2. Albay
3. Cotabato	3. Camarines Sur	3. Cavite	3. Bataan
4. Ilocos Norte	4. Ilocos Sur	4. La Union	4. Bukidnon
5. Negros Oriental	5. Occidental Mindoro	5. Leyte	5. Bulacan
6. Oriental Mindoro		6. Misamis Oriental	6. Isabela
7. Surigao		7. Pampanga	7. Laguna
8. Zamboanga Norte		8. Pangasinan	8. Misamis Occidental
9. Zamboanga Sur		9. Quezon	9. Nueva Ecija
			10. Nueva Viscaya
			11. Tarlac

dominates. Every group records the highest yield during one year but lags behind during the others (table 2). But the provinces in each group exhibit a striking internal similarity in the patterns of rice yields formed over the years (tables 1 and 4). Considerable improvements characterize yield changes in group A. The 1974 average rice yield is almost double that in 1970. Group C had relatively stable yields. In contrast, groups B and D follow up and down patterns. Nevertheless, group differences in yield patterns appear to be significant (table 3). The distinctiveness between groups which are internally homogeneous would have significant implications for agricultural planning. The nature of yield changes common to a number of provinces in every group could be a good indicator that some factors which influence rice productivity may be specific to agricultural regions. There could be a preliminary suggestion that rice production problems possibly lend to a regional treatment. The evidence would reinforce the validity of focusing on regional needs in agricultural planning.

2.6.2 Land resource characteristics. All four groups show statistically significant differences with respect to land resource variables (table 6). Let us take groups B and D. Cropping intensity and land idleness are higher but the

percent of rice land is lower in group B than in group D (table 5).[5] Such group characteristics may be used to explore alternative strategies for increasing rice output and also to identify the program areas. Land is the single most important input to agriculture. But as the provinces exhaust the idle arable lands, cultivation intensity would increasingly become a source of output growth. Where the intensity of cultivation has reached its limit, additional rice crop must come through land expansion. As much idle lands as possible must be brought into cultivation. In some provinces, particularly those in group C, both methods would seem feasible.

One way to augment the land resource is to develop technologies and strategies to relieve the constraints to increasing effective land use. Land augmentation may be in the form of a better yielding second-crop rice variety, soil management practices, dependable irrigation, credit, and supply of purchased inputs. To undertake irrigation improvements to allow greater cropping intensity of existing hectarage would probably suit group D provinces better than the rest, given the low intensity index and percent idle land, as well as the

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[5] We must caution the readers that, although our land resource data are the latest available figures, they might be out of date. The results, therefore, are to be taken in the context of illustrative, rather than contemporary significance.

Table 5. - Characteristics of Provincial Groupings Based on Land Resource Variables

	GROUP AVERAGE			
	A	B	C	D
1. Effective cropping index for rice (percent)	134.00	134.77	111.56	109.62
2. Percent rice area	55.70	41.12	30.85	72.17
3. Percent of rice area irrigated	16.04	33.29	24.97	37.49
4. Percent land graded over 30 degrees	33.60	30.60	39.73	49.50
5. Percent idle land	22.24	25.04	27.40	14.31

Table 6. - Matrix of F Statistics for the Hypothesis of no Difference Between a Pair of Vectors of Group Means for Land Resource Variables

	Group A	Group B	Group C
Group B	10.82*		
Group C	51.72*	30.02*	
Group D	24.24*	11.16*	16.81*

*Significant at 1% level; the critical F value at 5 and 39 degrees of freedom is less than 3.699 at 1% level.

Table 7. - Distribution of Provinces Among the Different Land Resource Groups

Group A	Group B	Group C	
1. Bohol	1. Agusan	1. Bukidnon	1. Abra
2. Cagayan	2. Albay	2. Cavite	2. Aklan
3. Capiz	3. Bataan	3. Cebu	3. Antique
4. Iloilo	4. Batangas	4. Davao	4. Cotabato
5. Marinduque	5. Bulacan	5. Ilocos Norte	5. Ilocos Sur
	6. Camarines Norte	6. Laguna	6. Isabela
	7. Camarines Sur	7. Lanao	7. La Union
	8. Catanduanes	8. Masbate	8. Nueva Ecija
	9. Leyte	9. Misamis Oriental	9. Nueva Viscaya
	10. Misamis Occidental	10. Negros Occidental	10. Pampanga
	11. Quezon	11. Negros Oriental	11. Pangasinan
	12. Samar	12. Occidental Mindoro	12. Tarlac
	13. Surigao	13. Oriental Mindoro	13. Zambales
		14. Palawan	
		15. Zamboanga Norte	
		16. Zamboanga Sur	

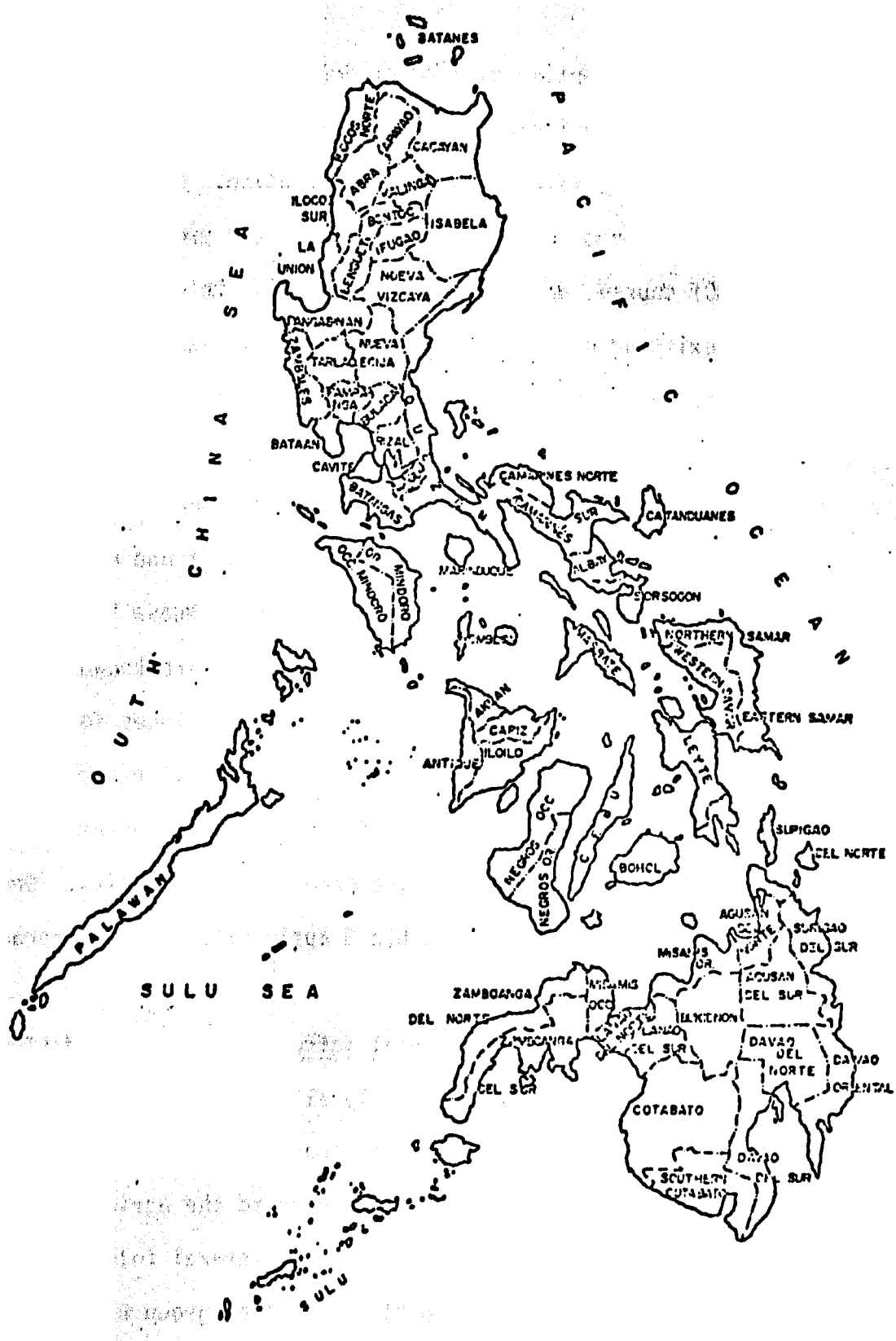

Figure 3. A Map of the Philippines

high proportion of land graded over 30 degrees. For other areas, the irrigation facilities may be developed to bring currently idle lands into cultivation. Provinces in group B would seem to be the areas where such programs could be undertaken. Of course, developing the irrigation to expand the use of existing hectarage or to open up idle lands to cultivation are not necessarily mutually exclusive and may be combined for maximum impact.

Based on a prior knowledge of some provinces, the grouping in table 7 would be consistent with what one might expect. For example, group D provinces such as Nueva Viscaya, Nueva Ecija, Pangasinan, Tarlac and Pampanga are known to resemble each other in land resource. These provinces form the central part of Luzon (figure 3). They have similar agriculture and have been the pilot areas for government programs in irrigation development and other rice production activities. Undoubtedly, the group profile in table 5 aptly reflects the characteristics of such provinces.

2.6.3 Agricultural infrastructure. The differences between groups of internally alike provinces continue to stand out and, like before, these differences are statistically significant (table 9). The loans to the agricultural sector of provinces in group B exceed by several fold those made to other provinces (table 8). In all of group B provinces, sugarcane

is a major cash crop and it is highly likely that the loans to the sugarcane sector normally constitute a very high proportion of the institutional agricultural credit. The financial institutions tend to participate more actively in the agricultural sector of sugarcane provinces (table 10). This fact would probably surprise nobody because of the capital requirements of the sugarcane sector, the degree of commercialization, and its economic importance to the foreign trade of the country.

What is surprising is to find the highest concentration of milling and warehousing capacities in group C provinces (table 8). With the possible exception of Cotabato, these provinces are not the major rice areas. In contrast, group D (table 10) with the traditional rice growing provinces like Bulacan, Nueva Ecija, Pangasinan, and Tarlac record the lowest average milling and warehousing capacities. It is indeed possible that the facilities are convertible to corn milling and warehousing and that corn hectarage should have been added to the deflator to reflect the real standardized capacities. Otherwise these figures could mean one of two things. Either there is a capacity surplus in group C or a severe shortage in group D. At the very least the figure would indicate a spatial imbalance in the distribution of capacities.

Again, the evidence from the infrastructure groups would

Table 8. - Characteristics of Provincial Groupings Based on Agricultural Infrastructures

	GROUP AVERAGE			
	A	B	C	D
1. Loans to agriculture (pesos per arable hectare)	77.73	512.60	42.31	67.06
2. Percent earth road	28.79	22.66	36.85	16.78
3. Ratio of 1972 to 1960 irrigated rice area	2.54	1.83	2.09	1.34
4. Rice milling capacity (cavans per day per 10,000 rice hectares)	42.35	45.64	127.05	28.58
5. Warehouse capacity (cavans/rice hectare)	49.85	43.02	158.51	17.26
6. Road density (kilometers of road per 1,000 arable hectares)	26.71	13.80	10.46	13.42

Table 9. - Matrix of F Statistics for the Hypothesis of no Difference Between a Pair of Vectors of Group Means for Agricultural Infrastructures

	Group A	Group B	Group C
Group B	23.34*		
Group C	31.27*	23.10*	
Group D	20.02*	22.10*	8.28*

*Significant at 1% level; the critical F value at 6 and 38 degrees of freedom is less than 3.474 at 1% level.

Table 10. - Distribution of Provinces Among the Groupings Based on Agricultural Infrastructures

Group A	Group B	Group C	Group D
1. Abra	1. Cavite	1. Bukidnon	1. Agusan
2. Bataan	2. Iloilo	2. Camarines Sur	2. Aklan
3. Batangas	3. Laguna	3. Cebu	3. Albay
4. Bohol	4. Negros Occidental	4. Cotabato	4. Antique
5. Ilocos Norte	5. Pampanga	5. Davao	5. Bulacan
6. Ilocos Sur		6. Lanao	6. Cagayan
7. La Union		7. Masbate	7. Camarines Norte
8. Misamis Occidental		8. Negros Oriental	8. Capiz
9. Misamis Oriental		9. Surigao	9. Catanduanes
10. Nueva Viscaya		10. Zamboanga Sur	10. Isabela
11. Occidental Mindoro			11. Leyte
12. Zambales			12. Marinduque
			13. Nueva Ecija
			14. Oriental Mindoro
			15. Palawan
			16. Pangasinan
			17. Quezon
			18. Samar
			19. Tarlac
			20. Zamboanga Norte

tend to confirm the capability of the discriminant procedure to distinguish among provinces and to group similar ones. One is the grouping together of sugarcane provinces. Based on the assertion that institutional credit in agriculture is relatively concentrated in the sugarcane sector, then group B provinces would be expected to fall in the same group as they did. The provinces are expectedly characterized uniformly by higher institutional credit (table 8). Another indication comes from a prior knowledge that some areas in Mindanace (Southern Philippines) have relatively poor roads and lower road density. The distribution of provinces into infrastrucutre regions in table 10 would show this. Cotabato, Davao, and Lanao (figure 3) are included in the region with the highest percentage of earth road and the lowest road to arable hectanes ratio.

2.6.4 Population characteristics. Table 1 presents the group summary of the population characteristics of the provinces. Although both self and family employment constitute the major source of jobs for all groups, their total varies. Self employment and family employment together account for percentages ranging from a low of 57 percent of the jobs in group A to a high of 69 percent in group D. These figures underscore the tremendous benefits to the national economy from agricultural progress. In most cases, these jobs are likely to be agricultural. Notice that self and family

employment tend to increase with the labor force in agriculture. The exception is group B. But group B has the smallest proportion of rural population. It also ranks highest in income tax per capita. Both suggest the lieklihood of relatively more off-the-farm employment.

The differences in the extent of paid employment and in the availability of nonagricultural jobs perhaps correlate well with the discrepancies in the annual budget surplus per family. For example, group B, followed by group A, are highest in annual surplus. The proportion of the labor force in agriculture is lowest in group B while group A has the least proportion of those self and family employed.

There are also noticeable variations among groups with respect to other attributes. Population density varies from an average of 114.63 persons per square kilometer in group D to 181.59 in group A. Literacy rate has a narrower spread. It is from 79.94 percent in group D to 86.16 percent in group C. As a whole the observed variations among groups are significant (table 12).

2.6.5 Soil composition. The groups of provinces are found to be of dissimilar soil constitution (table 14). Of all the soil series common to all provinces, only the undifferentiated and clay loam types predominate the soils in group A. On the average, clay soils account for a mere 6.41 percent in the same

Table 11. - Characteristics of Provincial Groupings Based on Population Variables

	GROUP AVERAGE			
	A	B	C	D
1. Percent self employed	35.47	38.60	47.14	43.01
2. Percent rural population	82.76	67.91	79.54	81.02
3. Income tax per capita	8.83	13.07	9.08	8.91
4. Literacy rate	82.15	84.26	86.16	79.94
5. Percent family labor	22.06	19.48	20.60	26.15
6. Percent of labor force in agriculture	56.84	48.78	59.68	63.84
7. Annual budget surplus per family (pesos)	551.00	599.25	396.54	289.00
8. Population density (number of persons per square kilometer)	181.59	177.44	139.90	114.63

Table 12. - Matrix of F Statistics for the Hypothesis of no Difference Between a Pair of Vectors of Group Means for Population Variables

	Group A	Group B	Group C
Group B	20.08*		
Group C	18.47*	11.55*	
Group D	6.57*	9.02*	5.58*

*Significant at 1% level; the critical F value at 8 and 36 degrees of freedom is less than 3.173 at 1% level.

Table 13. - Distribution of Provinces Among the Groupings Based on Population Variables

Group A	Group B	Group C	Group D
1. Aklan	1. Bataan	1. Bohol	1. Abra
2. Albay	2. Bulacan	2. Camarines Norte	2. Agusan
3. Cagayan	3. Catanduanes	3. Camarines Sur	3. Antique
4. Capiz	4. Cavite	4. Leyte	4. Batangas
5. Ilocos Sur	5. Cebu	5. Marinduque	5. Bukidnon
6. Isabela	6. Ilocos Norte	6. Masbate	6. Cotabato
7. La Union	7. Laguna	7. Nueva Ecija	7. Davao
8. Negros Occidental	8. Lanao	8. Occidental Mindoro	8. Iloilo
9. Negros Oriental	9. Nueva Viscaya	9. Oriental Mindoro	9. Misamis Occidental
10. Pampanga	10. Palawan	10. Pangasinan	10. Misamis Oriental
11. Tarlac	11. Surigao	11. Quezon	11. Samar
	12. Zambales		12. Zamboanga Norte
			3. Zamboanga Sur

group and less than 5 percent each for the rest.

Five of the seven soil series constitute on the average about 87 percent of the soils in the provinces belonging to group B. In a declining order of magnitude the soil types are clay loam, undifferentiated, sandy loam, clay, and loam. The soil composition of provinces in group C shows the predominance of clay, which averaged over 43 percent. Clay loam and undifferentiated are the two other major soil types with 22.26 and 13.61 percent, respectively. The same three types make up the soil in the provinces in group D. But in the last group the undifferentiated soil series ranks first with 36.71 percent, followed by clay loam with 27.84 percent, and by clay with 14.66 percent.

The test statistics in table 15 show that every pair of groups has statistically significant differences with respect to the given soil types. In all cases the null hypothesis of no difference cannot be accepted at the 1 percent level of significance.

2.6.6 Rainfall. The pattern of rainfall over a period of years is more meaningful for planning purposes than rainfall during a particular year. For a climatic grouping of provinces the monthly means of rainfall observations over time represent a more stable basis than a single year's data. Besides, it is quite difficult to judge whether rainfall in one year is typical or not without reference to what it has been like in the long

Table 14. - Soil Composition of the Various Provincial Groupings

	GROUP AVERAGE			
	A	B	C	D
1. Sandy loan	3.61	17.40	1.80	2.36
2. Clay	6.41	14.92	43.09	14.66
3. Undifferentiated	14.88	20.84	13.61	36.71
4. Clay loam	16.01	22.20	22.26	27.84
5. Loam	2.48	12.04	6.85	6.91
6. Sand	0.83	1.16	2.62	1.34
7. Silt loam	4.35	5.18	3.63	5.24

Table 15. - Matrix of F Statistics for the Hypothesis of no Difference Between a Pair of Vectors of Group Means for the Different Soil Series

	Group A	Group B	Group C
Group B	25.51*		
Group C	42.79*	12.96*	
Group D	25.78*	11.75*	11.56*

*Significant at 1% level; the critical F value at 7 and 33 degrees of freedom is less than 3.474 at 1% level.

Table 16. - Distribution of Provinces Among the Groupings Based on Soil Composition

Group A	Group B	Group C	Group D
1. Antique	1. Albay	1. Bataan	1. Abra
2. Catanduanes	2. Davao	2. Batangas	2. Agusan
3. Cotabato	3. Isabela	3. Bohol	3. Bulacan
4. Occidental Mindoro	4. Pangasinan	4. Bukidnon	4. Cagayan
5. Oriental Mindoro	5. Sorsogon	5. Camarines Norte	5. Capiz
6. Palawan		6. Camarines Sur	6. Ilocos Norte
		7. Cebu	7. Ilocos Sur
		8. Iloilo	8. Misamis Occidental
		9. Laguna	9. Nebros Oriental
		10. La Union	10. Nueva Ecija
		11. Leyte	11. Nueva Viscaya
		12. Marinduque	12. Quezon
		13. Masbate	13. Samar
		14. Misamis Oriental	14. Zamboanga Norte
		15. Negros Occidental	
		16. Pampanga	
		17. Zambales	

run. Expectedly, yearly fluctuations around average values are usual occurences. But they would presumably be random and not systematic deviations. Public sector activities in agriculture which rely on rainfall information would be better served by the systematic geographic rainfall pattern rather than by that based on a single year's observations. For example, it is impractical to formulate and recommend crop calendars for rice in various regions based on what rainfall was during one particular year. Recommendations usually look beyond one year and could not be reset year after year.

There is some consistency in the pattern of differences among the groups of provinces based on the normal rainfall over a period of years. Provinces under group A receive less rainfall throughout the year when compared to provinces in groups B and C. The monthly rainfall in the same provinces is also lower than for group D except during January and February (tables 17 and 20). The minimum average rainfall is observed in group D during these two months.

From January to March, the average rainfall is highest in group C (table 17). During the same quarter, group B averages more rainfall than group D. In the third quarter, groups B and C record higher average rainfall than does group D, but the latter registers the maximum average during the last quarter (table 20)

Table 17. - Average Monthly Rainfall Pattern of Provincial Groupings During the First Semester

	GROUP AVERAGE			
	A	B	C	D
	(millimeters of rain)			
1. January	76.63	145.56	287.74	39.88
2. February	42.80	69.64	191.40	18.44
3. March	38.56	87.40	137.46	39.44
4. April	33.52	74.06	84.60	57.36
5. May	114.85	168.07	160.42	206.17
6. June	166.57	350.36	197.78	331.28

Table 18. - Matrix of F Statistics for the Hypothesis of no Difference Between a Pair of Vectors of Group Means for the First Semester Rainfall

	Group A	Group B	Group C
Group B	37.86*		
Group C	24.26*	54.48*	
Group D	11.61*	13.32*	39.62*

*Significant at 1% level; the critical F value at 6 and 36 degrees of freedom is less than 3.474 at 1% level.

Judging from tables 19 and 22, the conglomeration of provinces by rainfall pattern changes between the first and second semesters. The semestral change should not be lost by those who would use the rainfall regions. In the context of our cropping calendar example, identical plans for land preparation and planting dates, etc. may be drawn for a particular set of provinces during the first semester. But the same provinces would vary with respect to the cropping calendar for the other semester.

2.7 Composite Agroclimatic Regions

The grouping of provinces was made independently for each set of agroclimatic criteria. Combining the separate groups based on land resource characteristics, agricultural infrastructures, population characteristics, soil types and the semestral rainfall patterns would result in a composite grouping. However, we have seen that the aggrupation of the provinces into agricultural regions is highly varied from one classification to another. The immediate implication is that few, if any, provinces would have identical composite characteristics. The scattered distribution would not be unexpected because closely related variables were grouped into sets of agroclimatic criteria. This could have reduced the dependence between regional groupings, as well as their memberships. Also, six classifications of four groups each would generate a multitude

Table 19. - Distribution of Provinces Among the Different Rainfall Groups, First Semester

Group A	Group B	Group C	Group D
1. Agusan	1. Albay	1. Laguna	1. Abra
2. Aklan	2. Bulacan	2. Leyte	2. Bataan
3. Antique	3. Camarines Norte	3. Quezon	3. Batangas
4. Bohol	4. Camarines Sur	4. Samar	4. Marinduque
5. Bukidnon	5. Cavite	5. Sorsogon	5. Nueva Viscaya
6. Cagayan	6. Ilocos Norte		6. Occidental Mindoro
7. Capiz	7. Ilocos Sur		7. Oriental Mindoro
8. Catanduanes	8. Pangasinan		8. Pampanga
9. Cebu			9. Romblon
10. Iloilo			10. Tarlac
11. Isabela			11. Zambales
12. Lanao			
13. La Union			
14. Masbate			
15. Misamis Occidental			
16. Misamis Oriental			
17. Nebros Occidental			
18. Negros Oriental			
19. Nueva Ecija			
20. Palawan			
21. Surigao			

Table 20. - Average Monthly Rainfall Pattern of Provincial Groupings During the Second Semester

	GROUP AVERAGE			
	A	B	C	D
	(millimeters of rain)			
1. July	176.18	389.90	408.63	287.44
2. August	152.46	428.93	410.61	294.59
3. September	141.45	388.40	274.30	266.82
4. October	171.41	242.07	222.27	245.28
5. November	139.17	225.67	258.66	303.01
6. December	81.08	189.97	173.21	235.80

Table 21. - Matrix of F Statistics for the Hypothesis of no Difference Between a Pair of Vectors of Group Means for the Second Semester Rainfall

	Group A	Group B	Group C
Group B	18.82*		
Group C	20.40*	23.31*	
Group D	12.70*	9.25*	5.49*

*Significant at 1% level; the critical F value at 6 and 36 degrees of freedom is less than 3.474 at 1% level.

Table 22. - Distribution of Provinces Among the Different Rainfall Groups, Second Semester

Group A	Group B	Group C	Group D
1. Agusan	1. Abra	1. Batangas	1. Albay
2. Aklan	2. Camarines Norte	2. Bulacan	2. Bataan
3. Antique	3. Camarines Sur	3. Cagayan	3. Catanduanes
4. Bohol	4. Cavite	La Union	4. Isabela
5. Bukidnon	5. Ilocos Norte	Marinduque	5. Laguna
6. Capiz	6. Ilocos Sur	Samar	6. Leyte
7. Cebu	7. Nueva Ecija	Zambales	7. Masbate
8. Iloilo	8. Pangasinan		8. Nueva Viscaya
9. Lanao	9. Quezon		9. Palawan
10. Misamis Occidental	10. Tarlac		10. Pampanga
11. Misamis Oriental			11. Sorsogon
12. Negros Occidental			
13. Negros Oriental			
14. Occidental Mindoro			
15. Oriental Mindoro			
16. Romblon			
17. Surigao			

of possible composite groups (4096). There is hardly a sufficient number of provinces to start with to be able to put one province in each composite group. Therefore, to construct composite group would almost be tantamount to considering each province as distinct from the rest.

One benefit from combining related variables to classify observations through discriminant analysis would be the ability to sidestep the problem of multicollinearity among the variables. In the framework of equation (1.1) in Chapter I, entering collinear variables separately would not, in general, help bring out intelligible results. Collinear variables should be aggregated in such a fashion as to distinguish observations as much as possible. In the same way, some degree of independence among the provincial memberships in the various agricultural regions is methodologically desirable to allow a measurement of the separate effects of the agroclimatic factors. Nevertheless, such independence does not preclude the synthesis of the aggregate impact or the pooled effects from the component effects. Compared with the aggregate impact, the component effects would seem more valuable to development planning. For example, the composite or overall difference in rice production could appear insignificant even if the underlying variations due to each agroclimatic factors might be interesting and substantial. In other words, without examining the components, one would have no guarantee that the composite is not deceiving. It is

these components that are the real object of development planning. In practice, agricultural programs are conceive to deal separately with different agroclimatic dimensions.

In the next chapter, the agricultural regions shall be utilized to create dummy variables for the provinces in order to represent the external variables in the production relationshi in equation (1.1). The regression analysis in the next chapter shall make use of the regional delineations based on agricultural infrastructures, population characteristics, soil composition and rainfall patterns. For farm level analysis, the land resource characteristics are updated by using farm specific land quality and irrigation situations.

CHAPTER III

STRUCTURE OF RICE PRODUCTION

This chapter attempts to measure the regional impact of agroclimatic factors on rice production. The scheme of homogeneous agricultural regions developed earlier is employed to construct measures for environmental factors. Regression models are applied both at the provincial and farm levels. Because of the unavailability of input information for each province, the provincial regression analysis is limited only to the gross association between rice productivity and agroclimatic factors. Interregional rice productivity is analyzed by comparing provincial rice yields among agroclimatic regions. At the farm level, the production relationship integrates the information on rice production and inputs from a nationwide survey of farms with the regional distribution of provinces. The analysis of farms suggests significant regional differences. The regression results are presented, discussed, and translated into regional production ratios.

3.1 Distribution of Provinces

With respect to the final distribution of provinces, there was no clear correspondence between the productivity groups and those of other agroclimatic variables. The provinces with similar rice yields over the years are not precisely the same units which made up the homogeneous regions

based on other criteria. This should not be construed to imply an absence of a relationship between rice productivity, on the one hand, and regional attributes on the other. On the contrary, a perfect correspondence in the provincial distribution from one criteria to another would have looked fortuitous.[1]

The correlation betwen regional characteristics and geographic rice yields is not obvious from a visual inspection of the group profiles. Not only is there too much information to absorb, but the absence of any definite productivity ranking that remains consistent over the years makes it difficult to see the relationship between productivity and regional characteristics. The changing distribution of provinces would imply a complex enough relationship between rice yields and the regional characteristics as to be unrecognizable from an ocular inspection of several tables. It should also be remembered that while the productivity variable has a time dimension, the others have not. In most cases, the single year, for which the variables were measured, varies. It is plausible to assert that the group membership for any delineation not based on permanent attributes can change over time.

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[1]A perfect correspondence in the provincial distribution from one grouping to another would have also caused a methodological difficulty in measuring the separate effects of each set of agroclimatic factors.

3.2 Mapping Regional Variations in Rice Yield

To explain and sort out regional effects in a very general manner, the rice yields of individual provinces may be regressed on the agroclimatic characteristics. The results of discriminant analysis could be employed to create dummy variables for the agroclimatic regions. Earlier six sets of variables, other than rice productivity, were defined to construct agricultural regions. For each set of variables four groups were delineated. In the model on the next page, D_{ij} is a dummy variable where the subscript $_j$ corresponds to the membership of a province in ith group for the $_j$th set of agoclimatic factors. The subscript $_j$ is 1 for land resource, 2 for agricultural infrastructure, 3 for population characteristics, 4 for soil composition, 5 for first semester rainfall and 6 for second semester rainfall.[2] The provincial rice yield data are for a period of 5 years. In (3.1) on the next page represents the year and t=1 for 1971. Then, the model takes for form:

$$Y_{kt} = \sum_{i=1}^{4} \sum_{j=1}^{6} \beta'_{ij} D_{ijk} + \sum_{t=1}^{5} \Gamma'_t D_t + e_{kt} \quad (3.1)$$

where:

Y_{kt} is rice yield of kth province in time t

D_{ijk} = 1 if kth province belongs to ith group of a given ith set

= 0, otherwi

[2]See Table 23 where the dummy variables are made explicit.

D_t is a binary variable for year effects

Depending on the nature of the error term e_{kt}, an appropriate estimation procedure can be devised to obtain efficient and unbiased estimators of β'_{ij} and Γ'_t. I shall assume the error term to possess such characteristics as to make ordinary least-square estimators unbiased and efficient. That suggests that the error term should have a finite and constant variance for all t's.[3]

Note that (3.1) provides no interaction effects among the six sets of variables. The model is completely additive. The difference in rice yields between any two groups in set j remains constant over all i's of other sets. The model assumes that there is significant interactive influence on rice yields from the sets of variables. Adding interaction terms would have greatly reduced the degrees of freedom from a limited number of observations. This was the overriding consideration in

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[3]Presumably, the provincial rice yield Y_{kt} is an average figure. Consequently, the term e_{kt} in (3.1) above involves a summation of the error terms of individual foam. If the component errors are assumed to be homoskedastic, the error term e_{kt} would, in general, be heteroskedastic. Thus, e_{kt} should also be assumed to have a finite and constant Y_{kt} should be assumed to have a common denomination for all k; that is, the average yield data should have been based on an equal number of sample farms from every province.

formulating an additive model.[4]

The purpose of the analysis is to compare interregional productivity and to analyze the impact of agroclimatic factors on provincial rice yields. This would imply the need to test the significance of group differences for each agroclimatic factors. The null hypotheses are:

$$\begin{aligned} Ho: \quad \beta'_{i1} - \beta'_{i'1} &= 0 \\ \beta'_{i2} - \beta_{i'2} &= 0 \\ &\vdots \\ \beta_{i6} - \beta_{i'6} &= 0 \end{aligned} \qquad (3.2)$$

for all $i \neq i'$.

It is not difficult to see that (3.1) can not be estimated. Since there is perfect collinearity.

$$\sum_{i=1}^{m} D_{ij} = 1 \text{ for all } j \text{ and } \sum_{t=1}^{5} D_t = 1,$$

We modify (3.1) by eliminating D_{4j} for all $\underline{j}$'s as well as D_5 and incorporate an intercept term as follows:

$$Y_{kt} = \alpha \sum_{i=1}^{3} \sum_{j=1}^{6} (\beta'_{ij} \quad \beta'_{mj})D_{ij} + \sum_{t=1}^{4} (\Gamma'_t - \Gamma'_T)D_t + e_{kt} \qquad (3.3)$$

which is equivalent to:

$$Y_{kt} = \alpha + \sum_{i=1}^{3} \sum_{j=1}^{6} \beta_{ij} D_{ij} + \sum_{t=1}^{4} \Gamma_t D_t + e_{kt}$$

It follows from (3.2) and (3.3) that a test of significance of β_{ij} if actually equivalent to a test of significance of a difference

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[4]An alternative formulation could be a linear model in which the left-hand variable in (3.1) would be the logarithm of Y_{kt}. In the original scale of output, the model would be multiplicative.

in rice yields between group 4 and group i. Other forms of (3.1) may be specified and estimated but (3.3) had the convenience of a direct test of the hypothesis in (3.2) where the reference is group D (i' = 4) and the base year is 1974 (t = 5).

The test procedure for significance of individual coefficients is a t-test.[5] The test of significance of a subset of coefficients could utilize the F-statistic. Equation (3.3') is estimated as:

$$Y_{kt} = \hat{\alpha} + \sum_{i=1}^{3} \sum_{j=1}^{9} \hat{\beta}_{ij} D_{ij} + \sum_{t=1}^{4} \hat{\Gamma}_t D_t + \hat{e}_{kt}$$

[5]The test statistic could be computed as

$$t = \frac{(\hat{\beta}_{ij} - \text{constant})}{\text{S.E. } (\hat{\beta}_{ij})}, \quad i-1,2,3 \text{ and } j-1,2,3,4$$

For the null hypothesi

$$H_0: \quad \beta_{ij} = 0$$

the test statistic would simply be the ratio of β_{ij} to its standard error.

A set of simultaneous hypotheses, e.g.

$$H_o: \beta_{11} = \beta_{23} = \ldots = \beta_{rj} = 0$$

could be imposed on (3.3'). It would result in a constrained regression such as:

$$Y_{kt} = \hat{\alpha}^* + \sum_{i \neq r}^{3} \sum_{j=1}^{6} \hat{\beta}_{ij} D_{ij} + \sum_{t=1} \hat{\Gamma}^* D_t + \hat{v}$$

The F-statistics to test Ho could be calculated a:

$$F = \frac{\left[\sum_{k=1}^{K} \sum_{t=1}^{5} \hat{v}_{kt}^2 - \sum_{k=1}^{5} \sum_{t=1} \hat{e}_{kt}^2\right]}{\sum_{k=1}^{K} \sum_{t=1}^{5} \hat{e}_{kt}^2} \quad \frac{(r), \text{ number of restriction}}{(5K - [(3)(6)+4] - 1)}$$

At the provincial level, what could be estimated is only an incompletely specified version of equation (1.1). For lack of input information, the X variables could not be included. The estimating equation in the form of (3.3'), in the strict sense, is not a production function. It should be regarded

only as a scheme for comparing the provincial rice yields among the agroclimatic regions.[6] The function would reflect only the gross association between provincial rice yields and the agroclimatic characteristics.

Table 23 summarizes the regression results. In this table are the coefficients and related statistics of the more general relationship which postulates that all agroclimatic variables relate significantly to rice yields. Hence, the first regression at the provincial level includes all group and time dummies.

The regression constant would be the average of the rice yields in 1970 for the provinces which belong to group D of every classification. The other coefficients measure the deviation in rice productivity between a given group and group D. At the same time, the coefficients would also be the estimated of how much of the overall yield gaps could be accounted for by the set of agroclimatic variables. Let us pick a province, for example, one which is classified in group A with respect to all the agroclimatic variables. From table 23, it could be shown that the example would have a yield

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[6]Had the model included all possible interaction terms, the analysis would have been equivalent to an analysis of variance to test the differences in the means of composite agroclimatic groups (J. Kmenta, 1971).

Table 23. Coefficients and related statistics of a regression of provincial rice yields on agroclimatic variables.

	Regression Coefficients	"t" Values
Land Resource		
D_{11} - group A	-7.91	-1.927
D_{21} - group B	-10.67**	-3.191
D_{31} - group C	-12.59**	-3.757
Agricultural Infrastructures		
D_{12} - group A	-0.84	-0.318
D_{22} - group B	-1.54	-0.357
D_{32} - group C	-0.76	-0.312
Population Characteristics		
D_{13} - group A	-13.28**	-4.686
D_{23} - group B	-7.82**	-2.679
D_{33} - group C	19.10**	-4.397
Soil Composition		
D_{14} - group A	-1.88	-0.561
D_{24} - group B	5.36	1.674
D_{34} - group C	9.35**	4.002
Rainfall, First Semester		
D_{15} - group A	7.40	1.673
D_{25} - group B	6.21	1.831
D_{35} - group C	4.82	1.429
Rainfall, Second Semester		
D_{16} - group A	-2.41	-0.659
D_{26} - group B	0.68	0.197
D_{36} - group C	13.24**	3.148
Year Dummies		
D_1 - 1971	-0.52	-0.232
D_2 - 1972	9.88*	3.830
D_3 - 1973	8.29**	3.215
D_4 - 1974	17.76**	6.885
Constant Term	65.23**	14.804
Residual Sum of Squares		20483.1505
Coefficient of Determination		0.4552
Adjusted Coefficient of Determination		0.3889
F Statistics for Significance of Regression (22, 181)		6.8743**

** Significant at 1% level; the critical "t" value for a two tailed test at 1% level of significance is 2.576 and the critical F value at 22 and 181 degrees of freedom is less than 2.336 at 1% level of significance.

lower than the base province. The estimate total difference would -26.32 cavans per hectare. Of this, -7.91 could be attributed to hand resource, -13.28 to population characterisitcs, 7.40 to first semester rainfall, etc. A similar accounting of the yield differentials could be made for any of the possible combinations of groups by examining the appropriate coefficients.

Land resource and population characteristics could explain the greater part of the yield differences (table 23). Of course, the coefficients would reflect the effect of the excluded variables to the extent that they are correlated with the included ones. Looking back at table 5, the provincial yield differences could be linked positively with the percentages of rice area and irrigated hectarage but negatively with cropping intensity. The readers should be reminded that the land resource data related to the year 1960. To explain the relationship, it is essential to update our information on land resource. From a knowledge of government rice programs, one can argue that group D provinces would still have the highest percent rice area and effective rice area irrigated in 1972. But cropping intensity would have changed significently with the development of short-maturing, photoperiod insensitive rice. Public sector programs from rice have been relatively concentrated in group D provinces. The rice cropping intensity would have increased more rapidly in group D provinces relative to the rest. Therefore, it would only be normal to expect that

rice yield is highest in a group with a major percent to the crop area planted to rice and with the highest percentage of the rice area irrigated.

The percentage of unpaid family labor would appear to be directly related to rice productivity if group B in table 1 is disregarded. Working for oneself has apparently provided more motivation. As regards group B, remember that it is more urbanized and externalities could have helped rice yields. In urban areas, farms are nearer to the sources of supporting inputs. Further, there are more competing uses for land and the opportunity cost could be such that marginal lands need to be diverted out of rice farming. The same could be true for labor. Only those productive in rice farming might plant rice. Furthermore, with more case incomes and a budget surplus there could have been a greater ability to provide for the purchase inputs.

The year effects on rice productivity are also evident (table 23). The inter-year variability could be interpreted as a reflection of factors which may have changed over time. It could have been a manifestation of year to year weather variations, implementation of government agricultural programs, and/or temporal changes in the agroclimatic variables themselves. For instance, the year effect of 18.11 cavans in 1974 may for the most part be credited to the Masagana 99 program which

was in full operation during the period.

The set of hypotheses that all terms, where the standard error exceeds the magnitude of the corresponding coefficient, are simultaneously insignificant was tested. Table 24 reports the results of the regression with the restrictions imposed on the model. The seven coefficients tested were not statistically different from zero.[8] The test would suggest that agricultural infrastructures could not be significantly associated with rice yield differences among groups. The insignificance could have easily arisen out of exclusion bias. However, assuming that the test is valid and the coefficients are indeed insignificant, the results would not be conclusive that agriculture infrastructures are unimportant determinants of geographic productivity.

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[7]The Masagana 99 is a program for increasing rice production. The program encourages the use of purchased inputs through credit and fertilizer subsidies. The government extends non-collateral production loans to participants in the program.

[8]The F-statistics for the set of null hypotheses is:

$$F = \frac{(20581.4466 - 20483.1505)/7}{20483.1505)/(204 - 23)} = 0.7513 .$$

For a 1 percent level of significance, the critical F-value at 7 and 181 degrees of freedom is about 2.79. Since the computed F is much less than 2.79, there would be no reason to reject the hypotheses.

Table 24. Regression coefficients and other statistics for the constrained regression of provincial rice yields on agroclimatic characteristics.

	Regression Coefficients	"t" Values
Land Resource		
D_{11} - group A	-7.88*	-2.011
D_{21} - group B	-9.09**	-3.899
D_{31} - group C	-11.17**	-4.381
Population Characteristics		
D_{13} - group A	-12.81**	-5.211
D_{23} - group B	-7.31**	-3.026
D_{33} - group C	-17.76**	-4.860
Soil Composition		
D_{24} - group B	5.80I	2.059
D_{34} - group C	9.06II	5.048
Rainfall, First Semester		
D_{15} - group A	4.90*	2.025
D_{25} - group B	6.23*	2.302
D_{35} - group C	4.55	1.583
Rainfall, Second Semester		
D_{36} - group C	12.67II	3.943
Year Dummies		
D_2 - 1972	10.22**	4.936
D_3 - 1973	8.64**	4.169
D_4 - 1974	18.11**	8.740
Constant Term	62.66**	23.508

Residual Sum of Squares	20581.4466
Coefficient of Determination	0.4526
Adjusted Coefficient of Determination	0.4089
F Statistics for Significance of Regression (15, 188)	10.3623**

*Significant at 5% level; the critical "t" value for a two tailed test at 5% level of significance is 1.960.

**Significant at 1% level; the critical "t" value for a two tailed test at 1% level of significance is 2.576 and the critical F value at 15 and 188 degrees of freedom is less than 2.336 at 1% level of significance.

The agricultural infrastructure could influence market efficiency. It would directly affect farm input usage because of its impact on the prices of inputs, as well as output. Ther the test results might be consistent with points B and B' in figure 1.[9] It is not uncommon for rice farmers to grow the new varieties under traditional cultural practices and lower input use. In such instances, land productivity may not have improved but there is certainly a greater gain in the efficienc of using the variable inputs. In other words, the results may not be inconsistent with the existence of constraints to the economic and physical availability of inputs. From a methodological point of view, the results would provide some evidence of the limitations of merely comparing regional productivity based on partial measures. The model appears inadequate and could lead to misleading inferences.

3.3 Rice Production Functions

Partial productivity measures like land and labor productivity assume away the contribution of other inputs and factors. They are quite inadequate for analyzing the effects of exogenous variables closely associated with productive efficiency. Because of data constraints, improving the

[9]See figure 1 in Chapter 1.

specification requires estimating farm level rice production functions.

The Integrated Agricultural Survey (IAS) provides a wealth of information on rice production. The IAS is based on several rounds of interview conducted by the Bureau of Agricultural Economics (BAEcon), Department of Agriculture of the Philippine Government. The IAS forms the basis for official crop and livestock statistics published annually on an aggregated or regional level.[10] Usually the survey concentrates only on production and hectarage information. Occasionally, BAEcon undertakes more complete surveys that include farm inputs as the agency did in January 1972.

The basic rice production and input data were obtained from January, 1972 IAS. The survey covered the second semester crop of rice. The respondents reported rice harvests primarily for October and November. There were also some harvest reports for September and December. The information includes education and experience of farm operators, land, labor, fertilizer, plant protection chemical, variety planted, and farm production.

The respondent farms are classified as irrigated, rainfed, or upland. This analysis includes only the first group

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[10]The Philippines is presently divided into eleven BAEcon regions. These regions are formed on the basis of geographic and administrative boundaries. The BAEcon regions are different from any of our delineations.

of farms.[11] Consequently, the land input measures only the hectarage of the irrigated farm or parcel. It is further characterized by methods of irrigation. There are four categories: gravity, surface water, shallow-well and deep-well. Fertilizer application is originally measured in terms of bags of fertilizer but is transformed to elemental equivalents of nitrogen and phospohrus. No distinction with respect to the method and timing of fertilizer differentiated as to source or kinds.

Plant protection chemicals could not be measured in a continuous fashion. It is simply a reference to either use or non-use of any plant protection chemicals. To construct a continuous measure for chemical use, requires a knowledge of the nature, level and concentration of the active ingredients and other information which may be too technical for survey respondents to recall.

The varietal information includes the dwarf, stiffstrawed, early maturing varieties. Examples in this category are the IR

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[11] I eliminated the rainfed and upland farms from the analysis due to insufficiency of input information. Either the farms are not reporting usage of inputs other than land and labor or the data are altogether missing. Also, the sample farms from the provinces which could not be grouped under every set of agro-climatic region were excluded from the analysis. The exceptions were observations from Cotabato and Davao.

series of rice strains developed at the International Rice Research Institute and the C-4 variety released by the University of the Philippines at Los Banos. Taller varieties are classified as traditional.

Labor input is measured not by actual mandays worked in the farm but by the number of household members associated with farm operations. Therefore, strictly speaking, the labor variable refers to the stock of labor available and not necessarily to the actual labor input. In general, there would be an upward bias on the labor input. Most likely, the bias would be inversely related with the size of farm, off-farm employment and level of production but directly associated with family size.

3.4 Model Specification

Several variants of the production relationship in (1.1) are used in regression. All the production functions are linear in logarithms.[12] The first regression estimated at the farm level includes only traditional inputs and technological variable.

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[12]To narrow down the scope of the present study, I made no attempt to wrestle with the problem of alternative functional forms. Instead, I relied on other previous studies and assume that a linear logarithmic model would likewise be adequate for my purposes (Y. Hayami and V.W. Ruttam 1971; L.J. Lau and P.A. Yotopoulos, 1971; and S.S. Sidhy, 1972).

$$\ell nY = \sum_{i=1} \beta_i \ell nX_i + \alpha_0 + \alpha_1 V + \alpha_2 X_7 + U^* \qquad (3.4)$$

where:

X_1 is education of farm operator in terms of number of years in school;[13]

X_2 is relative farming experience of operator

X_3 is the hectarage of irrigated parcel;

X_4 is the number of household members working in the farm;

X_5 is the total amount of elemental N in kilograms which applied to the irrigated parcel;

X_6 is the total amount of phosphorus in kilograms which is applied to the irrigated parcel

X_7 is a binary variable for chemical application and is unity for users or zero for non-users;

V is a binary variable for rice variety and is assigned a value of unit for modern variety and zero, otherwise;

[13]Education could be alternatively specified as an intercept shiftor; that is, to estimate separate production functions by educational levels. One reason to do this is the exogeneity of education to any given farm. Also, the change in production in response to a unit change in education, other things being constant, may not be equal throughout the range of educational attainment. The present specification is perhaps appropriate because of our interest in development policy implications. For development purposes, education could be considered a reproducible factor and it therefore a possible policy variable. The formulation would show directly the payoff to be expected, for instance, from educational campaigns or programs. With respect to the assumption of constant production response to a unit change in schooling, it may not be a very strong assumption to make because the model measure such response in relative terms. Also, the range of educational attainment of the respondent farms is not very wide.

Y is kilograms of rice produced from the irrigated land; and

U* is assumed as a random error which has a zero mean and a finite and constant variance.

This production function excluded any influence of environmental factors on agricultural production. To the extent that one feels the agroclimatic variables to be important in rice production, then equation (3.4) may be incompletely specified. The estimates of β_i^*'s and α_i^*'s would be biased by omitting key variables.

Equation (3.5) below incorporates the effects of variation in land resource and labor characteristics, infrastructure, soil types and rainfall regimes together with traditional inputs and technology. The second regression estimated is:

$$\ln Y = \beta_1' \ln X_1 + \beta_2' \ln X_2 + \sum_{i=1} \beta_{3i}' W_i \ln X_3 + \sum_{i=1} \beta_{4i}' D_{i3} \ln X_4$$

$$+ (\beta_{50}' + \beta_{51}' V) \ln X_5 + (\beta_{60}' + \beta_{61}' V) \ln X_6 + \alpha_0' + \alpha_1' V$$

$$+ \alpha_2' X_7 + \alpha_3' X_7 V + \sum_{i=1}^{3} \gamma_i' W_i + \sum_{i=1}^{3} \gamma_{i2}' D_{i2}$$

$$+ \sum_{i=1}^{3} \gamma_{i4}' D_{i4} + \sum_{i=1}^{3} \gamma_{i6}' + U' \qquad (3.5)$$

where W represents the source of irrigation water; W_1 stands for gravity irrigated farms, W_2 for surface water irrigation, W_3 for shallow-well and W_4 for deep-well pumps. The principal difference between the first and second regression is the inclusion in the latter of dummy variables to represent the agroclimatic environment. The second regression allows for more influences through the intercept shiftors and the interaction terms for land and irrigation type, labor and population characteristics, and fertilizers and rice varieties. It is interesting to point out that regression (3.4) is essentially regression (3.5) or (3.6) with a set of linear restrictions on the parameters. In other words, regression (3.4) is a constrained version of regression (3.5) or (3.6). Thus, regressions (3.4) and (3.5) on (3.6) can be compared statistically by testing the significance of the set of linear restrictions.[14]

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[14]The following hypotheses represent the set of linear restrictions on (3.5):

$$\beta'_{31} = \beta'_{32} = \beta'_{33} = \beta'_{34} = \beta^*_3$$

$$\beta'_{41} = \beta'_{42} = \beta'_{43} = \beta'_{44} = \beta^*_4$$

$$\beta'_{51} = \beta'_{61} = \alpha'_3 = \gamma'_i = \gamma'_{ij} = 0 \text{ for } i = 1, 2, 3$$

and $j = 2, 4, 6$. As regards (3.6), there would be an additional restriction that $\alpha = 0$. Similarly, equation (3.5) can be viewed as equation (3.6) with the restriction that $\alpha_A = 0$.

D_{ij}'s are binary variables for agricultural infrastructure (j = 2), population characteristics (j = 3), soil types (j = 4), or rainfall regimes (j = 6). For example D_{14} equals one for observations from provinces which belong to group A of the soil classification. Otherwise, D_{14} equals zero. All other variables have been defined previously.

Ideally, irrigation water ought to be separately measured. But although all farms in our analysis are irrigated. water use is classified only be source. The type of irrigation alone differentiates water use and degree of water control in the respondent farms. For want of a continuous measure, I exploit the close association between land quality and nature of water availability to define land in a broader context. Indeed, the adequacy of irrigation facilities in the farm is a land quality attribute and the land variable can include water input. Consequently, (3.5) distinguishes production elasticities and intercepts between differently irrigated lands. The distinction amounts to separate regressions by land types where coefficients are correspondingly identical for other inputs. Thus, the land coefficients are to be interpreted accordingly.

In a similar fashion, production elasticity of labor varies among groups with divergent population characteristics. The formulation is compatible with regional employment alternatives, wage level and general quality of labor. The conditions prevailing in the labor market and household labor flexibility determine

family labor use on the farm.

Modern and traditional varieties are distinct biological technologies. The short stiff stature of modern varieties make them more resistant to lodging and tolerant of higher fertilizer application. Compared to traditional rice, the modern varieties possess a potential superiority in fertilizer response. But indigenous traditional varieties have, perhaps due to a natural selection process, better resistance to local pest and diseases. In addition, the response to chemical input varies between traditional and modern varieties. Equation (3.5) accounts for these possible differences with slope dummies for nitrogen and phosphorus fertilizers, separate intercepts for varieties and a term for variety and chemical use interaction.

The inclusion of infrastructures, soil types and rainfall regimes presumable complete the specification of production relationships. The group intercepts in (3.5) capture whatever neutral shifts in production surface that arise out of regional differences with respect to infrastructure, soil types or rainfall. A neutral effect is assumed because my interest lies mainly in the neutral impact of these agroclimatic factors. It would be simpler to concentrate on the technical dimension and, for the present, to stay away as much as possible from allocative efficiency question than to consider both aspects simultaneously. Take for example agricultural infrastructures. With slope dummies, the implicit presumption is that input elasticities would vary across

infrastructure groups. There is no reason to believe this to be technically induced. Allocative efficiency differences may not be negligible. But I chose to ignore this issue to reduce analytical complications. Dealing with production due to technical and allocative dimensions at the same time could easily lead to confusion. Therefore, the present objective is only to bring to light the underlying production regimes. Where on any particular function a farmer or group of farmers operates is an entirely separate problem to which would not be addressed in the present analysis.

In 1972 during the months for which our survey data were gathered, there was widespread tungro virus infestation. Undoubtedly, this disease outbreak adversely influenced the rice output of some respondent farms. The virus caused heavy rice crop losses in Central Luzon provinces. Modern varieties are particularly susceptible to the attack. To account for tungro virus damage, a location and variety variable (P) is added to (3.5). The revised equation represents the third regression which was estimated.

$$\ln Y = \beta_1 \ln X_1 + \beta_2 \ln X_2 + \sum_{i=1}^{7} \beta_{3i} W_i \ln X_3 + \sum_{i=1}^{7} \beta_{4i} D_{i3} \ln X_4$$

$$+ (\beta_{50} + \beta_{51} V) \ln X_5 + (\beta_{60} + \beta_{61} V) \ln X_6 + \alpha_o + \alpha_1 V$$

$$+ \alpha_2 X_7 + \alpha_3 X_7 V + \alpha_4 P + \sum_{i=1}^{3} \gamma_i W_i + \sum_{i=1}^{3} \gamma_{i2} D_{i2} + \sum_{i=1}^{3} \gamma_{i4} D_{i4}$$

$$+ \sum_{i=1}^{3} \gamma_{i6} D_{i6} + U \qquad (3.6)$$

The <u>tungro</u> virus dummy variable, (P), was assigned unity for farms in Central Luzon provinces which grew modern rice varieties. For all others, P was zero.

3.5 Adjustments for Estimation

The regional dummies were included in such a way as to make (3.4) and (3.6) estimable. In order to clarify the coefficients, let us discuss the adjustments to arrive at (3.6). The basic model follows:

$$\ln Y = \beta_1 \ln X_1 + \beta_2 \ln X_2 + \sum_{i=1}^{4} \beta_{3i} W_i \ln X_3 + \sum_{i=1}^{4} \beta_{4i} D_{i3} \ln X_4$$

$$+ (\beta_{50} + \beta_{51} V) \ln X_5 + (\beta_{60} + \beta_{61} V) \ln X_6 + \alpha_o'' + \alpha_1 V + \alpha_2 X_7$$

$$+ \alpha_3 X_7 V + \alpha_4 P + \sum_{i=1}^{4} \gamma_i'' W_i + \sum_{i=1}^{4} \gamma_{i2}'' D_{i2} + \sum_{i=1}^{4} \gamma_{i4}'' D_{i4}$$

$$+ \sum_{i=1}^{4} \gamma_{i6}'' D_{i6} + U \qquad (3.6)$$

There are four mutually exlusive groups, and correspondingly four binary variable, ($i = 1, 2, 3, 4$ for each D_{ij} and W_i), in each classification.

This implies:

$$\sum_{i=1}^{4} D_{ij} = 1 \text{ for every } j \text{ and also } \sum_{i=1}^{4} W_i = 1$$

and the parameters can not be estimated from (3.6') due to perfect collinearity among the intercept dummies. Define:

$$D_{4j} = 1 - \sum_{i=1}^{3} D_{ij}$$

$$W_4 = 1 - \sum_{i=1}^{3} W_i$$

Replacing D_{4j} and W_4 in the intercept terms results in (3.6") as follows:

$$\begin{aligned} \ln Y = {} & \beta_1 \ln X_1 + \beta_2 \ln X_2 + \sum_{i=1} \beta_{3i} W_i \ln X_3 + \sum_{i=1} \beta_{4i} D_{i3} \ln X_4 \\ & + (\beta_{50} + \beta_{51} V) \ln X_5 + (\beta_{60} + \beta_{61} V) \ln X_6 + \alpha_o'' + \alpha_1 V + \alpha_2 X_7 \\ & + \alpha_3 X_7 V + \alpha_4 P + \sum_{i=1}^{3} (\gamma_i'' - \gamma_4'') W_i + \gamma_4'' + \sum_{i=1}^{3} (\gamma_{i2}'' - \gamma_{42}'') D_{i2} \\ & + \gamma_{42}'' + \sum_{i=1}^{3} (\gamma_{i4}'' - \gamma_{44}'') D_{i4} + \gamma_{44}'' + \sum_{i=1}^{3} (\gamma_{i6}'' - \gamma_{46}'') D_{i6} \\ & + \gamma_{42}'' + U \end{aligned} \qquad (3.6")$$

3.6 Neutral Shiftors

Comparing (3.6) and (3.6') shows these equalities:

$$\alpha_o = \alpha_o'' + \gamma_4'' + \gamma_{42}'' + \gamma_{44}'' + \gamma_{46}''$$

$$\gamma_i = \gamma_i'' - \gamma_4'', \quad i = 1, 2, 3$$

$$\gamma_{i2} = \gamma_{i2}'' - \gamma_{42}'', \quad i = 1, 2, 3$$

$$\gamma_{i4} = \gamma_{i4}'' - \gamma_{44}'' \quad i = 1, 2, 3$$

$$\gamma_{i6} = \gamma_{i6}'' - \gamma_{46}'' \quad i = 1, 2, 3$$

The intercept term (α_o) in (3.6) contains the regresssion constant (α_o'') of (3.6') plus the shift effects for group D's of the agro-climatic regions. The coefficients of W_i's and D_{ij}'s are intercept shiftors which reflect any neutral differences in production efficiency. In general, γ_{ij} in (3.6) is a measure of the relative efficiency of group i compared to group D that would be attributable to their differences with respect to jth set of agroclimatic characteristics. In a two dimensional input space as in figure 4 let there be unit isoguants AA, DD and A'A' for a constant output level.[15] Further, let DD be the reference isoquant, one that corresponds to our base group D. A positive γ_{ij} means a downward

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[15]The relative magnitudes of downward and upward shifts in the unit isoquants, as depicted in figure 4, correspond to a constant return to scale. For a decreasing return to scale, the shift from DD to AA would be less than the shift from DD to A'A'.

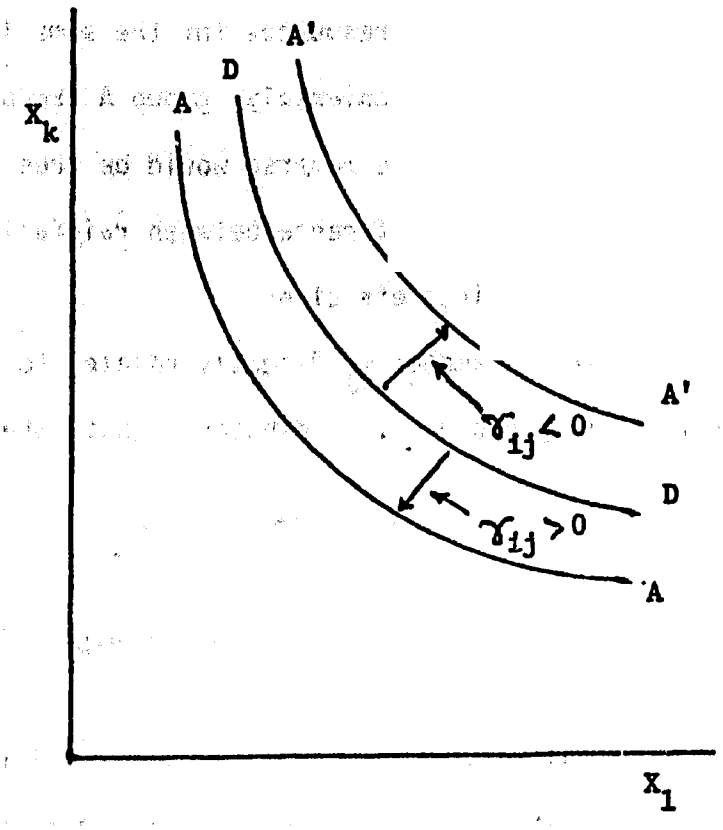

Figure 4. Shifts in technical efficiency

shift in the unit isoquant. If $\gamma_{ij} < 0$, the unit isoquant changes in the reverse direction. For example, $\gamma_{16} > 0$ implies greater technical efficiency for rainfall group A relative to group D. Group A employs less resources for the same level of output as in AA compared to DD. Conversely, group A produces more from a given amount of inputs. The reverse would be true if $\gamma_{16} < 0$. If $\gamma_{16} = 0$, there would be no difference between rainfall groups A and D with regard to technical efficiency.

The parameter α_{ij} directly relates to the output ratio of group i to group D. If Y denotes output, then:

$$\ln Y_{ij} - \ln Y_{4j} = \alpha_{ij}$$

$$Y_{ij}/Y_{4j} = \exp(\alpha_{ij}) \qquad (3.7)$$

under the assumption that groups i and D differ in j alone. A similar relationship holds between any pair of groups i and k for each j. That is:

$$\ln Y_{ij} - \ln Y_{kj} = \alpha_{ij} - \alpha_{kj}$$

$$Y_{ij}/Y_{kj} = \exp(\alpha_{ij} - \alpha_{kj}) \qquad (3.8)$$

$$i, k, = 1, 2, 3$$

Equations (3.7) and (3.8) provide us with a device to qualify in relative terms the neutral influence of agroclimatic variables on rice production. To generalize, sum the differences for each

j:[16]

$$\ln Y^{(1)} - \ln Y^{(2)} = \sum_j (\alpha_{ij} - \alpha_{kj})$$

$$Y^{(1)}/Y^{(2)} = \exp\left[\sum_j (\alpha_{ij} - \alpha_{kj})\right] \qquad (3.9)$$

The ratio $Y^{(1)}/Y^{(2)}$ reflects total output variations which result from all possible differences in the agroclimatic intercept shiftors. Clearly, the ratio in (3.9) indicates the combined influences of the composite agroclimatic characteristics.

The other intercept shiftors in (3.6) are variety, chemicals and tungro virus. Translated as in (3.7), exp (α_4) is the efficiency ratio of tungro virus damaged rice output to virus-free harvest. It could be taken as an output discount parameter from tungro virus susceptibility of modern varieties. Rice variety and plant protection chemical intercept shiftors are interactive. The productivity difference between rice technologies interrelates with chemical use. The output ratio of modern to traditional varieties, with no chemicals, is exp (α_1). For chemical users, the output ratio is exp $(\alpha_1 + \alpha_3)$. The output benefit from chemicals is exp (α_2) for traditional varieties and exp $(\alpha_2 + \alpha_3)$ for modern varieties.

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[16]The indices i and k are not necessarily invariant over all j's. It is conceivable to have i=1, k=2 when j=2, then k=2, k=3 when j=4 and so forth. Group membership is independent from one set of agroclimatic variables to another. The values of indices i and k soley depend upon the memberships of the observations in the particular classification being considered.

3.7 Production Elasticities

Regional production gaps may have components due to differential responses to inputs. The β parameters or indices of output sensitivity to inputs reflect the other dimension of production differences. Of specific interest to us are the partial elasticities for land, labor and fertilizer. In (3.6), β_{3i} and β_{4i} define land and labor productivity, respectively, of the ith class. Alone by itself β_{3i} or β_{4i} says nothing about relative output difference. For any pair of groups i and j, the relative output difference is directly related to $(\beta_{3i} - \beta_{3j})$ or $(\beta_{4i} - \beta_{4j})$. Expressed as a ratio in original output scales, rice production differs between groups i and j by:

$$\ln Y_{3i} - \ln Y_{3j} = (\beta_{3i} - \beta_{3j}) \ln X_3$$

$$Y_{3i}/Y_{3j} = X_3^{\beta_{3i} - \beta_{3j}} \tag{3.10}$$

due to land quality and

$$\ln Y_{4i} - \ln Y_{4j} = (\beta_{4i} - \beta_{4j}) \ln X_4$$

$$Y_{4i}/Y_{4j} = X_4^{\beta_{4i} - \beta_{4j}} \tag{3.11}$$

due to labor quality, all other things being equal. As regards fertilizer, β_{5i} and β_{6i} reflect the extent of varietal distinction in crop response to nitrogen and phosphorus fertilizers, respectively. The additional production elasticity of modern varieties translates into an output advantage of:

$$\ln Y_M - \ln Y_T = \beta_{51} \ln X_5 + \beta_{61} \ln X_6$$

$$Y_M/Y_T = X_5^{\beta_{51}} X_6^{\beta_{61}} \qquad (3.12)$$

Remember that (3.12) indicates only the input response difference between traditional and modern varieties. A case where $\beta_{51} = \beta_{61} =$ would not necessarily imply that modern varieties possess no advanta over traditional rice. If the corresponding parameters for modern varieties are not trivial, $\beta_{51} = \beta_{61} = 0$ would suggest a purely neutral difference in rice production.[17]

3.8 Normative Sign of the Parameters

Apart from the usual statistical test criteria, the sign of the parameters conditions the acceptance or rejection of empirical results. Indeed, seeking a conformity of empirical results with expectations is often an integral part of the specification process. Logic helps build a model and specify its prior characteristics. In this way, nonsensical results may be ruled out.

The parameters in 3.6 should at least be nonnegative. Education (x_1) and experience (x_2) of the farm operator contribute to production in a positive manner. Experience is a form of informal education. And education is associated with the ability to think and be creative. With more education, there is a greater propensity to develop thorough familiarity with rice production

[17] In this paper, technology is a narrow sense and refers only to varietal improvement. See footnote in Chapter I.

processes. The better educated farmers are likely to benefit more from experiment station bulletins and other extension aids. In similar manner labor should exhibit a positive coefficient of elasticity (β_{4i}) which should be directly proportional to labor quality.

The coefficients of land (X_3) should be positive. Inherent in the land variable is the source of irrigation. Better water control implies higher land quality. Consequently rice production is expectedly greater. Water control refers to the ability to regulate water flow; that is the capacity to irrigate or drain the field as the need arises. In equation (3.5), the β_{3i}'s and intercept shiftors γ_i's measure the elasticity and technical efficiency of irrigation and land quality. The β_{3i}'s must be nonnegative and should range to reflect positive benefits from good irrigation. In other words, β_{3i} ought to be greater than β_{3j} when group i has better irrigation than group j. By construction γ_i is a relative measure which may be negative, zero, or positive. Just the same, γ_i ought to vary in direct proportion to land quality.

In terms of water availability, a deep-well pump serves at least as well as a gravity irrigation system. A pump can always be turned on whenever water is needed. The same degree of control may or may not exist in a gravity system. Irrigation turns are determined by a number of farms and their service schedule. In addition, the effective volume of water that reaches the field varies according to distance of the farm and the condition of system laterals. The dissimilarity between deep-well pumps and gravity irrigation with respect to water availability would be more

pronounced during periods of critical water need as in the dry season. However, there is more likelihood that a gravity system possesses superior drainage capability. Its principal laterals and main distributaries are potential drainage devices too. Installed in such a network of canals are end-checks and diversion structures which can be actuated to release surplus water. In addition, the same gradual slope that helps distribute water can facilitate drainage. On top of these, there is always a lake or downstream outlet to run off excess water from the system.

Surface water and shallow well irrigation are variants of the previous systems. A shallow-well pump closely resembles a deep-well pump except that the former has a more limited capacity to draw water. This is especially true in the dry season when the water table recedes. In areas where water table is shallow, a greater concentration of shallow-well pumps relative to deep-well pumps can be expected. Thus, farms served by shallow-well pumps are bound to be more easily waterlogged and less drainable during the rainy season. In other words, the deep-well system is definitely superior to a shallow-well pump considering irrigation and drainage capabilities.

The influence of soil on agricultural output interrelates with irrigation and drainage characteristics of the farms. In the absence of assured irrigation, soil texture may be a critical drought factor. Finer soil texture promotes better water holding capacity. Plants in heavy clay soils would be subject to less

irrigation, soil texture becomes inconsequential to water availability. As water stress and soil texture interaction diminishes, the drainage and other properties of the various soil types assume greater significance. Lighter soils drain better than heavy soils. Further, there is better puddling during land preparation as the soil gets lighter. In short, γ_{i4} depends on soil texture and water supply conditions. γ_{i4} should be positive for irrigated farms with lighter soils. Otherwise, when water stress is critical, the higher water retention of heavy soils would be more favorable for rice production. In this situation γ_{i4} should be negative for lighter soils.

Rainfall relates to water stress and amount of solar radiation received by plants. Solar radiation is important for photosynthesis but also builds up water stress. Presumably, there is inverse correlation between the amounts of rainfall and sunshine. In fact, a practical alternative to gauge solar radiation is cloudiness. Since wet days are, as a rule, cloudy, there would be less solar radiation with more rainfall. When rainfall prevents or relieves water stress, the effect on rice production would be positive. At the same time, more rainfall would mean less sunshine and would reduce the availability of energy for photosynthesis. For rice, solar radiation promotes maximum grain filling during the ripening stage about 45 days before harvesting. Whether γ_{i6} is positive or negative would be determined by opposite water stress and solar radiation effects. Equally offsetting effects would

conceal the influence of rainfall pattern differences and $_{i6}$ could appear to be negligible. If water is forthcoming from alternative sources other than rainfall, then γ_{i6} should vary directly with solar radiation or inversely with the amount of rainfall.

Insecticides and other plant protection checmicals can be beneficial. Applied in a preventive fashion, chemicals would ward off crop losses from pests and diseases as well as weeds. Assuming correct timing, method and rate of application, α_2 and α_3 should be positive. At least, they should be nonnegative. But they can be negative when the purpose of chemical usage is curative and not prophylactic. When a crop damage has been done, chemical application thus becomes a dummy variable for infestation. Consequently, a α_2 or α_3 like α_4 can be negative.

Modern rice varieties are potentially superior to traditional rice in terms of yield. Since β_{51}, β_{61} and α_1 measure the yield payoff, the coefficients ought to be nonnegative, at least. Under normal conditions, modern varieties would perfor at least as well as indigenous rice.

3.9 Estimated Elasticities

Table 25 summarizes the regression results. The estimates are based on a total of 2,459 observations which comprise the irrigated farms in the 1972 Integrated Agricultural Survey. The first batch of figures in the table consists of the slope estimators or partial production elasticities. The second group of coefficients

Table 25. Coefficients of regression of rice production on farm inputs, variety and regional agroclimatic characteristics, wet season, 1971.

	Regression 3.4	Regression 3.5	Regression 3.6
Production Elasticities			
Education (X_1)	.0037** (.0013)	.0028* (.0013)	.0026* (.0013)
Experience (X_2)	.0091 (.0555)	.0320 (.0524)	.0606 (.0539)
Land 1 ($W_1 \ln X_3$)	.9396[a]*** (.0180)	.9071*** (.0238)	.9119*** (.0236)
Land 2 ($W_2 \ln X_3$)	b	.7809*** (.0557)	.7877*** (.0551)
Land 3 ($W_3 \ln X_3$)	b	.8087*** (.1322)	.8135*** (.1309)
Land 4 ($W_4 \ln X_3$)	b	1.0340*** (.0251)	1.0306*** (.0249)
Labor 1 ($D_{13} \ln X_4$)	-.0031[c] (.0166)	-.1181*** (.0415)	-.1166** (.0427)
Labor 2 ($D_{23} \ln X_4$)	d	.0902* (.0395)	.0888* (.0391)
Labor 3 ($D_{33} \ln X_4$)	d	-.0355 (.0244)	-.0163 (.0243)
Labor 4 ($D_{43} \ln X_4$)	d	.0032 (.0259)	-.0022 (.0258)
Nitrogen (X_5)	.0268*** (.0073)	.0551*** (.0124)	.0468*** (.0124)
Phosphorus (X_6)	.0104 (.0083)	.0078 (.0143)	.0070 (.0142)

Table 25. (continued)

	Regression 3.4	Regression 3.5	Regression 3.6
Nitrogen x Variety (X_5V)	-	-.0250* (.0142)	-.0010 (.0145)
Phosphorus x Variety (X_5V)	-	.0102 (.0172)	.0098 (.0170)
Neutral Shiftors			
Constant	7.2336*** (.0403)	7.1401*** (.0558)	7.1184*** (.0553)
Variety (V)	.1489*** (.0248)	.1770*** (.0416)	0.2333*** (.0420)
Chemicals (X_7)	.0199 (.0248)	.0238 .0437)	.0400 (.0434)
Chemicals x Variety (X_7V)	- (.0516)	-.0844 (.0514)	-.1265**
Gravity Irrigation (W_1)	-	.0549* (.0309)	.0636* (.0306)
Surface Water (W_2)	-	.0641 (.0546)	.0665 (.0540)
Shallow-well Pump (W_3)	-	-.1220 (.0427)	-.1152 (.0430)
Infrastructure 1 (D_{12})	-	.0992* (.0427)	.0437 (.0430)
Infrastructure 2 (D_{22})	-	-.0203 (.0600)	.0075 (.0596)
Infrastructure 3 (D_{32})	-	.2294*** (.0464)	.1870*** (.0464)
Soil 1 (D_{14})	-	.0676 (.0524)	.0915* (.0519)
Soil 2 (D_{24})	-	.2504*** (.0362)	.2140*** (.0362)
Soil 3 (D_{34})	-	-.0127 (.0422)	-.0614 (.0423)

Table 25. (continued

Rainfall 1 (D_{16})		.1161 (.0820)	.1560* (.0814)
Rainfall 2 (D_{26})		-.0803 (.0785)	-.0327 (.0780)
Rainfall 3 (D_{36})		-.1046 (.0588)	-.0596 (.0586)
Tungro Virus (P)		-	-.2540*** (.0366)
Number of cases	2,459	2,459	2,459
Residual sum of squares	823.42	757.07	742.36
Adjusted R^2	.6407	.6668	.6734

[a]This is the elasticity for the pooled land quality.

[b]See table footnote a above.

[c]The labor input is not separated in this regression and this coefficient is for the pooled labor input.

[d]See the preceeding table footnote c.

*Significant at .05 level.

**Significant at .01 level.

***Significant at .005 level.

is made up of the estimated intercept and shiftors. Special mention ought to be made of land and labor elasticities. Without regard to the different intercepts and shiftors, the production elasticities in table 25 correspond to 32 production functions (4 land classes x 4 labor categories x 2 kinds of rice). Therefore, when calculating returns to scale care should be taken as to consider only one of the mutually exclusive variables. The four land types, as well as labor groups, are mutually exclusive. Only one labor and one land coefficient should be included in the summation of the elasticities at a time. As regards rice varieties, the nitrogen x variety and phosphorus x variety coefficients are included in calculating the returns to scale for farms planted to modern varieties only.

In general, the regression results bear out prior expectations about the signs of the estimators. This holds true, even in regression 3.4, for the included variables. The sole exception is labor with negative but insignificant elasticity. Although there are reasonable grounds to believe regression 3.4 as incompletely specified, the results are presented here for comparative purposes; primarily to get some ideas how estimates would change from one specification to another. Among the estimators, β_1 apparently remains least affected by omitted variable bias. There appears to be no significant correlation between education and other omitted variables. In regression 3.4, land and labor inputs are each undifferentiated by quality, so that the coefficients represent average values. There is strong evidence that an average estimator

conceals interesting variations in land and labor coefficients due to input quality. A test of the set of linear restrictions indicated that the null hypotheses could be rejected.[18] The test would suggest that the response to input use would not be undifferentiated across different irrigation modes or population characteristics or that the technical efficiency differences across agroclimatic regions would not be negligible.[19]

Judging from regression 3.5, land and its attributes appear as the major production variable. The highly significant elasticity coefficients ranged from 0.78909 for surface water irrigated lands to 1.0340 for deep-well irrigated farms. The elasticity of deep-well irrigated land ought to be interpreted with caution.[20] The lead coefficients would presumably include the contribution of other excluded inputs which vary directly with land. Such inputs may be seeds, quality of management and machinery or equipment. Gravity irrigation (β_{s1} = 0.9071) is superior to surface water (β_{32} = 0.7809). Similarly, lands served by deep-well pumps turned out to be more productive than farms equipped with shallow-well pumps (β_{32} = 1.0340 versus β_{33} = 0.7809). The comparative values are entirely consistent with expectations. More

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[18] See footnote 14 in this chapter for the null hypotheses.

[19] The computed F valves for the corresponding sets of null hypotheses were 9.32 for (3.4) and (3.5); 10.86 for (3.4) and (3.6); and 47.17 for (3.5) and (3.6). These F valves are significant at .01 level.

[20] That output would double by doubling deep-well irrigated land, all other inputs held constant, does not seem to make sense.

importantly, productivity coefficients of land composite underscore the high payoff from land improvements even in irrigated hectarage. From surface water to deep-well pumps, the benefit is already considerable. From an unirrigated state, the payoff to land improvements would even be more dramatic.

The comparative magnitude of labor coefficients in regressions 3.5 and 3.6 appear consistent with population characteristics. The coefficients fit in an expected pattern of association with population characteristics in table 11. Compared with A, group B has greater urban influence, literacy rate, income tax per capita and average annual budget surplus. The estimate of labor productivity is highest in group B (β_{42} = .0902) and lowest in group A (β_{41} = -.1181).

There are a number of reasons to associate labor quality with degree of urbanization, income tax collected per capita, average family budget surplus and literacy rate. They are general indicators of economic activity and labor opportunities. First is the nature of labor allocation. That a farm is a residual claimant to household labor is commonplace in the Philippines. Assuming flexibility from one use to another, the opportunity cost of labor rises with more off-farm employment. People become more conscious about cash wages and would remain in farming only if comparatively more productive. Second, the probability is greater for farming to be more a business than a way of life in places where alternative sources of livelihood are relatively easier to come by. There would

be some pressure to be more efficient. Third, the literacy rate possibly reflects differences in educational facilities as well as the ability to avail of existing extension aids and services.

The negative labor coefficient in group A is certainly puzzling. There are several possibilities. The first suspect is measurement bias. There may be a greater tendency to overestimate labor input in rural areas, where alternative employment for household members is relatively scarce. Anybody who is unemployed off the farm may conceivably be counted in as potential farm worker. However, the enumerators of IAS 1972 were supposedly adequately trained and supervised. Further the survey questionnaires were systematically checked and edited. Presumably, these safeguards would have minimized reporting errors. Furthermore, theoretical reasons suggest that under certain conditions measurement errors alone could not have caused a negative estimate of labor productivity.

To simplify exposition, consider a two-variable relationship, rice production and labor input. Let there be measurement errors in the labor input L:

$$L = kL_t$$
$$\ln L = \ln L_t + \ln K$$
$$X = X_t + E \qquad (3.13)$$

variables with subscript t are assumed to be true values. Assuming that the error E is uncorrelated with anything but itself, the asymptotic bias will be:

$$\operatorname*{plim}_{n \to \infty} \beta - \beta = \frac{-\beta}{1 + \sigma^2_{X_t} / \sigma^2_E} \tag{3.14}$$

and the probability limit of the estimator is

$$\operatorname*{plim}_{n \to \infty} \hat{\beta} = \frac{\beta}{1 + \sigma^2_E / \sigma^2_{X_t}} \tag{3.15}$$

where β is an OLS estimator of β, the true labor productivity, σ^2_E and $\sigma^2_{X_t}$ are variances of E and X_t, respectively.

The magnitude of the asymptotic bias essentially depends upon β and the ratio of σ^2_E to $\sigma^2_{X_t}$. If $\beta > 0$ but very close to zero, the asymptotic bias is correspondingly small. That is:

$$\lim_{\beta \to 0} (\operatorname*{plim}_{n \to \infty} \hat{\beta} - \beta) = 0$$

In addition, σ^2_E relative to $\sigma^2_{X_t}$ can not be exceedingly large considering the quality control in data collection. In fact, should K in 3.13 be a constant, our estimator would be asymptotically unbiased. On the other extreme, when the ratio is high,

$$\lim_{\sigma_E^2 \to \infty} (\text{plim}_{n \to \infty} \hat{\beta} - \beta) = -\beta \tag{3.16}$$

which proves that the bias is at most equal to the absolute value of the true elasticity. The parameter can be underestimated only up to its extent or size. With respect to the asymptotic limit of the estimator, simplifying 3.16 or equivalently from 3.15

$$\lim_{\sigma_E^2 \to \infty} (\text{plim}_{n \to \infty} \hat{\beta}) = 0 .$$

With the measurement bias uncorrelated with anything but itself, the estimator β would range from zero to β. Thus, can be negative if and only if β is really negative. Equation (3.15) also precludes inconsistent signs for $\hat{\beta}$ and β.

Negative labor productivity in some regions may not be entirely inadmissible in view of conditions in remote areas.[21]

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[21]On the surface it may look as though labor coefficient changes sign in the same production function. This is seemingly inconsistent with the invariant elasticity associated with a linear logarithmic model. This is definitely not the case. Remember that in the formulation, I separated labor input by regions and estimated essentially separate production function for each labor category. In a labor surplus situation, it is feasible to obtain a negative elasticity.

Lack of alternative employment may have contributed to inefficient labor use. People would not normally remain idle when other household members are busy in the farm. In other words, the motivation for working may not necessarily be productivity. Moreover, the existence of excess labor is conducive to labor substitution for other inputs. To use labor, even if free, to an inefficient level may be irrational. But there is not evidence to presume that farme could allocate labor knowledgeably. Farmers are probably not exact conscious of production-labor relationships as to be able to detect counterproductive labor use.[22] In the absence of cash expenditure, farmers may not be overly concerned about how much labor is employe in the farm.

If the true labor coefficient is in fact nonegative, the theoretical explanation for the negative estimator is the correlation between the measurement error and the true labor input. If E is not independent of X_t, then:

$$\underset{n\to\infty}{\text{plim}}\ \hat{\beta} - \beta = -\frac{(\sigma_E^2 + \sigma_{X_tE})\beta}{\sigma_{X_t}^2 + \sigma_E^2 + {}^2\sigma_{X_tE}}$$

[22]The decline in output as labor increases is not a within-farm phenomenon. This could be one reason why a farmer may not necessarily be aware how his labor supply affects labor productivity. It would be extremely difficult for a farmer to observe that he puts in more labor than necessary if he does not experiment with varying amounts of labor input in his farm. Any difference in rice production that occurs between him and another farmer which is due to labor input may easily be wrongly attributed to other factors.

$$\underset{n \to \infty}{\text{plim}}\ \hat{\beta} = \frac{(\sigma_E^2 + \sigma_{X_t E})\beta}{\sigma_{X_t}^2 + \sigma_E^2 + 2\sigma_{X_t E}} \tag{3.17}$$

Notice that (3.17) reduces to (3.15) if I revert to the previous assumption that $\sigma_{X_t E} = 0$. A necessary condition for the plim $\hat{\beta}$ to be negative is $\sigma_{X_t E} < 0$.

The labor variable, as measured in the survey, is really the supply of family labor in terms of the number of household workers available. Since the stock of labor is relatively fixed within a farm, as more labor is actually employed, the residual unemployed labor diminishes. Thus, the error of measurement declines with increasing labor input. In the limit, the actual labor employed equals the stock of labor.

The necessary and sufficient condition for a negative plim $\hat{\beta}$, is β is nonegative beco

$$\frac{\sigma_{X_t}^2 + \sigma_{X_t E}}{\sigma_{X_t}^2 + \sigma_E^2 + 2\sigma_{X_t E}} >$$

or more simply:

$$\sigma^2_{X_t} \qquad \sigma_{X_t E} \tag{3.18}$$

Condition (3.18) follows from the fact that the denominator of (3.17) being the variance of X, is always nonnegative. Further, (3.15) subsumes the necessary condition that $\sigma_{X_t E} < 0$ since it will be satisfied if and only if the covariance between X_t and E is negative.[23] Remember that by definition $\sigma^2_{X_t}$, the variance of X_t, cannot be less than zero. Thus, it can only be less than a positive quantity or the negative of a negative value.

Under the assumption that $\sigma_{X_t E} = 0$, unfortunately, there is no way to infer how the absolute magnitude of plim $\hat{\beta}$ relates to β. However, judging from the estimates vis-a-vis what one would normally expect, the bias from measurement error could be worst in the rural area. The bias may expectedly be less serious when alternative employment can be identified easily.

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[23]It is shown carefully in Appendix C that a negative covariance between X_t and E has some implications on the covariance between X and X. Appendix C proves that inconsistent signs between plim β and β would be possible under very restrictive or unrealistic situations where the measurement error is overly glaring. While the inconsistency in signs is theoretically possible from measurement errors, it may be ruled out on an empirical basis.

Another plausible explanation for the negative labor elasticity would be the omission of power input from the regression. In the rural area, there might be a negative correlation between labor and mechanical power inputs because of surplus stock of labor. This negative association or the substitution of human labor for mechanical power could lead to a negative omitted variable bias. If the labor productivity is positive but near zero, the negative bias could possibly result in a negative estimator.

Regression (3.4) possibly underestimates the elasticity of nitrogen. It was only half as large as in the better specified regressions. In regression (3.5), the nitrogen-variety interaction was significant but negative; leaving the impression that traditional varieties would respond more to fertilizer. The inference directly contradicts the common knowledge about the high-nitrogen-response of modern varieties. The inferior resistance of modern varieties to tungro virus accounts for the bias. Crop losses from infestation negate the advantage of modern varieties. The nitrogen-variety interaction term integrates partly some decline in rice output. Adding tungro virus variable to regression (3.5) seems to correct the problem. The interaction term vanishes and becomes statistically insignificant. Interestingly, there was no differences between traditional and modern varieties in field level response to nitrogen during the crop season analyzed.

3.10 Neutral Productivity Differences

Omitted variables could lead to substantially smaller

efficiency estimates for modern rice varieties. The estimate ranges from 0.1489 to 0.2333. In regressions (3.4) and (3.5), the varietal coefficient absorbs a portion of greater disease damage for modern varieties which creates downward bias. The estimated shiftor in either regression (3.4) or (3.5) would reflect neither the full potential of new varieties under ideal disease-free situations nor the separate impact of pest and disease. Regression (3.6) would have both. In logarithmic scale, the production function shifts upward by 0.2333 for modern rice. However, tungro virus incidence shifts it back by 0.2540. For areas affected by the cirus, traditional varieties proved superior to modern varieties.

Chemical use accounts for some neutral production differences. Regressions (3.5) and (3.6) indicate insignificant gains from plant protection chemicals in traditional varieties. For modern varieties, production is inversely associated with chemical use. These findings would be realistic only when chemicals are employed for curative rather than preventive purposes. In effect, chemical application was a proxy for pest and disease problems. Again, differential resistance to these problems surfaces by varieties. Certainly, the natural resistance of indigenous traditional varieties can be instrumental in preventing crop losses. Prophylactic application of chemicals is more critical for modern varieties and presumably, brings greater

Taking regression (3.6) the varietal shiftor is 0.2333 but is negated by chemical-variety coefficients of -.1265 resulting in a net shiftor equal to 0.1068. Therefore, with normal pest and disease problems and without changing the respondents' way of chemical use, new varieties could still be expected to perform better than traditional varieties. By improving cultural practices at the farms, the advantage is apt to increase. However, the incidence of tungro virus would wipe out any remaining benefits from modern varieties. In fact, the tungro virus damage would more than offset the varietal advantage even without other pests and diseases. Fortunately, tungro virus outbreak is an extreme case which has occurred only infrequently.

The intercepts for land quality of irrigation source look reasonable when relative productive efficiency is related with drainage characteristics of the farm. Relative to deep-well irrigated lands, those served by the gravity and surface water system appear to have better drainage. Consequently, the intercepts for surface water and gravity irrigation rank high with 0.0665 and 0.0636, respectively. Shallow-well irrigated farms probably have the greatest drainage problem since they have lower intercept (-0.1152) than deep-well irrigated farms.

With regard to soil, it is unrealistic to expect the provincial soil profiles to exactly match the soil composition of individual farms. The soil variable is a composite index of the general soil characteristics of the region. Physical soil

properties determine water holding capacity and drainage. With irrigation, especially during the rainy season, the drainage characteristics of the soil would be relatively more important to production than water holding capacity. The capability to provide water from rainfall or existing sources precludes significant water (drought) stress on the rice plants. Relatively speaking, the order of soil coefficients is invariant between regressions 3.2 and 3.3. Farms from provinces in soils group B registered significant improvement of rice productivity as compared with those in group D. The shift (0.2130) almost equalled the advantage of modern over traditional varieties. In general, the soil coefficients correlated positively with loamy soils (table 14).

Soil and land quality coefficients imply a higher productive efficiency as drainage improves. The positive association between drainage and productivity is reasonable for a variety of reasons. One is soil fertility. Better drained soils are more aerobic and favorably promote decomposition of organic matter. The process provides a natural supply of nutrients. Drainage characteristics influence disease control. Draining the field after harvest would deny any host vegetation for the pathogen to complete its life cycle. Further, lighter soils are easier to work with during land preparation and other operations like weeding. These can add up to considerable production advantage for soils with less clay whenever irrigation can be assured.

The rainfall coefficients in regressions (3.5) and (3.6)

conform to expectations. Rainfall group C is at least in terms of relative efficiency, followed by groups B and D. Rainfall group A has the highest shiftor. Perusing the normal rainfall patterns (table 20) reveals that the production function shifts downward with increments in third quarter rainfall.[24] The predominant impact of rainfall manifests through its inverse association with solar radiation. Further, heavy rainfall could lead to undesirable flooding and, by itself, may be a good indicator of inclement weather Typhoons would not only cause considerable crop damage but would also create risks which may condition farmers to reduce input use.

Among infrastructure groups A, B and D, no significant difference in productive efficiency is evident from table 25. In contrast, group C registered strikingly large shiftors. In regression (3.6) the shiftor for infrastructure group C, 0.1870, is next only to the varietal and soil shiftors. The results seem puzzling in the light of regional variations in agricultural infrastructures. Of course, group C is noticeable different from the rest with respect to roads, milling and warehousing capacities. Region C has greater relative milling and warehousing capacities and the least road network in terms of density and quality. But the implication is a negative correlation, at least, between roads and productive efficiency. It might be plausible to argue that milling and storage capacities would be more critical where inter-regional flow of commodities is hampered by unfavorable roads. The

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[24]The rice crop analyzed here is harvested primarily in October and November. September and December harvests were also reported.

positive impact in group C could have been the interaction between road condition and capacities. Storage and processing capacities might significantly affect productive efficiency only when they are indispensable. However, there was some ambiguity in the provincial data with regard to these capacities as to preclude a definitive inference.[25]

In areas with poor roads, transport costs are expectedly relatively high. The added cost could partially be passed to the farmers in the form of lower farm price. It might be possible that the low price has a perverse effect on efficiency. There might have been an economic pressure to improve efficiency. Inefficient procedures could have been driven out of production and those who could remain, in general, would only be the highly efficient ones.

It is quite possible that the infrastructure dummy for group C, in fact, might have captured a location effect. Mindanao presumably has fertile newer lands and is endowed with favorable rainfall patterns. Comparing tables 10 and 22 shows a majority of provinces in infrastructure group C belongs to A in the rainfall classification. Further, Cotabato and Davao which account for the bulk of respondents from group C in table 10, are expected to have a rainfall pattern similar to Bukidnon.[26]

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[25]See the latter part of Section 2.6.3.

[26]In the absence of provincial rainfall data for Cotabato and Davao, they are not included in the discriminant analysis for second semester rainfall but are assumed to have a rainfall as Bukidnon.

3.11 Regional Productivity Implications

Interregional productivity is a composite manifestation of a number of factors. To rationalize the regional variations, I attempt to break the total difference into the component parts. Table 26 summarizes the relative production in various agricultural regions. With group D as a basis, the statistical regression results are transformed into production indices. These are measures of the partial influence of the agroclimatic characteristics. For example, the ratio of 1.0554 for A/D says that the production in region A is higher on the average than region D by 5.54 percent due to differences in land resource. Similarly, the ratios for labor would imply that rice production could be expected to be 17.38 percent lower in region A and 15.64 percent higher in region B relative to region D because of the differences in the population characteristics. The productivity ratio for any pair of regions can be obtained by dividing the corresponding indices. Regions A and B can be compared by taking the ratio of A/D to B/D in order to get A/B.

Table 26. Estimated partial impact of region. Specific factors on farm productivity, wet season, 1971

Explanatory Variables	Productivity Ratios		
	A/D	B/D	C/D
1. Land Resource[a]			
Neutral Component	1.0657	1.0688	0.8912
Response Difference Component[b]	0.9903	0.8812	0.8931
Total	1.0554	0.9418	0.7959
2. Agricultural Infrastructure	1.0000	1.0000	1.2056
3. Labor Resource[b]	0.8262	1.1564	1.0000
4. Soil Type	1.0958	1.2386	0.9404
5. Rainfall	1.1688	1.0000	1.0000

[a]The base for comparison is deep-well irrigated farms. Gravity irrigation corresponds to A, surface water to B and shallow-well pump to C.

[b]The productivity is evaluated at the overall mean level of inputs.

It would have been highly informative if the stability of the ratios could be established. Unfortunately, the productivity index is a ratio quantity. Even if the estimated variances of the original elements are obtainable from regression results, the variance of their ratio would not be a simple statistical concept.

One might infer from table 26 that the composite difference n production would conceal the sizable influence of each agro-limatic variable on rice production. The composite variation is summary measure which may have a limited usefulness from the erspective of development planning. It would show the differences in a gross way but would not explain how the differences come about. More seriously, large but nearly offsetting component effects would be undetected by focusing on the composite difference. What are most interesting for development planning purposes would remain hidden.

Land improvement would be a source of large output growth as shown by up to 21 percent difference in rice production between shallow-well and deep-well irrigated farms. Similarly, the production indices for labor resource and agricultural infrastructure range from 0.8262 to 1.1564 and from unity to 1.2056, respectively. These values would imply that labor quality alone could increase farm production by more than 30 percent. Favorable soil texture might account for over 25 percent increase in rice production. Soil texture is perhaps fixed or unalterable. But soil management and related cultural practices could be employed to approximate the conditions in favorable textured soils. Rainfall, as it relates to solar radiation, is another fixed environmental factor. If irrigation is assured, there exists the possibility of adjusting to the rainfall pattern. Cropping calendar could be planned so as to bring a coincidence between maximum solar radiation and grain filling stage.

Table 27 presents the production ratios due to factors which are not region specific. The figures represent the expected production variations between modern and traditional varieties which may be explained by seeds, pest and disease infestation, and tungro virus. Under field conditions, the modern varieties have a potential of producing about 26 percent more than the traditional varieties. But the observed yield advantage of the new seeds is less than 26 percent because of its weaker resistance to pests and diseases. In this case, its production advantage decreases to about 11 percent. Or equivalently, with pest and disease damage, the production ratio between modern and traditional varieties is 1.1137 (1.2627 x .8812). Certainly, with tungro virus infestation, the modern varieties would even be less attractive than the traditional varieties.

Table 27. Comparative rice production between traditional and modern rice varieties

	Production Index: Modern/Traditional Rice
Variety	1.2627
Chemical x Variety Interaction[a]	0.8812
Tungro virus	0.7757

[a]Recall from previous discussion that plant protection chemicals is applied for curative purposes and is an approximate proxy for the presence of pests and diseases, other than tungro virus.

CHAPTER IV

IMPLICATIONS FOR DEVELOPMENT PLANNING AND FUTURE RESEARCH

4.1 Uses of Regional Delineation

Delimitation of homogeneous areas is fundamental to capacity building in agriculture. A characterization of regions is quite essential to be able to identify the needs and to orient research activities towards the evolution of technologies and investments adaptable to the economic and physical setting of various regions. An inventory of regional characteristics and their agroclimatic differences would be helpful to locate areas where capacities exist or where they can be developed.

The statistical results suggest that the correspondence between administrative delineations of regions and agroclimatic classification is quite weak. It is not unexpected. The purposes for delineating them, not to mention the number of regions, differ. And so the regional compositions would also differ. The weak correspondence between the two would imply that the homogeneity with respect to the agroclimatic environment is independent of the administrative divisions. For development planning purposes, the administrative delineation might be inappropriate for determining development regions. The needs are region-specific but would not necessarily be homogeneous within administrative jurisdictions.

Perhaps, it is quite impractical, if not infeasible, to

propose to discard the administrative regions in favor of the agroclimatic classification. It would be extremely difficult and may be unacceptable to revise completely the administrative regions to conform to the agroclimatic structure. The administrative regions do not reflect the aggrupation of areas with homogeneous characteristics but they serve other legitimate purposes. Among other things, the administrative structures are set up to insure efficient implementation of government policies and programs by designating the areas of responsibility such that each jurisdiction would extend over a consolidated geographic region. In comparison, the agroclimatic regions consist of scattered provinces and would provide an efficient base for administration. Besides, the distribution of provinces changed substantially from one agroclimatic set of factors to another.

It would be easier to superimpose the results of the agroclimatic delineations on the existing administrative structure. Development regions could be defined from the results presented in Chapter II. The distribution of provinces based separately on each set of agroclimatic variables may be combined so as to be able to identify homogeneous subregions in terms of the composite agroclimatic environment. To map the composite subregions would greatly simplify the statistical results for policymaking purposes. The analysis suggests some evidence of significant regional variations in the environment. In addition, the regional differences were found to explain some of the variations in rice production. The

implication is that agricultural programs would have to be differentiated between areas with dissimilar agroclimatic environment. The composite subregions would be helpful in knowing which areas in each administrative region could be treated similarly for program purposes. In this way, agricultural development programs could be conceived on the basis of specific needs and could be implemented by the administrative machinery in the appropriate subregions. The scarce development resources would not be dissipated because there would be a correspondence between the development problem and the program to relieve the problem in each specific subregions.

The system of agroclimatic regions would be helpful also to other research such as in setting up detailed agroeconomic experiments to establish more accurate estimates of production parameters.[1] The scheme of regions may be employed to narrow down the location of intensive studies. By examining individual profiles,[2] the investigator could select appropriate core areas to locate agroeconomic experiments either for intra- or inter-regional comparative analysis such that as wide a geographic range as necessary would be included. It is then a simple step to

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[1]For example, the International Rice Agroeconomic Network project currently in progress at the International Rice Research Institute could possibly utilize the delineation in projecting the results of intensive analysis to a regional dimension.

[2]Appendix B contains the individual profiles of provinces

identify operationally the geographic bounds over which the results of intensive studies could be related without the need to duplicate the studies in each and every province.

Similarly, the agroclimatic classification is relevant to experimentation, for example, in field trials of varietal performance in different environments. The regional scheme is useful: (1) to know the range of environment for which adaptable varieties should be developed; (2) to insure that tests cover the whole range of distinct environment; (3) to eliminate unnecessary duplication and reduce the cost of experimentation; and (4) to draw some conclusions as to what is suited to which areas. Along the lines of varietal testing, constructing a regional classification that includes several countries could be justifiable since several areas in different countries may be similar.

To the practitioners of development planning, the characteristics of the provincial groups could present some guidance in the search for constraints to agricultural productivity.[3] The constraints and potentials would determine which development activities are feasible, what can be undertaken in what regions, and which is likely to bring the highest payoff. The land resource

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[3]The constraints would be important to any attempt for a balanced development. Integration of growth and regional income distribution goals in agricultural development necessitates eliminating the specific factors which inhibit the transfers of technical efficiency, Without conscious efforts to deal with such restraints, continued imbalance in regional growth is likely to accentuate disparities in income. Further, the inability to generate widespread distribution of productivity gains throughout the economy has been closely associated with agricultural stagnation and with the failure to utilize growth as a vehicle of a viable and dynamic process of sustained development (M. E. Abel and K. W. Easter, 1971).

characteristics present a good illustration.[4] Interestingly, there was a striking lack of positive relationship between irrigation and effective cropping index. In fact, the characteristics of regions A and D would suggest a negative association. It would seem immediately evident that the development of the irrigation facilities augmented the land supply which was not effectively utilized. The existing irrigation potential was not exploited to the full extent in terms of increasing the rice output through a greater cropped area.[5]

It should be remembered that the census data relate to the period before the development of modern rice varieties, the photoperiod insensitive, nonseasonal, short maturing varieties. The greater double cropping in region A than in region D could perhaps be explained by the differences in rice culture rather than the state of irrigation. Provinces in region A grew more upland and rainfed rice. Those in region D, mostly in the Central Plains of the Philippines cultivated lowland rice. During that period, the critical constraint to greater production was not irrigation but the lack of a lowland rice variety which could be grown fast enough regardless of daylengths to permit double

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[4]Refer back to table 5 in Chapter II for a review of the land characteristics of the regions.

[5]The irrigated land may be more productive so that rice production could have increased even if the effective cropping area did not change.

cropping.[6] Even more significant to note in this situation is that the benefits from improving the irrigation facilities were severely restricted by the more basic constraint which was the absence of nonphotoperiodic rice variety. The example aptly demonstrates the temporal sequence of relationship among the constraints; that is, the sequence of dealing with the constraints is just as crucial as eliminating each of them. Whichever is most limiting must be dealt with first. Otherwise, some effectiveness of the strategy would be sacrificed. Also, as the major constraint is eliminated, the other formerly minor factors could assume a greater importance. Whereas the gains from irrigation and credit program in region D during the 1960's would have been limited, the progress in rice breeding has completely altered the situation during the 1970's.

4.2 Opportunities for Increasing Rice Output

The statistical results of the production function analysis could suggest some alternatives to development planners. Undoubtedly, the evidence is ample that external factors do influence agricultural output. Some of the significant external factors are reproducible and alterable. The linkage between farm production and the regional

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[6]Compare the characteristics of traditional lowland versus the upland rice varieties. From sowing, Binato, an upland variety flowers in 62 days if daylength is 8 hours; 95 days if it is 16 hours. In contrast, Intan, a lowland variety takes 80 days from sowing to flowering for 8-hour daylengths and 149 days for 16-hour daylengths. This comparison would imply a longer growing period for the lowland areas. Also, the lowland variety exhibits greater photoperiod sensitivity which causes the rice plants to flower only during a certain time of the year.

environment implies that there could be some leeway to build capacities in the agricultual sector, particularly, in rice.

Augmenting or improving the land resource is the first possibility. The land resource has been the dominant agricultural input and has been the primary source of output. Unfortunately, of all inputs, the land resource probably has the most inelastic supply. To develop the irrigation facilities would be tantamount to increasing the amount of land available for cultivation. Agricultual output could be expected to increase because the cropping intensity would increase and the average productivity would also increase due to better quality lands. The information about the production regimes in different irrigation situations could be utilized to evaluate comparatively the various modes of irrigation. The evidence at hand would suggest unmistakably that one way to generate additional output is to improve water control in the rice farms.

The technological constraint represents another critical dimension in the strategy for increasing the rice output. The development of modern varieties has definitely been beneficial to rice production in the Philippines. The evidence in support of this is incontrovertible. The statistical results in the preceding chapter showed that the new seed technology has improved rice production. In irrigated areas, the estimated increment in rice output amounted to about 26 percent. The increase is a partial one that could be achieved just by shifting to the improved varieties

and would not include the other benefits that would accrue from other production changes. However, the potential benefit from the modern varieties was reduced by tungro virus damage as well as by a greater susceptibility of the new varieties to pest and disease. Given the neutral advantage, the modern varieties would produce more than their traditional counterparts irrespective of input levels and traditional cultural practices. The farmers possibly adopt the modern varieties because of the higher technical efficiency. Nevertheless, the risk from pest and disease damage may have discouraged corresponding increments in applying purchased inputs like fertilizers. The physical attributes of the modern varieties make them resistant to lodging and consequently more tolerant and responsive to high nitrogen dosage than the traditional varieties. Such advantage of the modern rice varieties may not have been adequately exploited at the farm level because of the risk from pest and disease damage.[7]

To extract the full benefits from the availability of modern varieties and make rice production based more on inputs with more elastic supply, adequate disease control must be developed to reduce production risks. There may be several possible methods of pest and disease control such as to breed resistant varieties, biological control, or to develop and stimulate the adoption of the cultural

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[7]In India, for example, insect problems almost eliminated the modern varieties during the wet season in Sambalpur village (K. W. Easter, 1974).

practices appropriate for breaking the transmission and life cycle processes of the pathogens and their carriers. The latter would involve early detection of disease problems, judicious spraying of plant protection chemicals, good water control and other farm management practices. Certainly, there is a need to determine the best method of disease control. The choice of any method would depend upon the cost and return associated with each alternative. Where the crop cover is relatively quite homogeneous as in major rice areas, it would also be necessary to recognize the externalities in pest and disease control. To be totally effective, pest and disease control measures should be adopted and coordinated by all farmers in a particular area so as to eliminate every possible source of disease. If the pathogen has been effectively eliminated, there would be no infestation even though the host and the disease carriers may be present. Otherwise, there would always be some risk of disease incidence.

That other region specific factors significantly account for production differences has also been indicated. Some regional factors may be fixed in nature like soil composition and the rainfall pattern. They help rationalize production differences but nothing much could be done to alter them. With respect to the rainfall pattern, the choice would perhaps be limited to adjusting the cropping pattern or planning the crop calendar as to suit the natural environment. For soils, no practical way is available to modify the basic composition but it just might be possible to achieve the

desired effects of favorable soil texture through other means. For instance, the lighter soil textures could be simulated by providing adequate drainage and the organic fertility in some types of soil could be replaced by chemical fertilizers.

The labor productivity in rice farming varied across regions with distinct population characteristics. The relative ordering of the regional labor productivities appears to be reasonable. The direct association between labor productivity and employment opportunities reflected the wage rate differentials between urban and rural areas. The predominant dependence of rural labor on agriculture resulting from the absence of alternative sources of income depressed labor productivity. This underscores the need to sustain improvements of labor absorbing rich technologies It also implies that the rural areas stand to gain larger benefits in terms of labor absorption and income from any progress made in agriculture. The surplus labor in the rural areas is as much an issue in increasing output by employing the abundant resource as it is in attempting to achieve a more equitable income distribution between urban and rural area. It also gives a hint to the policy-makers to be carefully selective of the regions where mechanization in rice production should be advocated.

There is some ambiguity in the observed association between agricultural infrastructure differences and technical efficiency in rice production. In three of four regions, the technical efficiency remained unaffected by agricultural infrastructures.

But one region registered an unmistakably significant shift in rice production. It would appear that this evidence might be inconclusive for reasons that have been cited earlier. The roles of agricultural infrastructures in promoting the growth in rice output remains unclear. On the technical side, the impact of the infrastructures, at best, appears to be confined to a single region. However, the present analysis would not preclude any influence that they may bear upon the availability and the level of input in the different regions.

4.3 Future Research Directions

To sum the discussion in the preceding section, there are several possibilities to stimulate a long term growth in rice output. It may be done through the development of land and labor resources, as well as by improving the cultural practices with regard to plant protection, crop planning, and the adoption of modern varieties. In short, the study suggests possible factors to examine when attempting to develop the capacity of the agricultural sector. As they are, the statistical evidences presented here would not directly assist the policymakers to make a decision with regard to the problem of choosing among the alternatives and the temporal sequence of development activities.

4.3.1 Benefit-Cost Analysis. For practical purposes, the policymakers require more than merely identifying the possible development activities. The strategies are not necessarily

mutually exclusive. Nevertheless, there is a problem of choice. The scarcity of resources for development imposes the selectivity as to what should be done first and which region should have the highest priorities with respect to the different activities. Selecting development regions is needed in view of the differences in regional environment and in order to maximize the returns from the development expenditures. In other words, there has to be a ranking of priorities. Clearly, a benefit cost analysis is the logical extension of the present analysis. Nothing has been done so far to evaluate the possibilities that compete for scarce development resource and translate their relative desirabilit in terms of benefit-cost ratios. Nevertheless, the study contains the basic elements for benefit-cost analysis.

The production indices the expected change in rice output from improving the separate facets of the agroclimatic environment The same is true with the figures presented in table 27 in the preceding chapter. For example, the stream of benefits from the modern varieties, pest and disease control, and tungro virus control can be calculated from the production ratios. With a base yield per hectare of 1,665.36 kilograms of rough rice[8] from traditional varieties, the advantage of modern varieties would amount to 437.49 kilograms of grains per hectare during the wet

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[8]The reference yield level is based on the aggregate mean production of the respondent farms used in the regression analysis. Strictly speaking, the benefits calculated in this section would vary by province depending upon the production function corresponding to the specific agroclimatic characteristics.

season. The present value of the wet season benefits, assuming a real rate of interest of 5 percent per annum, is 8.75 tons of grains per hectare.[9]

The production losses incurred because of tungro virus, other diseases, and pest would be equivalent to the potential gains from controlling them. What a farmer loses from pest and disease problems is what he stands to gain from eliminating them. For example, if tungro virus could be avoided, the addition to the rice yield would amount to 469.34 kilograms per hectare. However, considering the frequency with which the tungro virus had occurred and damaged the rice crop in the past,[10] the expected gain would amount only to 31.29 kilograms per hectare per wet season. Assuming that the tungro virus is permanently eliminated, either through varietal resistance or some other means, the wet season benefits would be forthcoming permanently.[11] The discounted value of the

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[9]This refers to the benefits accruing to the wet season crop only. If one considers whatever benefits derived during the dry season, the total benefits would be larger.

[10]The tungro virus has been known to have damaged the rice crops in 1941 and in 1957. Including 1971, the average probability of occurrence would be once in every fifteen years. The new varieties are more susceptible than the traditional varieties. Consequently, there would be more benefits from building resistance in the new varieties. In other words, using the probability of tungro virus damage in the traditional varieties to calculate the expected benefits would create a downward bias in the estimate.

[11]The calculation of the present values of the benefits assumes a stream of perpetual returns to pest and disease control. Alternatively, the benefit cost calculation could be made on an annual or seasonal basis; that is, the pest and disease control may be assumed to effective only within each production period. However, the basic elements of the benefit cost analysis would remain the same.

benefits, at 5%, would be 625.80 kilograms of rice per hectare. With regard to other pest and disease, they have occurred and damaged the rice crop much more frequently. Consequently, the potential benefits from controlling pest and disease other than tungro would be larger. If the pest and disease control is permanent, the benefits would be generated year after year. Based on the regression results, there would be an additional production of 197.84 kilograms per hectare during the wet season if there was no pest and disease damage. At a real discount rate of 5 percent, the present value of the additional yield generated year after year is 3.96 tons of grains per hectare.

The benefits above are calculated with the implicit assumption that other inputs and cultural practices are held at the traditional levels. If the risks from pest and disease impede the adoption of practices complimentary to the new seek technology, then controlling them would generate additional benefits to the extent that the elimination or reduction of production risks has stimulated greater application of inputs. Further, the future improvements in the production resources which expand the absolute cropping area and/or the intensity of planting would likewise increase the total benefits from the seed technology and control of pest and diseases. In term of the research expenditure on, say, breeding resistant varieties, the development cost per hectare also diminishes.

For region-specific programs, the agroclimatic characterization provides a framework to define the appropriate grographic

constraint, to project the aggregate benefits and to identify the regional income distribution effects associated with the program. Whether public programs may be decided on the basis of cost effectiveness or income distribution effects or both, the regional classification and the production relationship in each environment can be utilized.

4.3.2 Constraints to Input. In addition to the nature of response functions, the intensity of input application is the other determinant of the level of production. Consequently, the economic and sociological constraints to the use of input are crucial to agricultural development. They represent another avenue for increasing agricultural output.

The present analysis concentrated on establishing the production parameters in different regional environments and separated purposely the issue of economic efficiency. However, there is a direct linkage between the technical and economic aspects of production. For one thing, the term constraint implies knowing what is achievable or desirable. In the case of farm inputs, the normative demand is derived from the technical relationships and is also contingent upon the economic and sociological variables.

Identifying the constraints therefore requires the correct specification of the underlying production functions. The technical information contained in this study can be used to generate the derived demand functions for inputs. Economic and related data can be superimposed to estimate what input levels should have been

applied. In turn, the normative levels can be compared with the actual usage. Presumably, the divergence between the actual and normative levels might be a rough indication of the existence of constraints. In any event, using the farm level response relationships provide a standard for comparison and assures a more realistic basis for comparing how much inputs the farmers use with how much they ought to use, given the specific environment under which they operate. Further, the regional differences in input demand explainable by external factors would be adequately recognizable, thereby minimizing the chances of attributing such differences to the wrong reasons. Thus, inappropriate strategies from mistaken diagnosis could be significantly avoided or eliminated; for example, trying to stimulate input use which is in fact constrained by technical factors or the physical environment through an input subsidy or a credit program. The estimated technical parameters can be utilized to project the benefits from relaxing the constraint on inputs. The practical limits of government programs can also be calculated for different regions under existing technologies. With regard to the labor input, the negative elasticity would warrant a further analysis. It would be highly useful to verify the role of labor in rice production in the rural areas since labor is an abundant resource and agriculture is the primary source of employment in those areas.

4.4 Other Implications

The basic unit of analysis has been imposed on this study

by the availability of data. The province, as a unit of analysis, leaves much to be desired. Intraprovincial variability may be quite significant especially in the island provinces. Compared with continental countries like India or Thailand, the Philippines seems to warrant smaller building blocks for the agroclimatic regions. Over a fixed linear distance, one may expect greater variability among islands than comparable areas in a continent with respect to the topography, vegetation, rainfall and other physical characteristics. To assist development planning, there has to be a supporting and adequate data base on agroclimatic factors for areas smaller than a province, perhaps at the municipality level. The necessity for adequate information follows from the fact that the merits of a program depends on the wisdom of the supporting analysis. The results can only be as reliable as the data analyzed. Further, the agroclimatic characteristics change either as a natural course over time or as the existing programs to modify them take effect. Some may change rapidly. For others, the transformation may be imperceptible over short periods of time. Whenever necessary, periodic updating of the agroclimatic information would be highly desirable to reflect the changes that had occurred. The frequency of reporting such statistics should correspond to the nature of the agroclimatic variables.

For similar reasons, the national survey of production and inputs at the farm level should be conducted on a regular basis. I would like to see the inclusion of the information on hired and family labor, animal and mechanical power actually utilized in the

production process. The survey data must be self-contained and should include the prices paid and received by farmers in the same questionnaire and for the same respondents. In this way, there is a buit-in way of developing a time series of complete cross-section data system. Only with the availability of dependable statistics can the researchers come up with stable estimates, and furnish the policymakers with information needed to design, analyze and evaluate development strategies and programs.

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APPENDIX A

DISCRIMINANT FUNCTION COEFFICIENTS

APPENDIX A

The coefficients for classification are presented in Table A1 below. There are seven sets of four discriminant functions, one for each set of agroclimatic criteria. Every set of four discriminant functions is used independently of other sets. There corresponds one discriminant function for each group in every set. For example, for set I, Rice Productivity, the coefficients of the discriminant function for Group A appear in the first column, those for Group B appear in the second column, etc.

The coefficients in Table A1 may be used to classify new observations into the groupings delineated in this thesis, provided the new observations have the same data relating to all variables in the agroclimatic set within which a classification is to be made. Let me illustrate. Assume that there is an additional case to classify in the productivity groups and that there are data on rice productivity from 1970 through 1974. The ollowing functions are evaluated:

$$F_A = -71.74 + 2.5116X_1 - 0.0289X_2 + 0.3214X_3 - 0.0047X_4^2 + 0.2909X_5$$

$$F_B = -108.88 + 3.7932X_1 - 0.0951X_2 + 0.2562X_3 + 0.0887X_4^2 + 0.0177X_5$$

$$F_C = -140.84 + 4.4145X_1 - 0.0532X_2 + 0.3035X_3 - 0.0622X_4^2 + 0.0522X_5$$

$$F_D = -174.84 + 5.2094X_1 - 0.0994X_2 + 0.3238X_3 - 0.1563X_4^2 - 0.0662X_5$$

Table A1. - A Summary of Coefficients of the Final Discrimination Functions for Classifying the Provinces According to the Agroclimatic Variables

	Coefficients for Group			
	A	B	C	D
I. Rice Productivity				
1. 1970	2.5116	3.7932	4.4145	5.2094
2. 1971	-.0289	-.0951	-.0532	-.0994
3. 1972	.3214	.2562	.3035	.3238
4. 1973	-.0047	.0887	-.0622	-.1563
5. 1974	.2909	.0177	.0522	-.0662
Constant Term	-71.74	-108.88	-140.84	-174.84
II. Land Resource				
1. Effective cropping index for rice (percent)	6.5679	5.7992	4.8304	5.3660
2. Percent rice area	3.9276	3.4367	2.8730	3.3048
3. Percent of rice area irrigated	-4.1562	-3.5874	-2.9911	-3.3420
4. Percent land graded over 30 degrees	.3710	.3153	.3047	.3758
5. Percent idle land	.6250	.6175	.5578	.5721
Constant Term	-530.67	-415.66	-291.49	-365.49
III. Agricultural Infrastructures				
1. Loans to agriculture (pesos per arable hectare)	.0314	.1033	.0163	.0204
2. Percent of earth road	-.0328	.1783	.2565	.0341
3. Ratio of 1972 to 1960 irrigated rice area	2.0213	.0552	.5927	.7604
4. Rice Milling capacity (cavans per day per 10,000 rice hectares)	-.2791	-.1006	.0500	-.0710
5. Warehouse capacity (cavans/rice hectare)	.1752	.0639	-.0247	.0441
6. Road density (kilometers of road per 1,000 arable hectares)	2.0742	1.1318	.2735	.8783
Constant Term	-30.86	-36.82	-9.72	-8.13

Table A1. (continued)

	Coefficients for Group			
	A	B	C	D
V. Population Characteristics				
1. Percent self-employed	2.0503	-.2621	.0753	-.8893
2. Percent rural population	4.8048	3.4336	3.8301	4.1500
3. Income tax per capita	-7.1162	-5.5826	-6.8054	-6.7553
4. Literacy rate	8.9091	8.1873	9.0584	8.7484
5. Percent family labor	-.5225	-.9420	-1.5868	-.9419
6. Percent of labor force in agriculture	3.2324	3.0820	3.5346	3.2948
7. Annual budget surplus per family (pesos)	-.0055	-.0027	-.0062	-.0077
8. Population density (number of persons per square kilometer)	.1549	.1401	.1328	.1405
Constant Term	-597.03	-498.97	-612.10	-569.73
V. Soils				
1. Sandy loam	1.4682	4.0446	2.6610	2.3873
2. Clay	1.1126	2.3580	2.5870	2.1977
3. Undifferentiated	.9023	1.7450	1.7921	1.7862
4. Clay loam	1.0446	2.0711	2.1326	2.0280
5. Loam	1.1753	2.5865	2.8005	2.3613
6. Sand	2.4968	5.7060	6.3296	4.9326
7. Silt loam	.6958	1.0898	.9221	1.2311
Constant Term	-26.70	-117.04	-115.04	-96.03
VI. Rainfall, First Semester				
1. January	-.0317	.1905	-.2374	.0370
2. February	.1045	-.7069	.9142	-.2875
3. March	.0132	.4443	-.2238	.2479
4. April	-.0517	.4204	-.4081	.1532
5. May	.0264	-.3180	.1816	-.0820
6. June	.0062	.1654	-.0342	.0595
Constant Term	-3.83	-27.87	-33.25	-10.15
VII. Rainfall, Second Semester				
1. July	.0063	-.1144	.1795	.0370
2. August	.0005	.0794	-.0506	.0102

Table A1. (continued)

	Coefficients for Group			
	A	B	C	D
VII. Rainfall, Second Semester				
4. October	.0108	.0073	-.1904	-.0982
5. November	.0038	-.0145	.1947	.1036
6. December	-.0018	.0266	-.0220	-.0054
Constant Term	-3.33	-16.73	-20.25	-12.14

where X_1's represent the yearly rice productivity from 1970 to 1974. The new observation would be allocated to Group A if F_A is highest, to Group B if F_B is highest, to Group C if F_C is highest or to Group D if F_D is highest. The procedure is the same for classifying new observations with respect to any other agroclimatic groups.

APPENDIX B

GROUP MEMBERSHIP PROBABILITIES

Table B1. - Individual Profile of Provinces in Relation to the Land Resource Groups

Case #[a]	Square of Distance (D^2) from and Posterior Probability (p) for							
	Group A		Group B		Group C		Group D	
	D^2	p	D^2	p	D^2	p	D^2	p
Group A								
1	7.15	1.00	23.33	*	90.42	*	55.80	*
2	5.56	1.00	35.00	*	108.04	*	62.44	*
3	1.98	1.00	18.41	*	71.96	*	33.08	*
4	4.01	.96	10.13	.04	52.94	*	19.50	*
5	0.82	1.00	15.25	*	70.42	*	33.77	*
Group B								
1	33.47	*	4.90	.86	10.46	.05	9.50	.09
2	20.65	*	3.66	1.00	33.44	*	16.52	*
3	13.44	.02	5.68	.96	41.16	*	12.91	.02
4	19.12	*	6.82	.98	28.02	*	14.99	.02
5	15.66	.01	7.21	.50	35.23	*	7.23	.49
6	20.00	*	8.54	1.00	45.20	*	28.81	*
7	19.88	*	1.71	.94	21.05	*	7.08	.06
8	14.06	.02	6.33	.98	42.33	*	25.32	*
9	12.09	.01	1.41	.99	32.52	*	15.64	*
10	38.69	*	4.94	.80	10.41	.05	8.23	.15
11	9.88	.08	5.04	.92	39.99	*	15.71	*
12	39.05	*	9.26	.91	14.23	.08	17.95	.01
13	31.19	*	6.86	.98	18.36	*	15.50	.02
Group C								
1	85.70	*	30.80	*	1.54	1.00	19.64	*
2	85.44	*	29.61	*	4.20	1.00	18.14	*
3	86.92	*	30.17	*	8.55	1.00	27.53	*
4	80.16	*	27.94	*	1.60	1.00	17.40	*
5	114.94	*	52.48	*	15.52	.96	21.95	.04
6	86.60	*	29.26	*	8.75	1.00	22.56	*
7	63.89	*	19.91	*	2.31	.88	6.39	.11
8	59.32	*	16.74	.01	6.40	.99	16.68	*
9	87.28	*	29.30	*	2.36	1.00	21.46	*
10	61.79	*	18.23	*	3.01	.99	13.06	.01
11	85.08	*	29.94	*	2.16	1.00	19.48	*
12	96.13	*	38.02	*	2.92	1.00	20.51	*
13	67.70	*	21.16	*	1.09	.99	9.56	.01

Table B1 (continued)

Case #[a]	Square of Distance (D^2) from and Posterior Probability (p) for							
	Group A		Group B		Group C		Group D	
	D^2	p	D^2	p	D^2	p	D^2	p
Group C								
14	97.31	*	41.22	*	14.19	1.00	30.27	*
15	60.48	*	18.58	*	3.21	.98	11.14	.02
15	58.95	*	15.96	*	2.26	.98	10.59	.02
Group D								
1	42.62	*	12.42	.01	14.48	*	1.73	.99
2	23.15	*	6.56	.18	20.33	*	3.55	.82
3	44.43	*	17.64	*	17.25	*	2.51	1.00
4	40.59	*	9.99	.02	7.78	.07	2.52	.91
5	49.06	*	15.91	*	11.12	.01	1.06	.99
6	47.82	*	12.83	*	6.10	.11	1.85	.89
7	35.93	*	9.16	.02	13.30	*	1.60	.98
8	44.58	*	14.67	*	16.47	*	2.61	1.00
9	48.85	*	17.90	.01	23.87	*	9.11	.99
10	48.65	*	12.00	.06	12.91	.04	6.52	.90
11	42.20	*	11.38	.01	12.78	.01	2.07	.98
12	33.00	*	10.67	.01	19.20	*	1.08	.99
13	23.33	*	14.90	.02	35.38	*	6.82	.98

*The posterior probability is nil or zero.

[a]The case number corresponds to the province number in Table 7.

Table B2. - Individual Profile of Provinces in Relation to the Agricultural Infrastructure Groups

Case #[a]	Square of Distance (D^2) from and Posterior Probability (p) for							
	Group A		Group B		Group C		Group D	
	D^2	p	D^2	p	D^2	p	D^2	p
Group A								
1	10.77	1.00	57.98	*	57.22	*	41.79	*
2	11.23	1.00	26.58	*	58.45	*	29.30	*
3	22.44	.97	54.85	*	39.19	*	29.74	.03
4	6.82	1.00	79.84	*	64.97	*	38.23	*
5	5.34	.93	51.87	*	32.00	*	10.58	.07
6	1.81	1.00	50.37	*	36.98	*	19.75	*
7	3.72	1.00	55.27	*	64.47	*	35.10	*
8	2.95	1.00	43.14	*	39.28	*	19.17	*
9	5.86	.98	39.62	*	24.04	*	13.86	.02
10	2.93	.98	36.58	*	27.97	*	10.92	.02
11	18.69	1.00	91.17	*	80.70	*	49.41	*
12	4.65	1.00	48.71	*	30.10	*	16.85	*
Group B								
1	31.75	*	3.56	1.00	45.91	*	30.96	*
2	37.33	*	8.75	.94	21.22	*	14.26	.06
3	48.09	*	4.18	1.00	66.53	*	51.48	*
4	97.49	*	12.06	1.00	92.99	*	84.54	*
5	44.99	*	6.60	1.00	43.82	*	41.50	*
Group C								
1	38.59	*	50.61	*	0.62	.97	7.74	.03
2	41.78	*	50.14	*	0.99	.97	7.79	.03
3	85.92	*	94.65	*	38.09	1.00	56.12	*
4	44.60	*	51.57	*	4.16	1.00	16.63	*
5	39.53	*	50.88	*	2.31	.93	7.52	.07
6	51.27	*	53.29	*	2.98	.98	11.19	.02
7	41.00	*	51.73	*	2.72	.85	6.22	.15
8	35.98	*	25.59	*	7.76	.94	13.47	.06
9	25.90	*	54.24	*	6.37	.83	9.53	.17
10	53.46	*	56.64	*	2.74	1.00	16.84	*
Group D								
1	30.87	*	46.05	*	4.23	.27	2.26	.73
2	10.04	.02	39.35	*	10.58	.02	2.38	.96
3	11.33	.01	32.90	*	12.43	.01	2.54	.98

Table B2 (continued)

Case #[a]	Square of Distance (D^2) from and Posterior Probability (p) for							
	Group A		Group B		Group C		Group D	
	D^2	p	D^2	p	D^2	p	D^2	p
Group D								
4	18.92	*	36.85	*	5.31	.18	2.29	.82
5	13.44	.02	23.64	*	23.20	*	5.36	.98
6	29.74	*	50.19	*	5.11	.19	2.17	.81
7	21.16	*	34.94	*	14.43	*	1.58	1.00
8	28.86	*	27.37	*	5.59	.20	2.75	.80
9	16.33	*	50.15	*	17.54	*	2.76	1.00
10	19.13	*	39.63	*	6.62	.06	1.14	.94
11	21.70	*	37.54	*	9.57	.01	.45	.99
12	15.55	*	53.52	*	21.54	*	3.98	1.00
13	20.19	*	42.09	*	16.43	*	3.19	1.00
14	32.77	*	46.59	*	8.44	.14	4.84	.86
15	14.87	*	38.36	*	8.06	.07	2.86	.93
16	18.40	*	31.60	*	11.10	*	.53	1.00
17	17.27	*	31.18	*	15.15	*	2.59	1.00
18	30.72	*	56.23	*	15.51	*	4.18	1.00
19	30.81	*	38.69	*	5.97	.13	2.10	.87
20	17.25	*	50.33	*	8.72	.29	6.91	.71

*The posterior probability is nil or zero.

[a]The case number corresponds to the province number in Table 10.

Table B3. - Individual Profile of Provinces in Relation to the Groups Based on Population Characteristics

Case #[a]	Square of Distance (D^2) from and Posterior Probability (p) for							
	Group A		Group B		Group C		Group D	
	D^2	p	D^2	p	D^2	p	D^2	p
Group A								
1	9.30	1.00	65.02	*	69.73	*	35.85	*
2	7.79	.98	45.47	*	26.04	*	15.30	.02
3	3.66	.90	27.69	*	25.78	*	8.11	.10
4	4.34	1.00	49.76	*	43.97	*	18.45	*
5	5.22	.88	23.16	*	29.94	*	9.28	.12
6	5.54	.99	43.44	*	36.80	*	14.43	.01
7	6.88	.94	34.98	*	28.24	*	12.27	.06
8	15.80	.99	38.93	*	50.77	*	25.52	.01
9	4.68	.99	41.04	*	42.27	*	13.52	.01
10	12.16	1.00	29.34	*	47.87	*	25.66	*
11	10.79	1.00	55.12	*	37.55	*	23.64	*
Group B								
1	45.04	*	19.75	1.00	49.91	*	38.30	*
2	53.89	*	5.43	1.00	35.18	*	31.90	*
3	38.09	*	8.06	.99	20.25	*	17.24	.01
4	53.19	*	8.05	1.00	31.77	*	30.14	*
5	30.38	*	9.39	.99	30.98	*	18.76	.01
6	25.78	*	4.11	.75	15.72	*	6.37	.25
7	38.41	*	12.19	.98	24.30	*	19.78	.02
8	69.41	*	22.56	1.00	37.68	*	37.01	*
9	46.29	*	18.70	1.00	30.75	*	31.14	*
10	32.96	*	10.37	.98	36.97	*	18.50	.02
11	64.73	*	10.47	1.00	23.07	*	31.84	*
12	57.61	*	25.37	1.00	48.63	*	39.14	*
Group C								
1	42.96	*	15.79	.01	6.57	.97	14.14	.02
2	34.63	*	30.14	*	7.32	.99	17.05	.01
3	24.95	*	28.95	*	9.06	.95	14.87	.05
4	28.06	*	19.49	*	3.33	.84	6.72	.16
5	36.47	*	35.25	*	4.32	1.00	15.68	*
6	39.56	*	28.49	*	3.41	1.00	14.07	*
7	27.30	*	17.02	*	2.24	.92	7.21	.08
8	45.37	*	12.69	.03	5.98	.96	15.34	.01
9	53.02	*	33.41	*	3.53	1.00	20.74	*

Table B3 (continued)

Case #[a]	Square of Distance (D^2) from and Posterior Probability (p) for							
	Group A		Group B		Group C		Group D	
	D^2	p	D^2	p	D^2	p	D^2	p
Group C								
10	22.78	*	16.52	*	4.89	.74	7.04	.26
11	53.11	*	29.09	*	4.65	1.00	20.83	*
Group D								
1	13.01	.01	10.06	.04	17.56	*	3.82	.95
2	20.74	*	6.94	.16	9.16	.06	3.81	.78
3	8.29	.06	17.18	*	12.88	.01	2.90	.93
4	17.73	.01	19.25	*	10.78	.28	8.91	.71
5	8.96	.07	27.53	*	16.53	*	3.84	.93
6	18.49	*	9.85	.03	11.27	.02	3.14	.95
7	16.45	*	16.22	*	7.57	.06	1.89	.94
8	10.15	.02	18.13	*	9.39	.03	2.41	.95
9	11.70	.03	29.91	*	12.29	.02	4.89	.95
10	15.77	*	20.68	*	6.61	.12	2.72	.88
11	21.44	*	9.17	.05	10.84	.02	3.16	.93
12	10.78	.03	19.61	*	23.58	*	4.06	.97
13	11.75	.01	23.18	*	16.03	*	2.67	.99

*The Posterior probability is nil or zero.

[a]The case number corresponds to the province number in Table 13.

Table B4. - Individual Profile of Provinces in Relation to the Soil Groups

Case #[a]	Square of Distance (D^2) from and Posterior Probability (p) for							
	Group A		Group B		Group C		Group D	
	D^2	p	D^2	p	D^2	p	D^2	p
Group A								
1	5.76	1.00	47.96	*	54.16	*	32.09	*
2	8.41	1.00	122.29	*	114.10	*	78.05	*
3	8.85	1.00	56.83	*	40.39	*	24.50	*
4[b]	4.71	1.00	98.23	*	106.12	*	76.90	*
5[b]	4.71	1.00	98.23	*	106.12	*	76.90	*
6	4.23	1.00	91.84	*	76.38	*	58.51	*
7	11.14	.99	38.88	*	50.05	*	20.70	*
Group B								
1	65.38	*	2.76	1.00	29.30	*	30.73	*
2	117.51	*	10.80	1.00	69.06	*	66.84	*
3	61.05	*	7.34	1.00	22.58	*	18.76	*
4	69.78	*	8.42	.98	19.95	*	17.03	.02
5	83.36	*	6.01	1.00	33.19	*	33.95	*
Group C								
1	88.44	*	40.63	*	5.97	1.00	17.55	*
2	91.33	*	38.18	*	14.17	1.00	34.87	*
3	66.09	*	41.36	*	4.29	1.00	22.36	*
4	66.25	*	35.25	*	4.77	.70	6.47	.30
5	104.48	*	48.89	*	6.31	1.00	32.99	*
6	72.98	*	15.16	*	4.56	.96	11.36	.04
7	87.39	*	39.66	*	2.66	1.00	20.80	*
8	78.18	*	26.20	*	7.15	.99	16.56	.01
9	68.01	*	33.24	*	6.89	.93	12.20	.07
10	75.84	*	35.56	*	3.63	.98	11.66	.02
11	64.80	*	37.47	*	4.79	1.00	15.54	*
12	63.95	*	25.39	*	6.96	.83	10.14	.17
13	98.69	*	33.95	*	13.84	1.00	45.26	*
14	73.94	*	34.29	*	2.15	.97	9.15	.03
15	58.65	*	28.49	*	2.30	.98	9.99	.02
16	97.53	*	57.44	*	28.18	1.00	43.64	*
17	83.74	*	27.15	*	7.96	.99	17.73	.01
Group D								
1	61.15	*	32.06	*	11.13	.04	4.62	.96
2	41.07	*	27.24	*	24.30	*	3.45	1.00
3	42.01	*	35.61	*	16.73	*	3.29	1.00

Case #[a]	Square of Distance (D^2) from and Posterior Probability (p) for							
	Group A		Group B		Group C		Group D	
	D^2	p	D^2	p	D^2	p	D^2	p
Group D								
4	34.76	*	28.29	*	31.84	*	5.59	1.00
5	54.42	*	32.32	*	8.77	.06	3.46	.94
6	58.35	*	30.54	*	13.38	.01	3.20	.99
7	63.73	*	36.60	*	17.62	*	6.76	1.00
8	52.46	*	35.69	*	15.18	*	2.89	1.00
9	45.90	*	30.90	*	17.02	*	2.82	1.00
10	60.93	*	28.62	*	25.48	.01	15.37	.99
11	50.86	*	35.37	*	24.46	*	3.06	1.00
12	30.10	*	18.64	*	13.70	.01	4.38	.99
13	57.76	*	32.28	*	7.85	.10	3.41	.90
14	49.50	*	28.67	*	10.18	.01	1.02	.99

*The posterior probability is nil or zero.

[a]The case number corresponds to the province number in Table 16.

[b]The soil data refer to the whole Mindoro. The use of a common set of information explains the identical profiles of Occidental and Oriental Mindoro.

Table B5. - Individual Profile of Provinces in Relation to the Groups Based on First Semester Rainfall

Case #[a]	Square of Distance (D^2) from and Posterior Probability (p) for							
	Group A		Group B		Group C		Group D	
	D^2	p	D^2	p	D^2	p	D^2	p
Group A								
1	3.53	1.00	55.23	*	34.68	*	22.14	*
2	4.56	1.00	54.79	*	45.09	*	17.18	*
3	4.70	1.00	55.66	*	44.82	*	17.66	*
4	2.58	1.00	46.79	*	31.04	*	14.56	*
5	2.94	1.00	56.40	*	52.48	*	17.17	*
6	2.18	1.00	39.71	*	31.91	*	14.16	*
7	4.65	1.00	55.20	*	45.04	*	17.45	*
8	6.95	1.00	56.52	*	24.63	*	20.03	*
9	3.62	.89	25.35	*	50.34	*	7.82	.11
10	1.53	.89	35.77	*	54.79	*	5.71	.11
11	2.14	.92	32.83	*	47.31	*	7.03	.08
12	3.66	1.00	48.32	*	61.52	*	14.48	*
13	3.58	.97	46.15	*	42.34	*	10.28	.03
14	6.87	1.00	67.20	*	38.37	*	27.67	*
15	3.66	1.00	48.32	*	61.52	*	14.48	*
16	3.58	1.00	55.78	*	53.85	*	18.63	*
17	6.87	.89	35.77	*	54.79	*	5.71	.11
18	3.66	1.00	67.91	*	24.82	*	25.80	*
19	4.11	.65	41.56	*	56.90	*	5.32	.35
20	2.73	.66	31.96	*	54.46	*	4.09	.34
21	3.61	1.00	61.23	*	32.14	*	24.07	*
Group B								
1	44.42	*	4.13	1.00	111.05	*	24.19	*
2	59.86	*	4.81	1.00	142.98	*	27.30	*
3	43.87	*	5.35	1.00	100.34	*	24.62	*
4	43.71	*	4.35	1.00	105.26	*	24.00	*
5	93.08	*	19.73	1.00	192.77	*	52.29	*
6	39.48	*	5.68	1.00	111.31	*	21.54	*
7	45.97	*	2.89	1.00	124.49	*	23.06	*
8	42.54	*	8.73	.97	135.47	*	15.87	.03
Group C								
1	27.46	*	105.67	*	4.25	1.00	62.26	*
2	49.74	*	132.62	*	2.05	1.00	89.13	*
3	50.24	*	149.09	*	5.01	1.00	92.06	*

Case #[a]	Square of Distance (D^2) from and Posterior Probability (p) for							
	Group A		Group B		Group C		Group D	
	D^2	p	D^2	p	D^2	p	D^2	p
Group C								
4	46.99	*	86.26	*	14.72	1.00	71.05	*
5	75.54	*	176.02	*	18.64	1.00	123.94	*
Group D								
1	35.29	*	62.15	*	102.71	*	18.59	1.00
2	19.05	*	10.19	.03	87.09	*	3.35	.97
3	5.29	.18	23.40	*	68.29	*	2.22	.82
4	21.30	*	22.43	*	89.28	*	4.67	1.00
5	27.30	*	37.18	*	119.76	*	9.50	1.00
6	7.29	.09	28.48	*	79.31	*	2.67	.91
7	8.09	.04	23.08	*	75.70	*	1.50	.96
8	19.05	*	10.19	.03	87.09	*	3.35	.97
9	13.96	.03	18.05	*	88.50	*	7.12	.97
10	8.33	.03	22.64	*	68.72	*	1.09	.97
11	20.97	.01	23.37	*	64.89	*	10.99	.99

*The posterior probability is nil or zero.

[a]The case number corresponds to the province number in Table 19.

Table B6. - Individual Profile of Provinces in Relation to the Groups Based on Second Semester Rainfall

Case #[a]	Square of Distance (D^2) from and Posterior Probability (p) for							
	Group A		Group B		Group C		Group D	
	D^2	p	D^2	p	D^2	p	D^2	p
Group A								
1	3.25	1.00	26.86	*	33.30	*	17.76	*
2	4.20	1.00	23.64	*	38.78	*	20.85	*
3	4.39	1.00	23.78	*	39.84	*	21.50	*
4	.23	1.00	21.69	*	25.24	*	11.65	*
5	3.20	1.00	25.36	*	41.29	*	21.20	*
6	4.29	1.00	23.78	*	39.16	*	21.11	*
7	.56	.99	21.69	*	21.37	*	10.03	.01
8	3.63	.80	21.42	*	13.20	.01	6.51	.19
9	3.11	1.00	28.58	*	34.15	*	18.79	*
10	3.11	1.00	28.57	*	34.22	*	18.83	*
11	3.28	1.00	26.70	*	39.01	*	20.50	*
12	3.63	.80	21.42	*	13.21	.01	6.51	.19
13	.43	1.00	22.22	*	29.63	*	13.80	*
14	11.26	.99	19.95	.01	59.02	*	31.96	*
15	1.73	.90	15.12	*	19.75	*	6.11	.10
16	4.08	.99	27.38	*	20.49	*	13.37	.01
17	3.25	1.00	26.78	*	33.95	*	18.09	*
Group B								
1	21.09	*	4.38	.99	32.61	*	13.02	.01
2	41.56	*	10.96	1.00	64.47	*	29.54	*
3	22.25	*	6.65	.73	28.94	*	8.60	.27
4	26.49	*	2.91	1.00	57.70	*	22.16	*
5	32.47	*	4.42	1.00	42.74	*	18.28	*
6	70.81	*	19.22	1.00	96.21	*	54.21	*
7	12.58	.01	2.80	.99	41.36	*	13.75	*
8	21.88	*	2.50	1.00	34.10	*	13.09	*
9	8.24	.18	6.05	.56	29.52	*	7.57	.26
10	11.02	.02	4.21	.53	21.65	*	4.52	.45
Group C								
1	12.74	.03	36.27	*	5.82	.84	9.46	.13
2	50.02	*	52.19	*	6.15	1.00	20.50	*
3	24.78	*	30.77	*	4.71	.58	5.38	.42
4	30.30	*	36.73	*	5.25	.98	13.41	.02
5	35.61	*	48.60	*	5.68	.98	13.37	.02

Table B6 (continued)

Case #[a]	Square of Distance (D^2) from and Posterior Probability (p) for							
	Group A		Group B		Group C		Group D	
	D^2	p	D^2	p	D^2	p	D^2	p
Group C								
6	33.78	*	40.32	*	4.30	.96	10.74	.04
7	69.09	*	84.26	*	27.59	1.00	48.04	*
Group D								
1	18.64	*	18.02	*	9.11	.05	3.36	.95
2	16.74	*	12.93	*	9.19	.04	2.56	.96
3	15.89	.01	15.86	.01	17.57	*	6.98	.97
4	20.46	.02	24.37	*	27.16	*	12.48	.98
5	57.44	*	33.15	*	24.18	.03	17.09	.97
6	11.53	.02	27.01	*	6.91	.20	4.20	.78
7	8.92	.03	11.48	.01	14.66	*	1.71	.96
8	15.07	*	15.02	.01	13.91	.01	4.70	.98
9	7.70	.11	12.87	.01	13.22	.01	3.64	.87
10	16.74	*	12.93	*	9.19	.04	2.56	.96
11	18.62	*	13.85	.02	16.18	*	5.52	.98

*The posterior probability is nil or zero.

[a]The case number corresponds to the province number in Table 22.

APPENDIX C

A NOTE ON THE NEGATIVE LABOR PRODUCTIVITY

APPENDIX C

A NOTE ON NEGATIVE LABOR ELASTICITY

Let: L = measured labor

L_t = the true labor input

$L = kL_t$, $0 < k \neq 1$ and it varies between observations

Therefore, in logarithms,

$$\ln L = \ln L_t + \ln k$$

$$X = X^* + E$$

In a two-variable log-linear function, we have the true relationship:

$$y = \alpha x^* + (\varepsilon - \bar{\varepsilon}) \qquad (1)$$

where $y = \alpha x^* + \varepsilon$ since $E(\varepsilon) = \bar{\varepsilon} = 0$

Y = rice production

$y = \ln Y - (\overline{\ln Y}) =$

$x^* = X^* - \bar{X}^*$

Suppost (1) is estimated by the regression

$$y = \hat{\alpha}x + (\hat{u} - \bar{\hat{u}}) \qquad (2)$$

$$y = \hat{\alpha}x + \hat{u} \quad \text{since} \quad \frac{1}{n}\sum \hat{u} = 0$$

by construction, i.e. from one of the normal equations in an OLS fit.

Regression (2) implies:

$$\hat{\alpha} = \frac{\sum xy}{\sum x^2} \qquad (3)$$

Substituting (1) for y in (3):

$$\hat{\alpha} = \frac{\sum x\,(\alpha\, x^* + \varepsilon)}{\sum x^2}$$

$$\hat{\alpha} \quad \frac{\sum x\,(\alpha\, x^*)}{\sum x^2} + \frac{\sum x\varepsilon}{\sum x^2} \qquad (4)$$

From:

$$X = X^* + E$$

$$\overline{X} = \overline{X}^* + \overline{E}$$

Therefore: $X - \overline{X} = X^* - \overline{X}^* + E = \overline{E}$

$$x = x^* + e$$

$$x^* = x - e \qquad (5)$$

Substitute (5) in (4):

$$\hat{\alpha} = \frac{\sum x\,(x - \varepsilon)\alpha}{\sum x^2} + \frac{\sum x\varepsilon}{\sum x^2}$$

$$\hat{\alpha} = \frac{\alpha \sum x^2}{\sum x^2} - \frac{\alpha \sum x\varepsilon}{\sum x^2} + \frac{\sum x\varepsilon}{\sum x^2}$$

$$\hat{\alpha} = \alpha - \frac{\alpha \sum x\varepsilon}{\sum x^2} + \frac{\sum x\varepsilon}{\sum x^2}$$

If the number of observations increases,

$$\operatorname*{plim}_{n\to\infty} \hat{\alpha} = \alpha - (\alpha)\,\frac{\operatorname*{plim}_{n\to\infty} \left(\frac{1}{n}\ xe\right)}{\operatorname*{plim}_{n\to\infty} \left(\frac{1}{n}\ x^2\right)}$$

$$+ \frac{\operatorname*{plim}_{n \to \infty} \left(\frac{1}{n} \sum x\varepsilon\right)}{\operatorname*{plim}_{n \to \infty} \left(\frac{1}{n} \sum x^2\right)}$$

If the residual in (1) is independent of measured x, then:

$$\operatorname*{plim}_{n \to \infty} \hat{\alpha} = \alpha - \alpha \frac{\operatorname*{plim}_{n \to \infty} \left(\frac{1}{n} \sum x\varepsilon\right)}{\operatorname*{plim}_{n \to \infty} \left(\frac{1}{n} \sum x^2\right)}$$

But:

$$\operatorname*{plim}_{n \to \infty} \left(\frac{1}{n} \sum x\varepsilon\right) = \operatorname*{plim}_{n \to \infty} \left[\frac{1}{n} \sum (x^* + e)e\right]$$

$$= \operatorname*{plim}_{n \to \infty} \left[\frac{1}{n} \sum x^*e + \frac{1}{n} \sum e^2\right]$$

Define:

$$\operatorname*{plim}_{n \to \infty} \left(\frac{1}{n} \sum x^2\right) = \text{asymptotic variance of } X = \sigma_X^2$$

$$\operatorname*{plim}_{n \to \infty} \left(\frac{1}{n} x^*e\right) = \text{asymptotic covariance of } X^* \text{ and } E = \sigma_{X^*E}$$

$$\operatorname*{plim}_{n \to \infty} \frac{1}{n} \sum e^2 = \text{asymptotic variance of } E = \sigma_E^2$$

$$\operatorname*{plim}_{n \to \infty} \hat{\alpha} = \alpha - \alpha \left(\frac{\sigma_{X^*E} + \sigma_E^2}{\sigma_X^2}\right)$$

But: $\sigma_X^2 = \sigma_{X^*}^2 + \sigma_E^2 + 2\sigma_{X^*E}$

Therefore:

$$\underset{n \to \infty}{\text{plim}} \quad \hat{\alpha} = \alpha - \alpha \cdot \left[\frac{\sigma_{X*E} + \sigma_E^2}{\sigma_{X*}^2 + \sigma_E^2 + 2\sigma_{X*E}} \right]$$

$$\underset{n \to \infty}{\text{plim}} \quad \hat{\alpha} = \frac{(\sigma^2_{X*} + \sigma_{X*E})\,\alpha}{\sigma^2} \tag{6}$$

From equation (6) the sign of plim $\hat{\alpha}$ is unambiguously the same as the sign of the parameter α if the error in measurement is uncorrelated with the true labor input. Otherwise, there is some room for the possibility that plim $\hat{\alpha}$ is negative even though the true labor elasticity is positive.

If $\alpha > 0$, plim $\hat{\alpha}$ can be negative if and only if:

$$\frac{\sigma^2_{X*} + \sigma_{X*E}}{\sigma_X^2} < 0$$

which results in the necessary and sufficient condition that:

$$\sigma^2_{X*} < -\sigma_{X*E} \tag{7}$$

The inevitable question is: Is (7) empirically possible?

It can be shown that (7), though theoretically possible, could be ruled for the specific date set used in this analysis.

From $\qquad X = X^* + E$

we have:

$$E = X - X^*$$

or $$e = x - x^*$$

Further:

$$\sigma_{X^*E} = \underset{n \to \infty}{\text{plim}} \left[\frac{1}{n} \sum x^* e\right]$$

$$\sigma_{X^*E} = \underset{n \to \infty}{\text{plim}} \left[\frac{1}{n} \sum x^*(x - x^*)\right]$$

$$\sigma_{X^*E} = \underset{n \to \infty}{\text{plim}} \left(\frac{1}{n} \sum x^* x\right) - \underset{n \to \infty}{\text{plim}} \left(\frac{1}{n} \sum x^*\right)$$

$$\sigma_{X^*E} = \sigma_{X^*X} - \sigma^2_{X^*}$$

Equation (7) becomes:

$$\sigma^2_{X^*} < - \left[\sigma_{X^*X} - \sigma^2_{X^*}\right]$$

$$-\sigma_{X^*X} > 0$$

$$\sigma_{X^*X} < 0 \qquad (8)$$

As shown by (8), condition (7) in fact requires the true labor input to diminish as the stock of labor increases. Thus, there must be some unrealistically glaring measurement errors before the signs of plim $\hat{\alpha}$ and that of α could be inconsistent. Empirically, given the usual direct relationship between the measured labor and the true labor input, condition (7) would not be satisfied. We conclude that measurement error alone would not have caused a reversal in the sign of the estimated labor elasticity.