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9. ABSTRACT

A major objective of this study is to provide regional estimates of the agricultural production parameters which have been most useful in explaining productivity differences. Considerable attention is given to defining regions in North American and to systematically testing for changes in production parameters across those regions. The functional form employed throughout the study is the Cobb-Douglas production function. There are 89 observations for the North America production functions, and the data included state and province level observations from Canada, Mexico and the United States. The regional analysis for North America included the following specific results:(1) Fertilizer was quite important in explaining the productivity difference between the U.S. and Mexican Corn Belt and Irrigated Region but was far more important in accounting for the U.S. and Mexico's productivity difference in the Labor Intensive Region, where a fifth of the productivity is explained by fertilizer (2) Comparisons of wage ratios with the marginal value product of labor confirm that the problem of excess labor was more severe in Mexican agriculture than in the U.S. (3) Fertilizer is considerably less important in explaining farm productivity differences between Canada's three very important plains states and the U.S. plains states, than it is in explaining the overall Canada - U.S. farm productivity differences.

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By

Clayton Wallace Ogg

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TABLE OF CONTENTS

Acknowledgements..... ii

List of Tables..... v

List of Illustrations..... vii

Chapter

I. Introduction..... 1

II. Variable Construction for a Three Country Production Function..... 7

Land Specification
Power
Labor
Education
Technicians
Livestock
Number of Farms
Output Specification

III. North America Production Function Results..... 22

Results for the Continent as a Whole
The Problem of Bias and the Use of Dummy Variables
Comparison with Other Studies
Results for the Education Variable
Other Coefficient Changes Between Countries
Implications Concerning Resource Allocation
Accounting for Productivity Differences Between Countries

IV. Regional Differences in Agricultural Production Parameters within North America.....50

Estimation of Coefficients for the Northern Plains Region
Estimation of Coefficients for the Labor Intensive Region
Coefficient Shifts for the Irrigated and Corn Belt Region
Specification of a Production Function for the Regional Analysis
Summary of Regression Results

V. Sources of Regional Productivity Differences..... 73

Economic Analysis of Regional Resource Allocation
Mexico-United States Regional Growth Accounting
Accounting for Productivity Differences Between Regions in Mexico
Accounting for Productivity Differences Between the Canadian and United States Plains Region

VI. Summary and Conclusions.....89

Bibliography.....96

Appendix A.....99

List of Table

Table		Page
1.	Estimate of an Aggregate Agricultural Production Function on 89 State and Province Level Observations	23b
2.	Comparison of North America and World Agricultural Production Functions, Per Farm Data Centered on 1960	32
3.	Estimates of Aggregate Agricultural Production Functions on State and Province Level Data with Binary Variables for Countries	38
4.	Prices of Fertilizer and Labor and Present Estimates of Marginal Value Products for the United States, Mexico, and Canada, 1959, 1960, 1961	43
5.	Accounting for Per Farm Productivity Differences Between Countries in North America	46
6.	Estimates of Aggregate Agricultural Production Functions on State and Province Level Data with Binary Variables for the Northern Plains Region	61
7.	Estimates of Aggregate Agricultural Production Functions on State and Province Level Data with Binary Variables for the Labor Intensive Region	63
8.	Estimates of Aggregate Agricultural Production Functions on State and Province Level Data with Binary Variables for the Irrigated and Corn Belt Region	66
9.	Estimates of Aggregate Agricultural Production Functions on State and Province Level Data with Binary Variables Selected from Previous Tables (Per Farms Data, 1959, 1960, and 1961)	68
10.	Regional Marginal Value Product Estimates	75
11.	Accounting for Percentage Differences in Regional Output/Farm Between Mexico and the United States	80
12.	Growth Accounting Results for Two Regions in Mexico, Per Farm	85

13. Growth Accounting Results for the Northern Plains Region, Per Farm..... 88

14. Input and Output Data for the United States, Mexico, and Canada (1959), 1960, and 1961)..... 115

List of Illustrations

Figure

1. Labor and Land Productivities for North American States..... 53

2. Division of North America into Three Agricultural Regions..... 56

Chapter I

Introduction

Early agricultural production studies noted a problem in including groups of cross-sectional observations which are diverse in climate and history within the same national aggregate production function.[1] However, the difficulty of representing diverse regions by only one production function becomes a central issue for international production functions constructed from observations from different countries. In addition to large differences in crop patterns and climate across observations, we must now include countries at widely varing levels of technological development. In an effort to assign weights to differences in input use and to provide numerical estimates of the impact of technology, development economists have recently devoted considerable attention to the conceptual problems of including input variables which can represent the complex production impact of technology-producing inputs.[2]

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[1]For one example see an article by Zvi Griliches entitled "Research Expenditures, Education, and the Aggregate Agricultural Production Function" (1964).

[2]See Yujiro Hayami and Vernon Ruttan's Agricultural Development: an International Perspective (1970), where the authors defend the use of two non-conventional inputs in an international production function. Other efforts to measure the effects of technology with a production function using data from developed and less developed countries include Y. Kislov and Robert Evenson (1973). Both studies were viewed as corraborative of the Hayami-Ruttan results.

The major objective of this study is to identify and measure sources of productivity differences among regions in North America by employing an aggregate agricultural production function. Measures of research and education will represent the inputs which produce technologies, following the reasoning of Zvi Griliches and others in U.S. studies[3] and more recently, of Vernon W. Ruttan and Yujiro Hayami's international production study (1970). Production functions will be fitted to a sample of 89 observations based upon state and province level data from the United States, Mexico, and Canada. However, rather than simply assuming that the function has been specified to include all the inputs which can shift the production function, considerable attention will be devoted to defining regions with similar characteristics and testing the hypothesis that they are all on the same production function. Log-log production functions containing dummy variables will be employed in order to test specific hypothesis concerning changes in intercepts and in production elasticities between the three countries. Similar tests will be made for areas within countries; these areas will be

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[3]See Griliches (1964). Another study which employed an aggregate production to measure the effect of education for the United States is G. Fishelson (1968). See also Finis Welch (January, 1970, pp. 35-59).

identified according to climatic and crop mix similarities and according to factor scarcity characteristics in order to determine how these characteristics affect the same production parameters. The regional groupings will provide a basis for economic comparisons and also a thorough test of the hypothesis that production parameters vary between important regions in North America.

Production functions will be based on state and province-level observations which are primarily from the agricultural censuses of each of the three countries. Including state level data from three separate countries is a challenge of this research effort. Although all the variables are described in a very similar manner in each of the three censuses, the risk exists that a set of data in one country may contain elements that sets it apart from the other two countries.

In spite of this problem, potential benefit from this kind of effort is quite large. The North America regressions will provide rigorous measures for those production parameters which have been most useful in explaining the growth process. And successful estimation of regional production elasticities would make it possible for the first time to account for productivity differences between farms

in a particular region within one developed country and farms in a similar region within a less developed country. The analysis with dummy variables will also permit comparison of production elasticities and marginal value products between regions with very different relative prices while holding crop mix and other factors fairly constant. In addition, the study offers a unique opportunity to explore the applicability of production functions containing technology shifters to one particular part of the world.

The next chapter will define variables and discuss problems of constructing variables which represent the same inputs in all three countries.

Chapter 3 will present estimates of Cobb-Douglas production functions for the continent of North America. Production parameter estimates will be compared with those of other studies which employed reasonably similar techniques and which used data from approximately the same point in time. Those studies include Reed Hertford's work in Mexico (1970), Griliches' U.S. work (1964), and the Hayami-Ruttan cross-country study (1970).

In Chapter 4 binary variables will be used to test for the sameness of five of the variable coefficients for carefully defined geographic and political regions. If any

of the five binary variables is significantly different from zero at high levels of significance, this will be taken as support of the ypothesis that, as specified, production elasticities differ among the large regions being compared. A main objective of this part of the study is thus to seek out the limits to be placed on the use of the Chapter 3 estimates based on the whole continent.

If production parameters differ mainly between regions in Mexico and the two developed countries, it might indicate a failure to specify adequately the technology variables which shift the production function. This limits the usefulness of the production function for growth accounting. On the other hand, there may be differences in production elasticities because of climatic or crop mix characteristics; this would imply that the estimated elasticities can be powerful tools for accounting for productivity differences between similar regions in North America.

Chapter 5 will make use of regression results to analyze sources of agricultural productivity differences in North America. Estimated production elasticities are employed as weights and regional differences in productivity are assigned to differences in the use of the main agricultural inputs. Marginal value products are also estimated using the same production parameters, and a comparison is made concerning the

efficiency of resource allocation among regions in North America.

Chapter 2

Variable Construction for a Three Country Production Function

All observations used in this study are at the state level; in most cases data was obtained from agricultural censuses. An attempt was made to gather data for the same time period in all three countries, but this was not possible. For Mexico the most recent source of data was the 1960 Census. U. S. data are mainly from the 1959 Census of Agriculture. Canadian data are from the 1961 Canadian Agricultural Census. Although output data employed for each country are not from exactly the same point in time, output prices are most subject to change, and agricultural prices changed very little between 1959 and 1961.

A major objective is to compare present production elasticity estimates with those obtained from Hayami and Ruttan's (H-R) international cross-section of which Mexico, Canada, and the United States was only a sub-region. Variables should therefore, have the same specification as that employed by H-R. Their five conventional and two nonconventional inputs are listed below along with a brief description of the variable specification:[1]

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[1]For an explanation of this choice of variables see Yujiro Hayami and Vernon Ruttan (December, 1970, pp 896-897).

Conventional inputs

1. Land area, in hectares; permanent pastures and meadows were included.
2. Labor - number of farmers, hired laborers, and male farm family members of working age.
3. Fertilizer - measured in nutrient units.
4. Power - in horsepower.
5. Livestock - value of livestock.

Nonconventional inputs

1. Education - measured by literacy ratios or school enrollment ratios.
2. Technical manpower - number of agricultural technicians.

One objective of this selection of variables was to assign the large productivity differences among their groups of countries to three broad input categories. (1) Land and livestock represent resource accumulation. (2) Fertilizer and power represent those technologies which are "embodied in fixed or working capital." (3) And the two nonconventional inputs are given the task of representing human capital.

Breaking their thirty-six observations down into groups of developed and less developed countries, H-R also attempted to test the hypothesis that countries with very different levels of technology could be represented by the

one production function. After obtaining unreasonable results, it was concluded that measurement errors were too large in relation to the range of variation of the data to permit an adequate test (See Hayami-Ruttan , December, 1970, p. 899). Thus H-R had to rely heavily on their argument that the human capital variables were able to represent the technological inputs which shift the production function. It is hoped that the present study,with its 89 state level observations, will be able to test the reliability of the assumption that farmers in different countries or regions in North America face the same production function.

The detailed effort in the present study to specify each variable in an equivalent form to the H-R cross-country study has not put extra demands on the data since the Hayami-Ruttan variable specification was also forced to deal with some of the same problems inherent in the inclusion of data from separate countries. Where there is the possibility of obtaining superior specification with state and province level data, alternative variable specifications are tested.

The rest of this chapter will discuss the unique problems encountered in constructing data for the three-country production function. A more detailed discussion of data sources for all input and output variables is found in Appendix A.

Land Specification

It was felt that the data permitted more precise land specification than simply area units. A weighting scheme developed by Hans Binswanger is used as an alternative to the Hayami-Ruttan specification.[2] For the United States and Mexico land values in each state were used to convert hectares of various land categories to their equivalent worth in hectares of pasture. For the U.S. five categories of land were weighted by 1940 prices because relaible land prices were available for that year. Price weights for Mexico's six land categories were only available for 1960: these more recent prices take into account changes in land values that result from large-scale investment in irrigation.

Suppose for example, that in a particular state in the United States the price of irrigated crop land was ten times the price of pasture land in that state. The number of hectares of irrigated crop land would be multiplied by ten to arrive at pasture equivalents. The same weighting procedure was applied to the state's hectares of unirrigated cropland,

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[2]See Hans Binswanger (1973). His land price data was from Dale Hoover's thesis (1961).

irrigated pasture, and marginal land and the computed totals of pasture equivalents for that state were combined. Finally the computed pasture equivalents for each state within the U.S. and Mexico were weighted by the ratio of the price of pasture for that state divided by the average price of pasture for the respective country.

It was necessary to assume that pasture land in Mexico and Canada is equivalent to pasture in the United States. Fortunately, Mexico's census separates the large areas of dry, hilly pasture from the better pasture. Also, Canada separates pasture land into "improved" and "unimproved" categories.[3] Thus, it was assumed that Mexican non-hilly pasture and Canadian improved pasture is the same as U.S. pasture land.

Due to lack of land price data for Canada, land prices in Canadian provinces were assumed to be the same as prices in a U.S. state across the border. The procedure for doing this is outlined in Appendix A.

An unweighted land variable was also used in order

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[3]Appendix A lists official data sources for each variable.

to make North America regressions more comparable to those of Hayami-Ruttan. Total land in this construction includes private and public land which can be used for crops or pasture. In order to make the Canadian area measure comparable to that for the United States and Mexico, improved land and unimproved land, except for woodland, was included from the Canadian Census.

Finally, cropland was used as an alternative to total farm land; this eliminated variation in land quality between crop and livestock states. Idle or fallow cropland was included. Use of this variable assumes that cropland producing livestock feed accounts for most of the income from livestock.

Using total land without weights or using just cropland represents the extremes for land specification. The weighted land variable is a weighted average of the other two specifications in that it includes both pasture and cropland, with cropland being weighted more heavily.[4]

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[4]The present weighting system includes the effects of irrigation in the land variable and therefore does not permit separate estimation of the effects of irrigation. Hertford does analyze irrigation in his study (1970).

Power

A special problem for this study was to construct data which will mean the same thing for states in each of three countries. For all variables except power, labor, and technicians, input data with apparently similar definitions could be found for each country. Since Mexico employs large amounts of animal power, it was necessary to set up a weighting scheme that would make Mexican animal power sources comparable to mechanical power in all three countries.

The weighting scheme employed in this study follows that developed by Hayami and Ruttan which was based upon a study by Hayami and Associates (1971). FAO and OECD sources were used in assigning tractors a weight of 30 horsepower. The decision to assign draft animals a weight of one horsepower each was based upon estimates for 1200-pound horses.[5] The power variable, therefore, is given in terms of horsepower equivalents.

Labor

The most serious difficulty concerned data which appeared to be defined the same in each country, but were not. This was the case for labor. All three countries have

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[5]Sources cited by Hayami are listed in Appendix A.

numbers for each state's farmers, sharecroppers, hired workers, and family workers, but it was obvious that the figures do not mean the same thing across national boundaries. In particular, Mexico's Census has a separate classification for ejidal farmers who make up over one-fourth of the country's farm population. Since "ownership" of ejidal land is officially supposed to be contingent upon working the land one's self, there is an incentive for ejidatarios to claim to be farming when they are actually not. In addition, since inheritance of ejido land is not permitted, it is doubtful if the children of ejido operators contribute their labor as is expected of family members of other farmers. It was necessary to make a somewhat arbitrary decision in weighting various categories of labor in each country, and the decision was to give ejido operators a weight of one and to give ejido family labor a weight of zero. This decision was based upon negative coefficients obtained by Reed Hertford for family labor in his ejido sector production functions (pp. 75 and 79). Whether small farmers and ejido operators in Mexico work similar amounts compared to workers in the U.S. or whether there are regional differences in the amount worked are questions which could not be answered. However, the problem concerning regional differences in amount worked will be dealt with in part through the use of regional dummies.

It may also be argued that even though there is some inconsistency in the labor input specification between countries, or even for some of the other inputs, the errors are probably small in comparison to the large real differences in factor combinations across North America. For instance, Mexican labor data may be inconsistent with U.S. and Canadian data because Mexican farmers may do more or less actual work than U.S. or Canadian farmers; but the bias is surely small compared to the measured difference in labor supplied in Mexican states as compared to the other two countries. Since the errors are relatively small, the bias in coefficient estimates should be small as well.

Education

Ideally the education variable would represent the average or median level of educational attainment in each state or province. In this instance the Mexican data placed constraints on what could be done. School enrollment and literacy ratios are the only available cross-sectional data for education in Mexico. For the rural population only literacy ratios could be found. Yet it may be argued that literacy ratios would be highly correlated with any good measure of education, especially in Mexico where very few rural people go beyond elementary education. Also use of a

literacy variable is convenient for making regression comparisons with the cross-country regressions since Hayami and Ruttan were also forced to use school enrollment and literacy variables to represent educational attainment.

Actually, two different constructions of the U.S. literacy variable were employed because the Census does not have rural literacy figures. In some regressions Department of Commerce figures for the total population age 14 and above were used (1971, p. 2); in other regressions a variable was constructed for just the farm population. This construction was based upon Department of Commerce estimates for percentages of people having various numbers of years of school completed who are able to read and write. The exact procedure for estimation and sources of data are found in Appendix A. There were essentially no differences in regression results under the two constructions of the U.S. literacy variable.

For all three countries the literacy ratios were for persons in the 14 and above age group. There appeared to be no major conflict conerning definitions of literacy by the three data sources.

Technicians

Once one becomes reconciled to the labor and education specification, other variables are fairly easy to accept. Yet

some problems should be noted, especially for agricultural technicians. Agricultural technicians appear to be made up of very different types of specialists in Mexico as compared to the other two countries. This is because Mexico's investment in human capital has concentrated on irrigation engineers who build and maintain massive irrigation projects. This study treats an irrigation expert as equivalent to an agricultural scientist or extension specialist.

For the United States and Canada technologists were represented as numbers of earth scientists and agricultural scientists, including veterinarians. In Canada some agricultural scientists may be listed under biological scientists, which would mean the data for Canada is biased downward.

Fertilizer

Construction of the U.S. and Canadian fertilizer variable basically relied on Griliches' procedure for weighting plant nutrients at 1955 relative prices (1964). However, for Mexico, data on plant nutrient consumption was only available for the country as a whole; Mexico's plant nutrients were assigned to states on the basis of each state's share of the total expenditures by farmers in the purchase of commercial fertilizer as reported in the Census. It was necessary to assume that each state consumed the same mix of

plant nutrients.

Livestock

It may be reported that no special difficulties are apparent in the specification of livestock capital. Reported dollar values of livestock (one dollar = 12.5 pesos) in all three countries were used to represent this stock variable.

Number of Farms

Even in representing the number of farm units an important decision had to be made concerning the proper definition of an ejido unit. Farm units are, of course, intended to be defined as a decision-making unit. On an ejido, however, there are decisions made by ejido authorities and decisions made by the dozens or even hundreds of heads of families which generally are assigned individual plots of land. Since the important decisions conerning credit and factor availabilities are made by ejido authorities, the ejido was designated as the decision-making unit. This means that the Mexican farm unit used in the production functions is comparable in size to farm units in the other two countries. However, in the growth accounting sections of this study, comparisons will be made on the basis of per family unit comparison in order to account for the differences in family unit productivity.

The author is aware that differences in the specification of input variables in different countries may also be present due to possible differences in reporting techniques which would be nearly impossible to detect. On the other hand, it may be argued that in view of the very large real differences in agricultural input use and in productivities between countries, all of the aforementioned sources of error are hopefully small.

Output Specification

Variation in commodity prices across observations creates immense problems for those who would make productivity comparisons involving aggregates of outputs.

Suppose for example, that the prices of some major commodities were higher in the United States than in Mexico. The choice of price weights for aggregation purposes may be quite important both to the estimation of production parameters and to the examination of productivity differences, and there is no basis for deciding which price weights are the "correct" ones. Also, since Mexican resource allocation was based upon price incentives in Mexico, use of U.S. prices would give a downward bias to measures of Mexican output. Using actual market price weights which vary across observations, on the other hand, will give unequal weights to certain groups of

output observations wherever the price differences are not offsetting.

Fortunately, this aggregation problem does not present a major challenge to the present project because price differences in North America are confined mainly to a very few commodities grown only in Mexico and three or four states in the United States. Citrus and tomato prices have for various reasons been allowed to reach levels in the United States which are much higher than those offered by competitors south of the border. (Yet in this instance the production process and the products themselves are so different between the two countries that it is best to treat U.S. tomatoes and Mexican tomatoes as two separate commodities.) Some attention will be given to this weighting problem in Chapter 5 when comparisons involve regions of which California and Florida are a part.

Output data for the United States was constructed by G. Fishelson for his dissertation (1968).[6] Output figures were converted from 1949 to 1959 farm prices for this study.[7]

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[6]This aggregation problem also must be faced by studies which make cross-country income comparisons. It is discussed in a collection of papers edited by D. J. Daly (1972).

[7]The price index was for farm prices as found in U.S. Department of Agriculture (1967, p. 563).

Fishelson based his output specification on that of Griliches and carried out a regional price deflation based mainly on price weights for twelve commodity groups. Details and sources for output specification for all three countries are found in Appendix A.

The actual input and output data constructed and utilized in this study are presented in Appendix A.

Chapter 3

North America Production Function Results

This chapter reports the results of fitting an aggregate agricultural production function for North America. Statistical results will be discussed in some detail and compared to those of other studies which employed reasonably similar data and techniques. Later sections of the chapter will discuss the economic significance of the comparisons with other studies and will begin to apply the regression results to economic problems of resource allocation and of explaining productivity differences between countries. However, more extensive analysis concerning resource allocation and sources of regional productivity differences will wait for the tests for regional differences in production parameters which are presented in Chapter 4.

Viewing regression results often presents the reader with a problem in that he does not know how many regressions were run and how many changes were made before the apparently reliable statistical results were achieved. Almost all of the results presented here are for what was originally conceived as the most useful and economically sound functional form and construction of variables. Changes from earlier regressions were either due to the discovery of errors or of obvious deficiencies in the data, particularly in the land variable. The one exception is the inclusion of the country

intercept dummies which proved necessary after trying one regression without them. Since coefficient estimates are not the result of trial and error, statistical hypothesis tests should mean just what they appear to mean.

Results for the Continent as a Whole

Least squares estimates of four log-log production functions fitted to cross-section data for the U.S., Mexico, and Canada are presented in Table 1.[1] Standard errors are reported in parenthesis below each production elasticity, and the sums of conventional coefficients and coefficients of determination adjusted for degrees of freedom are found at the bottom of each column. Regression 1 gives the results of what was considered the best construction of input variables which data permitted. Regression 2 indicates the results for a change in the land specification that gives equal weight to all land types, and Regressions 3 and 4 demonstrate what happens when certain variables are excluded.

A brief examination of the results for Regression 1 through Regression 3 reveals coefficients which are reasonable

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[1]The Cobb-Douglas production function assumes unitary elasticity of substitution. Other functional forms may involve an assumption of even zero or infinite elasticity of substitution. Although lack of wage data prevented a test of the unitary elasticity of substitution assumption for North America, Griliches' test for the United States (1964) and Hayami-Ruttan's test for their cross-country production function (December, 1970) both found no significant basis for rejecting the unitary elasticity of substitution assumption.

Table 1. Estimate of an Aggregate Agricultural Production Function on 89 State and Province Level Observations (Per farm data, 1959, 1960, and 1961)

Regression number	1	2	3	4
Land (adj. for quality)	0.216 (0.057)		0.208 (0.056)	0.033 (0.060)
Land (unadj. for quality)		0.044 (0.053		
Fertilizer	0.196 (0.040)	0.204 (0.043)	0.214 (0.035)	0.241 (0.047)
Labor	0.490 (0.119)	0.539 (0.129)	0.508 (0.074)	0.308 (0.126)
Livestock	0.155 (0.080)	0.278 (0.095)	0.190 (0.074)	0.311 (0.093)
Technicians	0.047 (0.047)	0.027 (0.051)		-0.037 (0.054)
Education	0.248 (0.270)	0.292 (0.146)		0.475 (0.321)
Power	0.076 0.076	0.133 (0.061)	0.084 (0.075)	0.299 (0.083)
U.S. Dummy	0.628 (0.100)	0.458 (0.097)	0.622 (0.095)	
Canada Dummy	0.507 (0.112)	0.371 (0.118)	0.518 (0.107)	
Intercept	1.759 (0.551)	1,979 (0.606)	2.024 (0.107)	1.552 (0.669)
Coefficient of det. (adj)	0.915	0.901	0.916	0.873
Residual Mean Square	0.023	0.023	0.020	0.030
Sum of Conventional Coefficients	1.133 (0.118)	1.198 (0.126)	1.204	1.192

Note: Equations are of log-log form. Standard errors are given in parentheses.

in sign and in magnitude. Examination of the variables in relation to their standard errors also shows four of the five conventional inputs have relatively small standard errors. (Coefficients are significantly positive at high levels of significance.) The power input variable and the proxy variables for technical manpower and education of the farm population have larger standard errors in relation to their size but the coefficients themselves at least are of a reasonable size. In general, it appears that this has been a successful attempt to account for differences in per farm output within these countries.

The Problem of Bias and the Use of Dummy Variables

Regression 1 and Regression 2 differ somewhat from previous studies in their method for representing technological inputs: in addition to using the two human capital variables, the present study also includes an intercept dummy which allows the intercept to shift for the two developed countries.

The intercept dummies were considered necessary partly because the North America technicians variable was poorly specified, due to the upward bias in Mixecan data on agricultural technicians, and because research and extension programs are primarily national so they may reasonably be represented by country dummies. In Regression 1 the intercept

is 1.759, but Canada's intercept shifts up by 0.507 and the U.S. intercept shifts by 0.628.

In order to better understand the important role that the dummy variables and the technology variables are playing, separate regressions were run, first without the human capital variables and then without the intercept dummies. It was hypothesized that exclusion of any of the technology variables would bias the coefficients of the remaining variables which are correlated with the use of modern techniques of production.

If the technology variables are representing what they are intended to represent, it should be possible to predict how their exclusion will bias the other variables. Tests of hypothesis concerning direction of bias are based upon an article by Griliches entitled "Specification Bias in Estimates of Production Functions" (1957). In the section dealing with bias resulting from the exclusion of a variable (X_K) from a production function, Griliches demonstrates that "the expectation of the estimates of the included coefficients (b_i) is given by:"

$$E(b_i) = a_i + P_{iK}\, a_k$$

"where in the case of a Cobb-Douglas function, the P's come from the following regression:"

$$\log X_k = P_{1K} \log X_i \; . \; . \; . \; P_{K-1,\,K} \log X_{K-1} + V.$$

"That is, the P's are the coefficients in the regression of the logarithm of the excluded variable on the logarithms of all the included variables." (And the a_i are "true" coefficients which would result from a regression which no variables were excluded.[2]

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[2]Griliches developed this argument by first presenting the general case for estimation of a function based upon a matrix of independent variables $\overline{X}$ instead of the X matrix which contains all of the correct independent variables. Using his notation, the correct equation is the following:

$$(1) \quad Y = Xa + U$$

where Y, a, and U are column vectors for ouput, the parameter we would estimate, and the disturbance, respectively, and X is defined above. Instead of (1) we estimate:

$$(2) \quad Y = \overline{X}a + \overline{U}$$

The estimate of $\overline{a}$ is then called b and estimated as:

$$(3) \quad b = (\overline{X}'\overline{X})^{-1}\,\overline{X}'Y$$

Substituting (1) and (3) and then taking the expectation of b, yields:

$$(4) \quad E(b) = E(\overline{X}'\overline{X})^{-1}\overline{X}'(Xa + U) = (\overline{X}\overline{X})^{-1}\,\overline{X}'Xa.$$

Griliches concludes, "Let $(\overline{X}X)^{-1}\,\overline{X}'X = P$, then"

$$(5) \quad E(b) = PA$$

Thus, the elements of P are coefficient's of a set of regressions on the columns of X.

Unlike Griliches' case of the left-out variable, the present study has the necessary data to estimate P coefficients. If it is true that the proxy variables used here to represent land and labor saving technologies are correlated with the use of modern inputs, then regression of the logarithm of the North America technology variables on the logarithm of fertilizer, power, labor, land, and livestock would yield positive P coefficients for power and fertilizer and a negative P coefficient for labor. Thus, estimates of the fertilizer and power coefficient in a regression which excludes the dummy variable or the human capital variables would be larger than in the regressions which include those variables; also, the labor coefficient would be smaller. No hypothesis is made concerning the change in the land and livestock variables because it is hard to predict whether the correlation between those variables and the technology variables is positive or negative, or whether there is any correlation at all. There is also no hypothesis made concerning the scale parameter.[3]

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[2]In a footnote the general argument is applied to the case of a single left-out variable, which is the case that concerns the present study. The coefficients of the regressions which make up P are one or zero for the coefficients which result from all the columns except the column of the excluded variable, X_K. The P matrix can be shown to include an identity matrix and a column vector of coefficients for the regressions on X_K:

$$P = [\, I \;\; P_K \,]$$

(See Griliches, 1957, pp. 10-12).

Regression 3 indicates the effects of excluding the human capital variables. The coefficient for fertilizer increases from 0.196 to 0.214 and power increases from 0.076 to 0.084, indicating the expected positive correlation with the excluded variables. However, the main conclusion is that the two human capital variables are non-significant and that their exclusion raises the intercept but makes hardly any difference to the other coefficients.

Leaving out the intercept dummies has a very noticeable impact on the conventional inputs, and the coefficients shift in directions which are consistent with the hypothesis concerning their relationship to the other variables. For the power input the biased production elasticity of Regression 4 has become over three times the estimate in Regression 1. Fertilizer's production elasticity increases from 0.196 to 0.241, and the labor coefficient drops from 0.490 to 0.308. All of the Regression 4 changes in coefficients are consistent with the hypothesized directions of bias except for the drop in the land and the increase in the livestock

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[3]Exclusion of a variable will result in an upward bias or a downward bias in the scale parameter, depending on whether proportional changes in the included inputs are associated with more than proportional or less than proportional changes in the excluded variable (See Griliches, 1957, p. 12).

coefficient; no hypothesis was made concerning the way in which those two inputs are correlated with technology variables. (The same Regression 4 was also estimated using the P coefficients. The intercept variables which were left out in Regression 4 were combined in a separate regression in order to estimate the a_i and a_K, and estimated coefficients were used in the formula, $b_i = a_i + Pi_K A_K$.)

Since it seems apparent that the country dummy variables are needed to avoid biasing the conventional input coefficients, they are used throughout the analysis. Hopefully, the dummy variables and the human capital variables are representing the main effects of managerial skills and different levels of biological and mechanical technology. Thus, the Regression 1 fertilizer variable, for example, is assigned an unbiased production elasticity for actual physical units of fertilizer. Unfortunately, the dummy variable does not provide much real insight into the technological sources of productivity growth; it is only a crude device to provide a better fit to the data and avoid biasing coefficient estimates.

The Regression 1 coefficient of determination is 0.915 with the dummy variables, as compared to an estimate of 0.873 in Regression 4; this gives some additional evidence that there is a better fit with the dummy variables. There

is a more substantial difference in the residual mean square between those two regressions, which again favors use of Regression 1.

Comparison With Other Studies

One stated goal of this study was to make production parameter comparisons with the results of other studies. It was considered especially useful to determine whether the continent of North America is on the same production function as the much larger 36 country area included in the Hayami-ruttan production fuction of which North America is a sub-region. Since production elasticity estimates have been employed to provide important insights into the sources of productivity differences among countries, added information concerning the practical reliability of the growth accounting procedure is useful.

Finally, some of the comparisons in this section provide a good basis for examining the statistical reliability of my own estimates (and those of others) since the data in this project is somewhat unique in terms of what it encompasses. If present results are similar to those of other studies, or different in ways that can be predicted and explained, it gives added evidence as to the reliability of our techniques.

Regression 2 was run in an effort to make the production function for North America more comparable to the Hayami-Ruttan

estimates which included a land variable based upon a simple addition of hectares. What is remarkable about the differences in coefficient estimates between Regression 1 and Regression 2 is that, with the Hayami-Ruttan unweighted land specification, the North American land, livestock, power, and literacy coefficients all tend to move closer to the range of estimates obtained by Hayami and Ruttan in their cross-country study. (In Table 2, Regression 2 results can be compared with the range of estimates obtained by Hayami and Ruttan.) The Regression 1 estimates were already surprisingly close to those of Hayami and Ruttan except for the stock variables: the land coefficient of .216 looked like their livestock coefficient, while the Regression 1 livestock coefficient was only slightly larger than their land coefficients which range from 0.071 to 0.097. The unweighted land specification in Regression 2 makes land the smaller coefficient and is, of course, more consistent with the Hayami-Ruttan results. Apparently, the original differences between my "best" equation and the cross-country production function was not an indication that the North American sub-region is on a different production function; it may be hypothesized that a more precise variable construction has been achieved with the weighted state and province level land data.

It is remarkable that estimates of similar variables but from very different sources of data can yield such strikingly

Table 2. Comparison of North American and World Agricultural Production Functions, Per Farm Data Centered on 1960.

Sample Size	North America* 89	World Range of Estimates** 37 or 38
Land (unadjusted)	0.044 (0.053)	0.071 - 0.117 (0.062) (0.074)
Fertilizer	0.204 (0.043)	0.096 - 0.174 (0.053) (0.067)
Labor	0.539 (0.129)	0.336 - 0.190 (0.110) (0.121)
Livestock	0.278 (0.095)	0.166 - 0.249 (0.086) (0.097)
Technicians	0.027 (0.051)	0.146 - 0.197 (0.054) (0.060)
Education	0.292 (0.146)	0.348 - 0.366 (0.180) (0.196)
Power	0.133 (0.081)	0.038 - 0.205 (0.053) (0.067)
U.S. Intercept Dummy	0.458 (0.097)	
Canada Intercept Dummy	0.371 (0.118)	
Mexico Intercept	1.979 (0.606)	
Coefficient of det.	0.949	0.908 - 0.934
Sum of Conventional Coefficients	1.198	0.943 - 0.978

* Table 1, column 2.

** From the study by Hayami and Ruttan, (December, 1970).

similar production elasticity estimates. What differences do exist are fairly small. Taken together, the slightly larger coefficient estimates in Regression 1 of Table 1 would suggest increasing returns to scale (although the t statistic of 1.08 does not indicate the sum of the coefficients is significantly greater than one at a high level of significance). In this one aspect present results lend limited support to those of Griliches (1964, p. 966), which contradict the constant returns estimated by the Hayami-Ruttan cross-country study. The sum of Griliches' production elasticities for the United States ranged from 1.193 to 1.282 and they were significantly greater than one. Perhaps North America's production function differs from the cross-country function in this respect.

There is one noticeable difference between results obtained here and those of both Griliches and Hayami-Ruttan. The production elasticity for fertilizer was estimated here at 0.196 while the Hayami-Ruttan coefficients ranged from 0.096 to 0.174. The Griliches' figures ranged from 0.095 to 0.120 (1964, p. 966). Since present estimates for the fertilizer coefficient remain stable and have a small standard error, there is reason to think that agriculture for the continent of North America may yield this slightly higher response to fertilizer. If so, this may be due to high investment in fertilizer and plant technology, especially by the United States.

Results for the Education Variable

The variable representing education is viewed with particular interest. Recently Robert Herdt (1971) has contrasted his negative coefficients for state-level production functions in India with the large positive coefficients of Griliches and Hayami-Ruttan. Herdt argues that education has to have other inputs, such as research and extension, supplied with it. This should have implied that Griliches and H-R proxy variables for education were representing a lot more than simply education. He also argued that India was not on the H-R meta-production function, although it might more easily be argued that the literacy variable was simply not representing the same things with his state-level, Indian data.

Present results are not very decisive. The education coefficient for North America is smaller than that of Griliches and Hayami-Ruttan and has a larger standard error. In fact, it is not statistically significant. Also, when the proxies for education and technical manpower are dropped in Regression 3, nothing changes very much. The coefficient of determination does not change, and individual coefficients remain quite stable.[4]

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[4]Finis Welch has argued that, since the primary effect of education is on the ability to use new inputs, some of the effects of education on output in an aggregate production function are assigned to other inputs (See Finis Welch, January, 1970). On the other hand it is easy to see how exclusion of modern inputs from his value-added production function would give an upward bias to his education coefficient.

In the above-mentioned studies which included data from developed countries it seems likely that the education variable is correlated with other government services which increase output, such as extension and marketing services, etc. Thus, it was hoped that an education coefficient could be estimated separately for Mexico, where the absence of such services would make the upward bias less pronounced. Two techniques were employed to obtain separate estimation of the impact of education upon Mexican agricultural productivity. The first involved the use of a binary variable to shift the education coefficient for Mexico. The second was to estimate the production function using only Mexico's thirty-one state level observations. There were difficulties with both approaches.

In the United States and Canada, the literacy ratio for the farm population ranges from 86 to 99 percent with an average of 96 percent. For Mexico the ratio ranges from 36 to 82 percent with an over-all average of 58 percent. The problem of representing education in the production function becomes quite difficult when one attempts to allow the education coefficient to shift for Mexico. Regression 2 in Table 3 shows that the education input variable apparently takes over the functions of the intercept dummy variable and becomes unreasonably large.

When a separate regression was run with just the thirty-one Mexican observations, results were not entirely reasonable.

There were high levels of collinearity (r^2 of .70 and .80) and unreasonable and negative coefficients. Although negative education coefficients were obtained, they may have been due to multicollinearity.[5]

Thus the effort to provide additional insight into the meaning of the production elasticity estimates for education was largely unsuccessful. The 0.248 production elasticity for education obtained for North America (Table 1) and the even larger estimates found in other studies are difficult to interpret because the education variable is surely correlated with other inputs which cannot be included in the production function. And efforts to obtain production elasticity estimates for education in developing countries have been very inconclusive.

Other Coefficient Changes Between Countries

In testing for other coefficient changes between countries the emphasis was on differences between Mexico and the two developed countries. The slope and intercept dummies in Table 3 combine Canadian provinces with U.S. states. Unreported regressions which used separate slope dummies for Canada were similar to Table 3

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[5]See Karl A. Fox (1968, p. 262) to see how multicollinearity can cause negative coefficients.

regressions in the results for Mexico. Also, the Canada dummy tended to be similar to the U.S. dummy except for a few cases where the error term for the Canada slope dummy was quite large. On the other hand, separate estimation of the Canada and U.S. intercept dummy in Table 1 indicates that the U.S. intercept is somewhat above the Canada intercept.

The large and significant intercept dummies obtained in Table 1 indicated that Mexico is on a different production function from the rest of North America, regardless of whether production elasticities changed or remained the same across national boundaries. An F-test of the hypothesis that Mexico is one the same production function as the rest of North America was rejected at the .99 level of significance. However, the more interesting problem is to determine whether the production elasticities are different for Mexico, and if so, what are they?

Separate regressions with Mexico's 31 observations yielded unreasonable results as did a regression with slope dummies for the five conventional inputs. Results for separate regressions using all 89 observations and with a dummy variable for each coefficient are presented in Table 3. Generally, coefficient shifters for the countries are less easily interpreted than the coefficients based upon the regional divisions which will be presented later.

Table 3. Estimates of Aggregate Agricultural Production Function on State and Province Level Data with Binary Variables for Countries* (Per farm data, 1959, 1960, and 1961)

Regression number	1	2	3	4	5	6	7	8**
Sample size	89	89	89	89	89	89	89	89
Land (adjusted)	0.202	0.193	0.211	0.203	0.389	0.220	0.197	0.371
	(0.061)	(0.058)	(0.059)	(0.058)	(0.083)	(0.089)	(0.058)	(0.082)
Fertilizer	0.212	0.222	0.210	0.218	0.184	0.197	0.207	0.171
	(0.041)	(0.040)	(0.040)	(0.049)	(0.030)	(0.042)	(0.041)	(0.037)
Labor	0.576	0.616	0.466	0.586	0.557	0.590	0.576	0.591
	(0.117)	(0.117)	(0.180)	(0.121)	(0.109)	(0.114)	(0.115)	(0.106)
Livestock	0.159	0.195	0.151	0.158	0.182	0.239	0.167	0.165
	(0.082)	(0.082)	(0.082)	(0.082)	(0.070)	(0.100)	(0.082)	(0.077)
Technicians	0.025	0.027	0.025	0.025	0.013	0.032	0.093	0.021
	(0.047)	(0.047)	(0.047)	(0.046)	(0.144)	(0.046)	(0.108)	(0.044)
Education	0.167	0.168	0.189	0.141	-0.077	0.070	0.161	0.248
	(0.286)	(0.271)	(0.276)	(0.292)	(0.273)	(0.281)	(0.274)	
Power	0.089	0.695	0.096	0.090	0.104	0.082	0.077	0.091
	(0.086)	(0.079)	(0.078)	(0.079)	(0.074)	(0.077)	(0.081)	(0.074)
U.S. and Canada Dummy	0.613	-9.401	0.522	0.622	1.246	0.112	0.488	1.150
	(0.104)	(6.883)	(0.154)	(0.190)	(0.234)	(0.409)	(0.107)	(0.220)
Mexico Intercept	1.847	1.880	1.891	1.888	1.724	1.703	1.953	1.224
	(0.569)	(0.557)	(0.569)	(0.592)	(0.537)	(0.571)	(0.581)	(0.335)
U.S. and Canada Slope Dummies*								
Power	0.007							
	(0.121)							
Education		5.046						
		(3.487)						
Labor			0.153					
			(0.191)					
Fertilizer				-0.013				
				(0.066)				
Land					-0.245			-0.216
					(0.083)			(0.079)
Livestock						-0.132		
						(0.105)		
Technicians							0.075	
							(0.107)	
Residual Mean Square	0.021	0.020	0.021	0.021	0.019	0.021	0.021	0.019
Coef. of det. (adj.)	0.911	0.913	0.911	0.911	0.920	0.912	0.911	0.899

* In each regression the coefficient for the U.S. and Canada is equal to the slope dummy plus the Mexican regression coefficient listed above. If a t test indicates a variable is significantly different from zero, then the Mexico coefficient is considered different from the other two countries' coefficient.

** In Regression 8 the production elasticity for education is constrained to be 0.248.

Perhaps the most interesting result in Table 3 is the lack of any significant difference between fertilizer coefficients for the three countries. This result was supported by the separate regressions run for each country although, as was stated above, these separate U.S. and Mexican regressions generally did not provide very reliable results. In contrast to results of country comparisons in Regression 4, Table 3, later sections will describe large differences in fertilizer production elasticities across certain regions in North America.

The fact that the land coefficient is significantly lower for Canadian provinces and for the United States as compared to the relatively large land coefficient for Mexico is consistent with results obtained by Hertford (pp. 73-80). In his study of Mexican agriculture Hertford obtained land coefficients as high as .4 for the private sector both inside and outside publicly irrigated areas as well as in the dry-land ejido sector. The land coefficient for the U.S. and Canada is much smaller. In Regression 5 the Mexican land coefficient is 0.389 with a -0.245 slope dummy for the U.S. and Canadian coefficient; this makes the U.S. and Canada coefficient equal to 0.144, which is consistent with estimates in Table 1.[6]

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[6]The slope dummy variables take on zero value for Mexico and are one for Canada and the U.S. The coefficient for Canada and the U.S. is estimated as the sum of the dummy variable estimate and the coefficient for the rest of the population (which consists of 31 Mexican observations.) A t test performed on the slope dummy is used to indicate that the Canada and U.S. coefficient is not the same as the Mexico coefficient (Kmenta, 1971, p. 420).

The labor coefficient estimate is not significantly lower for Mexico than for the rest of North America. This result is again consistent with Hertford's estimates of labor coefficients at around .4 for his private sector estimates, although negative labor coefficients were obtained for family labor in his ejido sector. (The family labor input is known to be exaggerated in the ejido section of the Censo. Also, it should be kept in mind that in my labor specification, children of ejido farmers were excluded.)

Results for binary labor and land variables thus indicate that for growth accounting the weight which Table 3 regressions would assign to Mexico's abundant labor factor should be just as heavy as the weight placed on labor for the other two countries.[7] On the other hand, land, which is Mexico's scarce factor, would receive a heavier weight than does land in the U.S. and Canada.

Since land is the variable for which production elasticities are different for Mexico, Regression 5 of Table 3 would appear to be the appropriate regression to apply to the country level economic analysis of the following two sections.

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[7]The dummy variables for land and labor were estimated in separate regressions because attempts to include both inputs in one regression yielded negative and unreasonable coefficients of the type which accompanies multicollinearity problems.

However, with the increase in the number of variables in Regression 5, the production elasticity for education has become negative. Although the 0.248 estimate in Table 1 had a large standard error, it is considered a more reliable estimate than the Table 3 regression which contains more variables. Regression 8 constrains the education coefficient to 0.248, and provides estimates of the other coefficients which are similar to those of Regression 5. A t test in Regression 5 would not reject the null hypothesis that the education coefficient is 0.248. Regression 8 production elasticities will be used throughout the economic analysis in this chapter. Readers who are distrustful of the education coefficient may simply ignore the results based upon that coefficient.

Implications Concerning Resource Allocation

By comparing ratios of prices of conventional inputs to their marginal value products we can, for one point in time, obtain a measure of the incentives for changes in the allocation of resources. When these incentives have become particularly strong, it can perhaps be argued that resource allocators have been slow to respond, and that this slowness is a source of lower productivities.

Table 4 presents estimates of the value of the marginal product for the fertilizer and labor inputs, measured at the mean, and it gives their prices. (The VMP's were calculated using

elasticities from Regression 8, Table 3.) Since it is also difficult to estimate the cost of plant nutrients in both Mexico and Canada, 1962-63 price estimates by the Food and Agriculture Organization were relied upon to show that the U.S. price of plant nutrients is somewhat lower than in the other two countries.[8]

If it is true that Mexican fertilizer prices are only slightly higher than U.S. prices, then there was in 1960 even greater incentive for Mexican decision makers to apply more fertilizer than for the other two countries. At the margin the return was almost twenty-five percent higher in Mexico. For the U.S., the 250 dollar cost of obtaining plant nutrients is to be compared with a VMP of 762 dollars. This gap is almost one hundred dollars higher per ton than the Griliches estimate for 1959; the difference being due to the higher production elasticity estimates obtained here.

In the case of the labor input, Mexico appears to be further from equilibrium than the other two countries. The value of the marginal return for a year's farm labor in the U.S. is only $2,830 and this is not large even compared to a agricultural laborer's wage of $1,980/year. However, the U.S. labor VMP is almost fifteen times that of Mexico, while the U.S. agricultural wage rate is only about nine times that of

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[8]See footnote Nine of Table 4.

Table 4. Prices of Fertilizer and Labor and Present Estimates of Marginal Value Products for the United States, Mexico and Canada, 1959, 1960, 1961.

	United States	Mexico	Canada
VMP of Fertilizer ($/ton of plant nutrients)	762	952	772
Price of Fertilizer ($/ton of plant nutrients)[9]	250	275-300	275-300
WMP of Labor ($/man/year)	2,830	193	2,180
Wage Rate ($/year)[10]	1,980	225	2,283

Note: Chapter 5 will present regional VMP estimates for livestock and land. Data does not permit reliable estimates for education and technicians. VMP estimates in this table are based upon Regression 8 of Table 3.

[9]The U.S. plant nutrient price was from Griliches (1964, p. 969). FAO figures place Canadian prices for the main plant nutrients at fertilizer plants at about 10 percent higher than U.S. farm level prices. Mexican prices at the plant and without subsidies are similar to Canadian prices. (See United Nations, Food and Agriculture Organization, 1962 and 1963, pages 360 and 594 respectively.)

[10]Includes payment in kind and represents the product of the average daily farm wage times 300 days per year. (See United Nations Food and Agriculture Organization, 1963, pp. 395-6.)

Mexico. This indicates a much greater incentive for Mexican farmers to either leave agriculture or seek part-time employment. This result was obtained in spite of a labor specification which excluded 20 per cent of the Mexican Census labor figure by giving zero weight to the family members of ejido operators. The incentive for Canadian farmers to seek employment off the farm was also stronger than the U.S. incentive.

It should be emphasized at this point that the results of these comparisons between countries may not necessarily apply for even large regions within the countries. For instance, the marginal return to fertilizer in the larger farm areas of Northwestern Mexico where fertilizer is used fairly extensively may be much lower than in the small farm area near the Federal District. One of the main objectives of the next chapter is to find ways of identifying regions with different production parameters and to analyze those regions separately.

Accounting for Productivity Differences Between Countries

Production elasticities estimated by Cobb-Douglas production functions provide weights for inputs which have been used to account for agricultural productivity differences over time and between countries. Since Mexican data are not available for making comparisons over time, present analysis will be restricted to comparisons between countries and between regions. Regional comparisons will be presented in Chapter 5 and will show

that sources of productivity differences among certain large regions may be quite different from those implied by comparisons among countries. However, as a logical starting place for examining sources of productivity differences in North America, this section will present results for country level comparisons among Mexico, Canada and the United States.

Tests with binary variables showed that the coefficient for land in Mexico is higher than in the other two countries, and this result was supported by Hertford (pp. 73-80). (The Regression 8 coefficients in Table 3 were used in the growth accounting formula.) It was argued in the first sections of this chapter that the production elasticity estimates which are used as weights in accounting for productivity differences between Mexico and the United States are quite reliable.

The last line in Table 5 is the total percentage difference in productivity to be explained by the inputs listed above. The productivity differences accounted for by each of those inputs were estimated by dividing the difference in input use per farm between the U.S. and the other country by the U.S. input quantity, and then multiplying by the production elasticity. The resulting number tells us the percentage increase in output which would result from raising per farm input levels to the U.S. level. The numbers in parenthesis are an index with the total productivity difference set equal to 100.

Table 5. Accounting for Per Farm Productivity Differences Between Countries in North America

	Mexico as a Percent of the U.S.	Canada as a Percent of the U.S.	Mexico as a Percent of Canada
Technical Inputs:			
Fertilizer	11 (12)*	8 (17)	7 (8)
Power	9 (10)	1 (2)	8 (9)
Human Capital:			
General education	10 (11)	-1 (-2)	10 (11)
Technical education	-1 (-1)	-1 (-2)	0 (0)
Resource Accumulation:			
Land	13 (14)	-3 (-6)	18 (21)
Livestock	14 (15)	-1 (-2)	13 (15)
Labor:	-8 (-8)	19 (40)	-24 (-27)
Total difference in output per farm	87 (100)	47 (100)	84 (100)
The difference that is explained by the variables listed above.	48 (53)	22 (47)	32 (37)

* Inside of parenthesis are percentages with the total difference in output per farm set equal to 100.

Note: Input weights were based upon production elasticity estimates of Regression 8, Table 3.

Because so much of the difference in productivities between Mexico and the other two countries was assigned to the large intercept dummies, the five conventional inputs and the two non-conventional inputs were not expected to account for all of the total difference in output per farm. The rest is due mainly to technology differences which could not be included in the production function.[11] The procedure also accounted for barely half of the 47 percent productivity difference between Canada and the U.S.

Because of the relatively high weight assigned to Mexico's scarce land input, it is the input which accounts for the next largest share of the difference in farm productivity, accounting 14 percent of the total 87 percent difference between Mexican and U.S. output per farm. (Farms should be thought of here primarily as family holdings.) Land and livestock together account for twenty-nine percent of the total farm productivity difference.

Nevertheless, results here are similar to the labor productivity growth accounting results of Hayami and Ruttan

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[11]See Willis Peterson and Yujiro Hayami (1973, pp. 21-22) for a discussion of the problem of representing technological differences between groups of observations.

which show that nearly one-fourth of the gap in output per farm worker between developed and less developed countries can be closed through the purchase of technical inputs. Differences in fertilizer use per farm accounts for 11 percent of the farm productivity difference between Mexico and the U.S., and differences in the amount of power employed accounts for another ten percent.

Results here would indicate, on the other hand, that increasing literacy ratios does not result in productivity increases that are as large as those predicted by other studies. Raising Mexico's literacy rates to U.S. levels would, by present estimates, only result in an 11 percent increase in Mexican agricultural productivity.

The fact that Mexico is shown to be slightly ahead of the United States in terms of the number of agricultural technicians per farm probably indicates an error in the specification of what is an agricultural technician. However, because of Mexico's massive investment in public irrigation with the large amount of technical manpower that has gone with that investment, it is probably true that actual differences in the number of agricultural technicians per farm would not account for very much of the productivity gap between the United States and Mexico. In contrast to many developing

countries, Mexico began fairly early to make public investments to overcome at least part of their land scarcity constraint.

Because there are only ten observations for Canada, no tests were able to show whether the North America production coefficients actually apply to Canada. Thus, since the North America coefficients used as weights in the growth accounting formulas may not apply to Canada, not very much time will be spent in analyzing the possible unreliable results of the Canada - U.S. and Canada - Mexico accounting results. Rather, estimates in the last two columns in Table 5 will be briefly reviewed so that they can be compared with what will hopefully be more useful results in Chapter 5.

When the same production elasticities are applied to percentage differences in input use between Canada and Mexico, results are similar to those for the U.S. and Mexico except the share accounted for by fertilizer drops to 8 percent and farm size share increases to 21 percent.

Of the 47 percent difference in farm productivity between Canada and the U.S., labor and fertilizer are the only inputs which account for an important part of the difference. If the production elasticity for fertilizer is the correct weight, it would mean that fertilizer, alone, accounts for 17 percent of this difference in farm productivity.

Chapter 4

Regional Differences in Agricultural Production Parameters Within North America

There is good reason for questioning whether production function coefficients estimated from cross sections which include diverse regions can be considered anything but an averaging of several production functions which are really very different. The response to fertilizer application in a cattle region, for instance, may not be the same as in cotton region. We especially need to know whether the differences are so great as to make it necessary to estimate production parameters separately for each region.

Since the objective is still to estimate aggregate agricultural production functions, it is desirable to identify large regions with the same production parameters rather than simply to find areas with a similar crop mix. Crop mix is not the only characteristic of a region which could cause it to have a unique response to various inputs. Climatic conditions, factor scarcities, and historical factors may all conceivably lead to differences in production relationships.

So far, the main emphasis has been to compare countries with very different factor scarcities and very different histories in terms of agricultural development.

Yet within countries ratios of land productivities to labor productivities can also vary in a consistent pattern. In fact, three distinct regions within countries are identified here on the basis of factor scarcities, and these regions are then selected for tests of whether the production function was the same between regions.

The regions were identified in Figure 1 according to the ratio of labor productivities to land productivities. Even among states for the U.S. we find labor productivities varying by a factor of five between populated states in the East or South as compared to land intensive states further west. Land productivities vary even more widely with low labor productivity states generally among the highest in terms of cropland productivity.

It was convenient to divide Figure 1 into three groups of states. Probably the most uniform of the three groups was in the Plains Region. For the U.S. and Canada this region includes the main wheat and cattle ranching states. For Mexico, it includes mainly the dry plateau states of the northeast. They are the dry states that do not receive as heavy irrigation as the states in Northwestern Mexico. On the map of North America in Figure 2, the Plains Region is the shaded area.

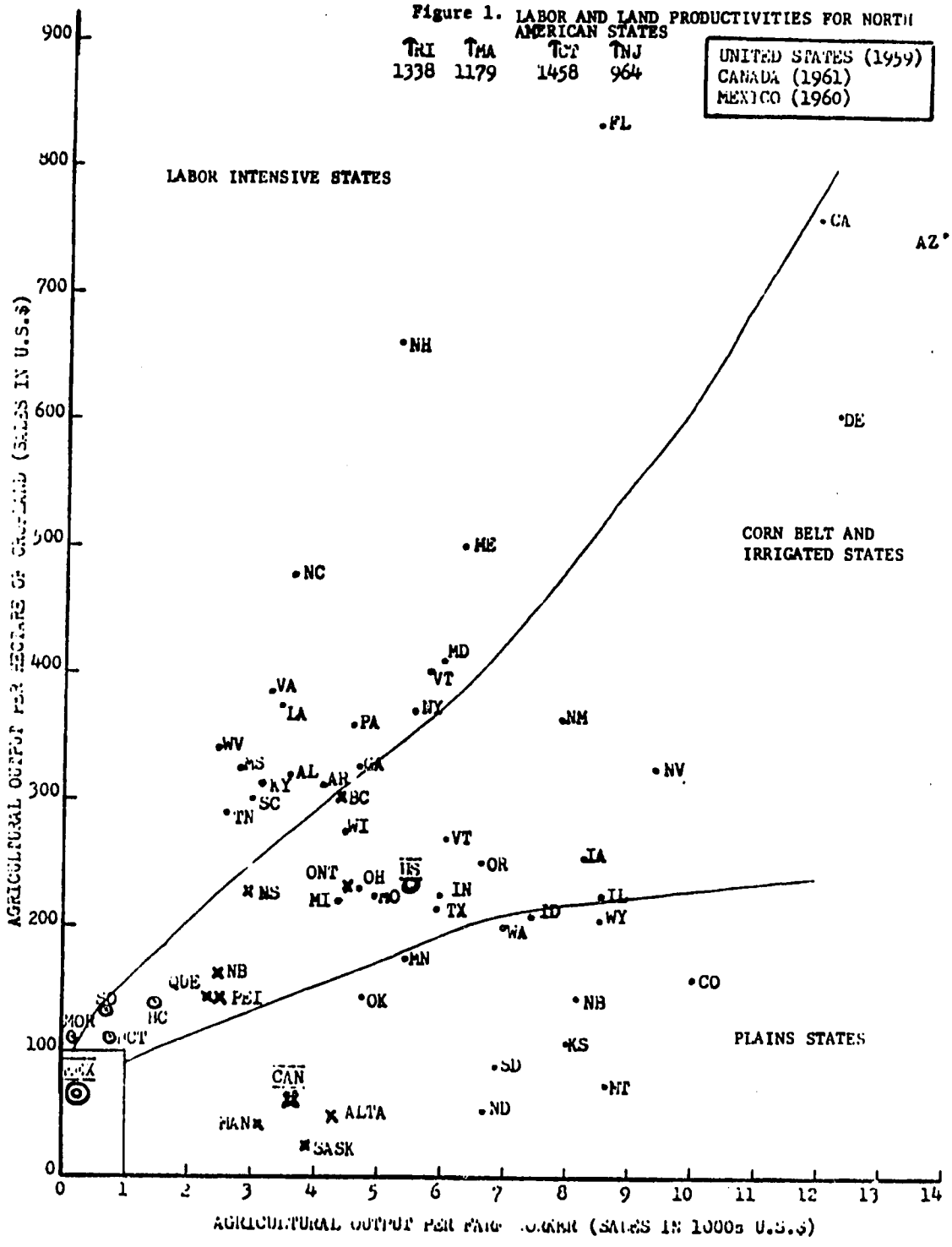
At the other extreme from the low land productivity states of the Plains Region, are the labor intensive states.

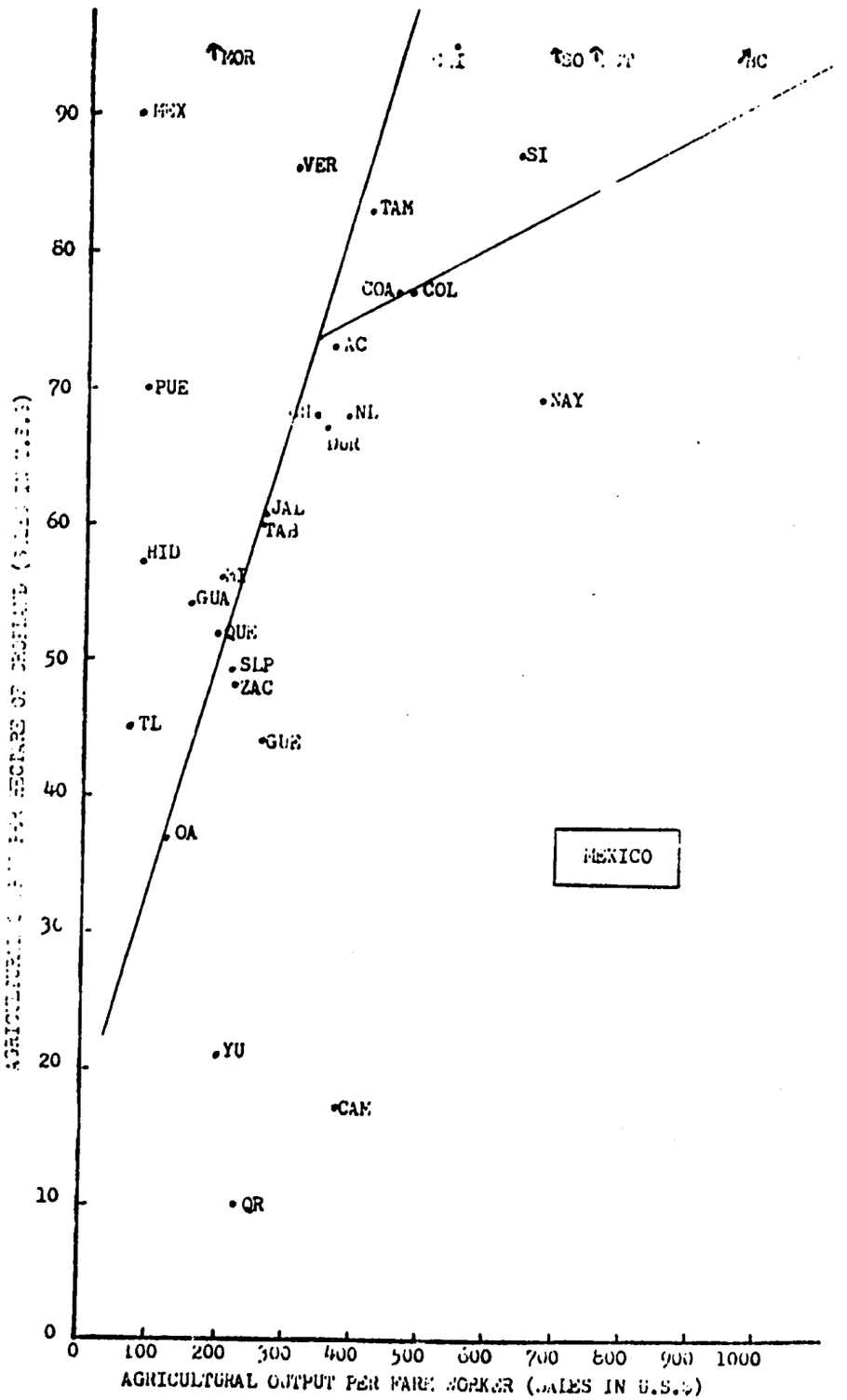
These states are either located near densely populated urban areas, such as the eastern U.S. cities and the Federal District in Mexico, or they are areas which have traditionally been labor intensive states. For instance, the states which have the most small ejido units in Mexico and the U.S. southern states, are part of the Labor Intensive Region. In Figure 2 the Labor Intensive Region is dotted.

The third group of states is in between the other two in its ratio of land productivity to labor productivity. These states really make up two regions: the first is the U.S. Corn Belt and Eastern Canada, and the second is the highly productive irrigated region of western United States and the heavily irrigated states directly across the border in Mexico. Mexican states in the irrigated region all have a great deal in common with Southwestern United States in crop patterns, climate, and in the use of irrigation. For Mexico they are also the most productive states, especially in terms of labor productivity. The Corn Belt and Irrigated Regions are striped in Figure 2.

Mexico has six states which were hard to place in any of the three categories. Four are from the Yucatan Peninsula which is the only large region that remains mostly unsettled jungle. Also Jalisco and Colima did not fit in either group because they are geographically adjacent to all three subregions and shared the agricultural characteristics

Figure 1. LABOR AND LAND PRODUCTIVITIES FOR NORTH AMERICAN STATES




MOR
SO
MC
MEX
VER
SI
TAM
COA
COL
AC
PUE
NAY
NL
DGO
JAL
TAB
HID
GUA
QUE
SLP
ZAC
TL
GUE
OA
MEXICO
YU
CAM
QR
0
10
20
30
40
50
60
70
80
90
0
100
200
300
400
500
600
700
800
900
1000
AGRICULTURAL OUTPUT PER FARM WORKER (DATES IN U.S.$)

Key to Mexican Abbreviations in Figures 1 and 2:

North

1. Coahuila - COA
2. Chihuahua - CHI
3. Durango - DUR
4. Nuevo Leon - NL
5. San Louis Potosi - SLP
6. Tamaulipas - TAM
7. Zacatecas - ZAC

Gulf of Mexico

8. Campeche - CAM
9. Quintana Rop - QR
10. Tabasca - TAB
11. Veracruz - VER
12. Yucatan - YU

North Pacific

13. Baja California - BC
14. Baja California T. - BCT
15. Nayarit - NAY
16. Sinaloa - SI
17. Sonora - SO

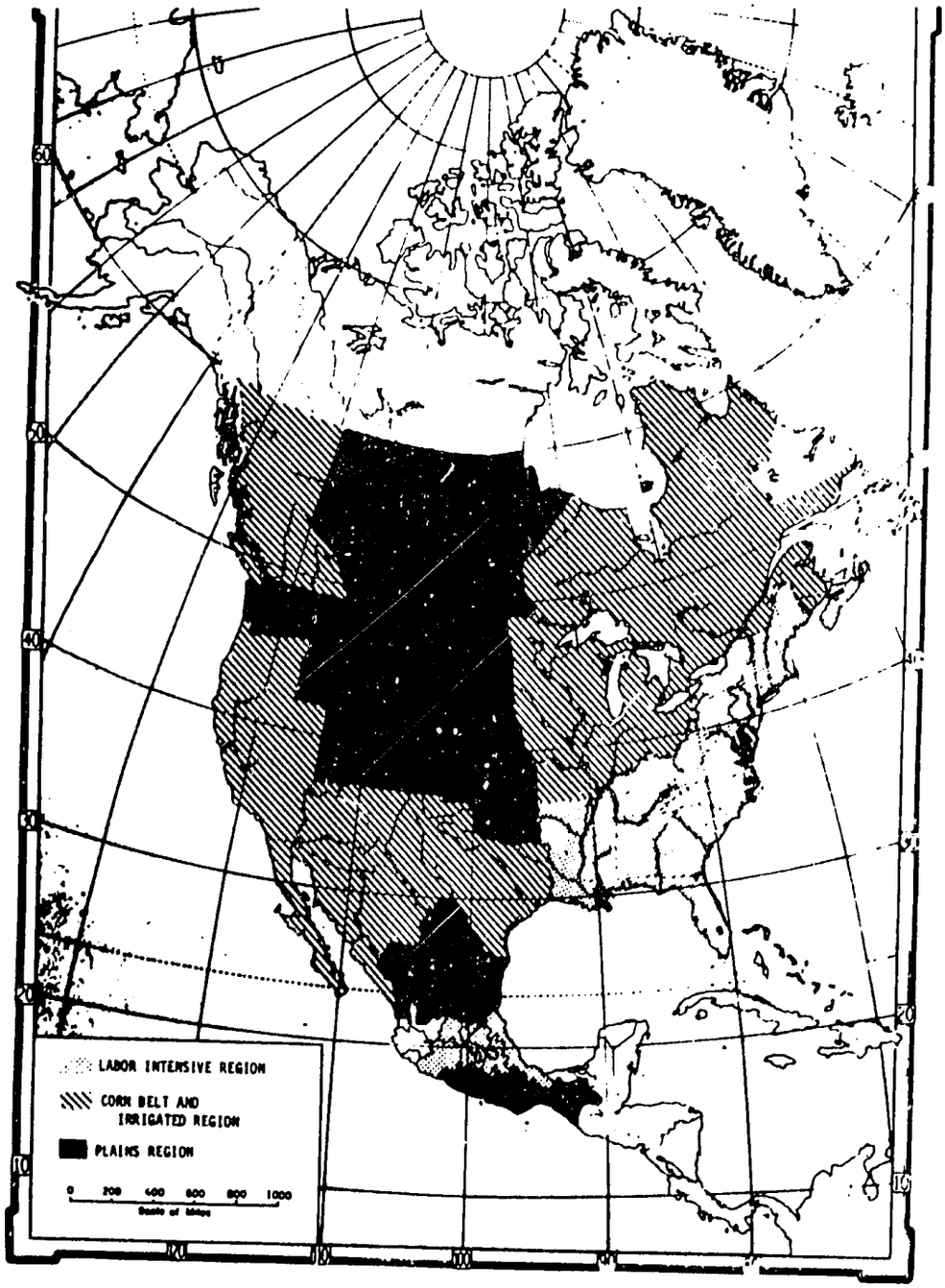
South Pacific

18. Colima - CO
19. Chiaps - CH
20. Guerreo - GUE
21. Oaxaca - OA

Central

22. Aguascalientas - AC
23. Distrio Federal - DF
24. Guanajuato - GUA
25. Hidalgo - HID
26. Jalisco - JAL
27. Mexico - MEX
28. Michoacan - MI
29. Morelos - MOR
30. Pueblo - PUE
31. Queratero - QUE
32. Tlaxcala - TL

Figure 2. Division of North America into Three Agricultural Regions



of all three groups of states. These states were not included in the regional analysis.

The regional groupings of states which are identified in Figure 1 and Figure 2 appear to provide a good starting place in the search for regional differences in production parameters. Geographic and climactic uniformity of each region reinforces the resource scarcity criteria by which they were identified. If it is possible to sort out he ways in which these regions differ from one another, that will be useful in itself. It would also be very useful to compare similar regions within different countries after sorting out the effects of factor scarcities which are not strongly reflected by regional differences in factor prices. (At least they are not reflected to the extent to which national factor scarcities are reflected by factor prices.)

The three Canadian states which are included in the Plains Region account for 46 percent of the value of Canada's agricultural output, while the U.S. states in that region account for only 18 percent of U.S. output. It therefore is particularly important to see whether the production elasticities and average products in the Plans Region are the same as those used in the growth accounting formula in Chapter 3. If they are not the same, it would clearly be more useful to attempt a separate comparison between Canadian and American Plains States

using the correct input weights.

Mexico's five states in the Irrigated Region are Mexico's modern, large-farm states, and they account for 20 percent of Mexico's output. Mexico's nine Labor Intensive States account for 35 percent of that country's agricultural output, and they are at the other extreme, representing the traditional, small holder agricultural sector. An effort will be made to estimate production parameters separately for the Corn Belt and Irrigated Region and for the Labor Intensive Region using observations from the United States and Mexico.[1] State level data from these regional divisions will provide a good basis for analyzing Mexico's dual approach to agricultural development.

Estimation of Coefficients for the Northern Plains Region

Three methods were used to obtain separate regional estimates of coefficients. Two of these involved the use of dummy or binary variables in order to allow coefficients to shift for each region: in one approach separate regressions were run with each containing a slope dummy for just one variable; in another approach several slope dummies were included in each regression in the hope of estimating a separate production function for the region being considered. In both cases the coefficients for the region were estimated as the sum of

[1]Throughout the rest of the analysis the Northern Plains Region will refer only to the Plains states from the U.S. and Canada. Similarly, analysis of the irrigated and Corn Belt region will exclude the Canadian states which fall in that region.

the slope dummy and the variable estimate for the rest of the population. A test of the hypothesis that the dummy variable is greater than zero was the basis for deciding whether the coefficient for the region was different from the coefficient for the rest of the population. (See Jan Kmenta, 1971, p. 420).

The third approach was to simply estimate a separate production function made up of the observations from each region. This approach was not expected to be successful because of the small number of degrees of freedom.

Since the Plains Region in Canada is so important to Canada's agricultural industry, it was hoped that separate production parameters could be estimated for the three Canadian Provinces and twelve American states which make up the Northern Plains Region. When more than one slope dummy variable was included in each regression, standard errors for the dummy variables all became quite large. A separate regression for the Northern Plains Region yielded unreasonable coefficients for all variables (with the possible exception of fertilizer) and simple correlation coefficients were between .70 and .80 among the stock inputs and labor. Regressions containing an intercept dummy for the region and one slope dummy provided the only reasonable results. However, the slope dummy coefficients in Table 6 all tend to have large standard errors.

Thus, there was no strong indication that the Northern Plains Region is on a separate production function from the rest of the continent.

In spite of some significant negative intercept dummies in Table 6, an F test based upon the separate regression for the Region's 15 observations provided no evidence that the Northern Plains Region is on a different production function from the rest of North America. Negative results for t tests for individual estimates of slope dummies supports the conclusion that the Northern Plains Region is not to be considered as a separate production function.

Estimation of Coefficients for the Labor Intensive Region

For the Labor Intensive Region there apparently are differences in production elasticities for the Region as compared to the rest of North America. As shown in Table 6 the direction of change of labor, land, and fertilizer coefficients implied by the slope dummy results are supported by separate estimation of a production function (Regression 1) using the 31 observations from the Labor Intensive Region. The F test supported the null hypothesis that the region is on a different production function at the 95 percent level.

Coefficients significantly different from zero were obtained for the slope dummy in Regression 2, Regression 3, and Regression 4. Tests provide fairly strong evidence that produc-

Table 6. Estimates of Aggregate Agricultural Production Functions on State and Province Level Data with Binary Variables for the Northern Plains Region (Per farm data, 1959, 1960, and 1961)

Regression Number	1	2	3	4	5
Sample size	89	89	89	89	89
Land	0.259	0.272	0.253	0.249	0.270
	(0.061)	(0.061)	(0.062)	(0.062)	(0.062)
Fertilizer	0.219	0.209	0.221	0.212	0.214
	(0.039)	(0.039)	(0.042)	(0.040)	(0.039)
Labor	0.487	0.455	0.470	0.491	0.491
	(0.119)	(0.120)	(0.121)	(0.121)	(0.120)
Livestock	0.138	0.148	0.167	0.163	0.120
	(0.081)	(0.079)	(0.080)	(0.081)	(0.085)
Technicians	0.033	0.017	0.033	0.024	0.022
	(0.045)	(0.045)	(0.046)	(0.046)	(0.045)
Literacy	0.107	0.076	0.068	0.095	0.109
	(0.266)	(0.265)	(0.270)	(0.269)	(0.266)
Power	0.086	0.110	0.086	0.097	0.105
	(0.073)	(0.075)	(0.077)	(0.076)	(0.075)
U.S. and Canada dummy	0.649	0.627	0.638	0.633	0.645
	(0.100)	(0.099)	(0.101)	(0.101)	(0.100)
Intercept	1.956	1.952	1.958	1.905	1.969
	(0.543)	(0.540)	(0.555)	(0.551)	(0.546)
Northern Plains Region intercept dummy	-0.252	-0.375	-0.090	-0.551	-1.043
	(0.092)	(0.142)	(0.060)	(0.495)	(0.559)
Northern Plains Region slope dummy					
Power	0.701				
	(0.386)				
Labor		1.045			
		(0.528)			
Fertilizer			-0.121		
			(0.120)		
Land				0.172	
				(0.196)	
Livestock					0.242
					(0.145)
Residual Mean Square	0.019	0.019	0.020	0.020	0.019
Coefficient of det. det. (adj.)	0.918	0.918	0.915	0.915	0.917

tion elasticity for fertilizer is greater for the Labor Intensive Region than for the rest of North America and that the Region's production elasticity for labor is lower. The Labor Intensive Region's production elasticity for labor, obtained by taking the sum of labor coefficient and the slope dummy for labor, is 0.246 as compared to the Table 1 estimate of 0.490. The Region's 0.231 estimated fertilizer production elasticity in Regression 4 is considerably higher than the Table 1 estimate of 0.196.

However, since those regressions could only contain one slope dummy in each regression, it seems likely that the included dummy variable may be correlated with other variables which would bias the results. As a further test of the magnitude of the difference, Regression 1 was run with just the nine Mexican states and the 22 United States states which fell in the Labor Intensive Region. Unreasonable results were obtained for land, livestock, and literacy coefficients, but the other coefficients seem reliable. The 0.247 fertilizer coefficient is higher than for the rest of North America and is comparable to the Regression 4 estimate of 0.231. The labor coefficient of 0.225 is lower than the Table 1 estimate, and is similar to the estimate in Regression 5. (The upward shift in the Region's power coefficient in Regression 2 was not supported by Regression 1.)

Table 7. Estimates of Aggregate Agricultural Production Functions on State and Province Level Data with Binary Variables for the Labor Intensive Region (Per farm data, 1959, 1960, 1961

Regression number	1	2	3	4	5	6	7
Sample size	31	89	89	89	89	89	89
Land	-0.083	0.296	0.231	0.268	0.233	0.292	0.234
	(0.198)	(0.068)	(0.067)	(0.068)	(0.072)	(0.064)	(0.064)
Fertilizer	0.247	0.225	0.198	0.181	0.210	0.206	0.191
	(0.090)	(0.039)	(0.041)	(0.041)	(0.041)	(0.051)	(0.040)
Labor	0.225	0.486	0.610	0.500	0.534	0.550	0.539
	(0.261)	(0.116)	(0.120)	(0.119)	(0.125)	(0.110)	(0.123)
Livestock	0.431	0.137	0.141	0.134	0.167	0.036	0.130
	(0.162)	(0.077)	(0.080)	(0.079)	(0.082)	(0.078)	(0.080)
Technicians	0.224	0.000	0.032	0.012	0.026	0.003	0.017
	(0.101)	(0.044)	(0.046)	(0.045)	(0.047)	(0.042)	(0.045)
Literacy	-0.478	-0.198	0.137	-0.067	0.080	-0.017	-0.106
	(0.536)	(0.286)	(0.277)	(0.281)	(0.292)	(0.258)	(0.281)
Power	0.038	0.013	0.092	0.113	0.092	0.070	0.107
	(0.140)	(0.076)	(0.076)	(0.075)	(0.078)	(0.070)	(0.076)
U.S. and Canada Dummy	0.681	0.662	0.631	0.603	0.607	0.669	0.625
	(0.270)	(0.100)	(0.104)	(0.101)	(0.106)	(0.096)	(0.102)
Intercept	3.249	2.339	1.884	2.234	1.931	2.344	2.398
	(1.145)	(0.589)	(0.599)	(0.600)	(0.617)	(0.561)	(0.591)
Labor Intensive Region Intercept Dummy		0.105	0.170	0.045	0.271	-1.246	
		(0.053)	(0.088)	(0.049)	(0.227)	(0.279)	
Labor Intensive Region Slope Dummy							
Power		0.241					
		(0.067)					
Labor			-0.364				0.004
			(0.163)				(0.095)
Fertilizer				0.150			0.137
				(0.050)			(0.053)
Land					-0.134		
					(0.111)		
Livestock						0.385	
						(0.084)	
Residual Mean Square	0.013	0.018	0.020	0.019	0.021	0.017	0.019
Coef. of det. (adj)	0.054	0.922	0.914	0.919	0.911	0.928	0.958

Regressions with more than one slope dummy variable again tended to yield negative and unreasonably large coefficients for some variables. However, Regression 7 was run as a further test of the regional results for fertilizer and labor. Regression 7 supports the previous result for fertilizer but indicates no shift for the labor coefficient.

When results for the Labor Intensive Region are compared with those for the sparsely populated Northern Plains Region, the contrast is especially sharp. Both tests showed that the fertilizer coefficient is higher for the Labor Intensive Region than for the rest of the continent, while the Northern Plains coefficient for fertilizer was lower than for the rest of the continent (although the negative slope dummy was not highly significant.) This result seems quite reasonable in view of the fact that the Labor Intensive Region produces cotton and other crops which respond well to fertilizer, while the Northern Plains Region produces cattle and wheat. The North America production function results in Table 1 apparently represent an averaging of regional production parameters which are really quite different. In making economic comparisons between regions in different countries it is helpful to take account of these differences.

Coefficient Shifts for the Irrigated and Corn Belt Regions

As may be recalled from the discussion of Figure 1, there is a third group of states and provinces whose ratio of land to labor productivity fell in between the high labor productivity states in the Plains Region and the more densely populated states which make up the Labor Intensive Region. This region contains two rather uniform groups of states: these are (1) the irrigated states in Southwestern United States and Northwestern Mexico and (2) the corn belt states in the U.S., plus Canada's provinces of Ontario, Quebec, New Brunswick, and Prince Edward's Island.

Again tests were run for the same five coefficients. However, Table 8 shows that binary variables do not even come close to being significantly different from zero.[2] Since previous tests suggest that the dummy variables are very sensitive for picking up coefficient shifts, this negative result for the test seems decisive. The F test for a separate regression for this region did not reject the hypothesis that the region is on the same production function as the rest of North America. This group of observations therefore does not need any special shift parameters.

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[2]The negative slope dummy for livestock in Regression 5 is significant, but the huge regional intercept dummy in Regression 5 casts considerable doubt on that result (an unreported regression which excluded the regional intercept dummy indicated no shift for the livestock dummy.)

Table 8. Estimates of Aggregate Agricultural Production Functions on State and Province Level Data with Binary Variables for the Irrigated and Corn Belt Region (Per farm data, 1959, 1960, 1961)

Regression number Sample size	1 89	2 89	3 89	4 89	5 89
Land	0.212 (0.060)	0.202 (0.059)	0.210 (0.060)	0.208 (0.062)	0.197 (0.056)
Fertilizer	0.212 (0.040)	0.220 (0.042)	0.223 (0.042)	0.215 (0.041)	0.194 (0.039)
Labor	0.653 (0.125)	0.652 (0.136)	0.627 (0.124)	0.603 (0.120)	0.742 (0.122)
Livestock	0.147 (0.082)	0.168 (0.082)	0.148 (0.083)	0.161 (0.082)	0.267 (0.085)
Technicians	0.019 (0.047)	0.021 (0.047)	0.022 (0.047)	0.027 (0.047)	0.029 (0.044)
Literacy	0.128 (0.274)	0.083 (0.285)	0.129 (0.276)	0.132 (0.279)	0.082 (0.263)
Power	0.114 (0.079)	0.095 (0.078)	0.095 (0.078)	0.094 (0.079)	0.046 (0.076)
U.S. and Canada Dummy	0.0657 (0.107)	0.628 (0.104)	0.631 (0.105)	0.618 (0.104)	0.722 (0.104)
Intercept	1.865 (0.560)	1.921 (0.567)	1.895 (0.565)	1.876 (0.567)	1.538 (0.547)
Irrigated and Corn Belt Region Intercept Dummy	0.007 (0.036)	0.073 (0.064)	0.022 (0.036)	0.131 (0.178)	1.036 (0.338)
Irrigated and Corn Belt Region Slope Dummies					
Power	-0.123 (0.089)				
Labor		-0.145 (0.146)			
Fertilizer			-0.062 (0.063)		
Land				0.049 (0.076)	
Livestock					-0.285 (0.094)
Residual mean squares	0.021	0.021	0.021	0.021	0.019
Coef. of det. (adj.)	0.912	0.911	0.091	0.910	0.919

Specification of a Production Function for the Regional Analysis

Regression analysis of this chapter and Chapter 3 give an indication of how production parameters change between regions in North America. Table 1 indicated a substantial intercept shift between Mexico and the two developed countries. Table 3 provided evidence that the Mexican production elasticity for land is nearly twice as large as the land production elasticity for the rest of North America. Finally, in Table 7 of Chapter 4 the production elasticity for the fertilizer input is about fifty percent larger in the Labor Intensive Region as in the rest of the continent according to two different approaches to estimating the regional production parameters.

Based upon these regional findings, the regressions in Table 9 re-estimate the regional shifts in production parameters. The Table 9 results are considered especially useful since all three of the significant dummy variables from earlier tables are included in each of the two regressions.

Regression 2 differs from Regression 1 of Table 9 in that the production elasticity for education in Regression 2 is constrained to the 0.248 figure estimated in Table 1. It may be recalled that present estimates of the production elasticity for education have generally been positive, but not significantly larger than zero. The negative coefficient for education in

Table 9. Estimates of Aggregate Agricultural Production Functions on State and Province Level Data with Binary Variables Selected from Previous Tables (Per Farm data 1959, 1960, 1961)

Regression number Sample size	1 89	2 89
Land	0.381 (0.089)	0.374 (0.090)
Fertilizer	0.171 (0.040)	0.153 (0.039)
Labor	0.506 (0.117)	0.538 (0.116)
Livestock	0.157 (0.079)	0.143 (0.079)
Technicians	0.007 (0.044)	0.015 (0.044)
Literacy	-0.166 (0.281)	0.248*
Power	0.116 (0.074)	0.101 (0.074)
U.S. and Canada dummy	1.047 (0.252)	0.952 (0.245)
Intercept	2.026 (0.600)	1.324 (0.364)
Labor Intensive Region Intercept dummy	0.035 (0.048)	0.047 (0.048)
Labor Intensive Region slope dummy for fertilizer	0.107 (0.054)	0.094 (0.053)
U.S. and Canada slope dummy for land	-0.171 (0.089)	-0.147 (0.089)
Residual Mean Squares	0.018	0.019
Coef. of det. (adj.)	0.921	0.900

* The literacy variable in Regression 2 is constrained to be 0.248.

Regression 1 is considered less reliable than the earlier estimates obtained from regressions with fewer variables. The 0.248 constraint imposed upon the Regression 2 production elasticity for education is also not significantly different from the Regression 1 coefficient for education. Since other coefficients in Regression 2 are quite similar to those in Regression 1, the decision to use Regression 2 in the economic analysis will not much affect results for the six other variables.

The results of regional production parameter estimates in Regression 2 of Table 9 are also very similar to the above-mentioned estimates in Table 1, Table 3 and Table 7. This production function represents what is considered the best available information concerning regional production parameters for North America. The production elasticity estimates of Regression 2 will be used throughout the remainder of the analysis .

Both the F test and the estimation of regional production elasticities indicated that the Labor Intensive Region was the only region that was different from the rest of the continent. This means that production parameters did not vary a great deal between regions. In fact, a regional shift in the fertilizer coefficient is the only really important regional dummy in this chapter. (This may be fortunate; if there had

been large and frequent regional variation in production parameters in the earlier tables, it would have necessitated the inclusion of more dummy variables in Table 9, and that could cause estimation problems.)

It was not possible to provide any clear evidence as to whether the fertilizer coefficient was uniform across the other two regions. One would expect a lower fertilizer coefficient for the Northern Plains Region, and there was a negative fertilizer slope dummy for that region (Table 6), although it was not significant. It must be concluded that there is a limit to the ability of the regression techniques to pick up slight shifts in production parameters, especially in view of the necessarily ad hoc procedure for identifying regions.

The regional analysis of this chapter makes it possible to go beyond the broad insights provided by the country level analysis of Chapter 3. The factor scarcity criteria employed here to identify regions allowed a test of the hypothesis that production parameters vary for regions within the continent, but they also facilitate interesting economic comparisons among regions. It will now be possible to consider specific policy issues concerning regional resource allocation.

In Chapter 5 particular attention will be given to the two regions which represent the modern and traditional sectors of Mexico's dual approach to agricultural development;[3] the concentration of development resources in the large farm areas will be analyzed in terms of the efficiency of resource allocation, and the consequence of alternative strategies will be measured imperically.

Summary of Regression Results

Chapter 3 presented production elasticity estimates based upon the total population that tended to support results of the Griliches study which employed U.S. state level cross sections from the same time period as well as those of the Hayami-Ruttan cross-country production function. Also, when country binary variables were employed, coefficients either shifted or did not shift as to support Reed Hertford's results for Mexico.

Similarities with the two state level studies (Griliches and Hertford) were especially remarkable in view of the different nature of the data employed. Similarities with the cross-country

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[3]The Irrigated and Corn Belt region represents Mexico's modern sector while the Labor Intensive Region includes states with predominantly traditional agriculture. References to the dual approach to development are made by several authors: Clark W. Reynolds (1970) describes in detail the concentration of irrigation and modern inputs in the large farm sector; Edmundo Flores (1970) places the problem in a larger political setting.

study may lend added support to the hypothesis of a meta-production function for the world and indicates that, taken as a whole, the continent of North America appears to be on the Hayami-Ruttan production function for the world.

However, test results for regions within the continent provide strong evidence that smaller regions can be found that are not on the same production function. With knowledge of crop patterns and factor scarcities within regions it was sometimes possible to predict how production parameters vary. It is also worth noting that the tests for differences in production parameters were generally as strong across regional divisions based upon factor scarcities and corresponding crop patterns than were the results for national divisions where large differences in factor scarcities were accompanied by large differences in factor prices. The land coefficient was, in fact, the only one which could be clearly shown to have changed between countries.

The largest differences in production elasticity estimates were found to exist between states and provinces with high ratios of labor productivity/land productivity as compared with two regional groupings of states having a lower ratio. Only one group of states could be shown to have coefficients which were not typical of the total population.

Estimates of regional production elasticities provide a basis for analyzing sources of regional productivity differences in North America. Regional production elasticities estimated in Table 9 of this chapter will be used for the economic analysis which follows.

Chapter 5

Sources of Regional Productivity Differences in North America

The estimates of regional production parameters make it possible to gain further insight into country level growth accounting results and the VMP comparisons of Chapter 3. Regional differences in production elasticities or differences in factor proportions can lead to quite different conclusions concerning sources of productivity differences between groups of states in Mexico and between groups of states in the other two countries in North America. The next two sections will re-estimate the VMP and growth accounting exercises of Table 4 and Table 5 of Chapter 3 for groupings of United States, Canadian, and Mexican states. This will be followed by a section on growth accounting between large and small farm states in Mexico and a final section presenting growth accounting results for the Northern Plains Region.

Economic Analysis of Regional Resource Allocation

Any difference between the Table 10 VMP estimates for the Mexican and U.S. Irrigated and Corn Belt Region and the Northern Plains Region as compared to county level estimates in Chapter 3 will be due mainly to differences in average

products between the region and the larger national groupings of states and provinces because those regions have been shown (Table 9) to have production elasticities which are similar to the North America estimates used in Chapter 3.

VMP estimates for the Labor Intensive Region are also based upon roughly the same production elasticities, except for the fertilizer input. The F tests in Chapter 4 gave strong evidence that the production elasticities for at least some variables are not the same for the Labor Intensive Region as for the rest of North America. The production elasticity for labor in the Labor Intensive Region was apparently lower than the figure for the rest of North America, and the production elasticity for fertilizer was found to be consistently higher than for the rest of the continent, although the magnitude of the differences for labor varied for alternative estimating procedures. VMP estimates for labor in the Labor Intensive Region may be viewed then as probably an upper bound estimate while the VMP estimate for fertilizer in this region is based upon a production elasticity of 0.247, which was obtained from Regression 2, Table 9, (as are all figures presented in this chapter).

Notice that, while the Table 10 VMP for fertilizer in the Labor Intensive Region in the United States is not particularly high, the VMP of fertilizer for the Labor Intensive Region in Mexico is by far the highest for North America.

TABLE 10. Regional Marginal Value Product Estimates

	Mexico		United States			Canada
	Irrigated and Corn Belt Region	Labor Intensive Region	Irrigated Corn Belt Region	Labor Intensive Region	Northern Plains Region	Northern Plains Region
1. Fertilizer	$447	$2308	$762	$806	$968	$560
2. Labor	$480	$124	$3079	$1799	$3419	$2103
3. Livestock	19.2	18.5	39.0	44.1	23.3	16.6
4. Land	$ 2.3	$ 2.6	$ 11.5	$ 30.5	$ 7.0	3.0

Note; Row 1 is in dollars per ton of plant nutrients; row 2 represents dollars per year per man; row 3 is measured as percentage return; and row 4 is in dollars per pasture equivalent hectar per year. Figures are based upon production elasticity estimates of Regression 2, Table 9.

The huge difference between the 447 dollar VMP for fertilizer for Mexico's large farms of the Irrigated and Corn Belt Region and the 2308 dollar estimate for the very small farm Labor Intensive Region is surely an indication of that country's resource allocation problem. Reports of the CIMMYT Puebla Project support the view that small corn producers in the state of Puebla in the Labor Intensive Region apparently have been unable to finance the purchase of fertilizer even in areas where native corn varieties are highly responsive to chemical fertilizer.[1] Whether it will be possible to increase fertilizer consumption in the Labor Intensive Region is a very important question both for the Region's small farm or ejido operators and for the efficiency of the agricultural sector in fulfilling is role in the nation's economic growth.

Later sections of this chapter will attempt to quantify the importance of the differences in fertilizer consumption in explaining regional differences in agricultural productivity both within Mexico and between regions in Mexico and the United States.

The VMP estimates for labor focus attention on another much discussed resource allocation problem for Mexico. The VMP estimate for labor in the five state region of the Northwest is

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[1]For results of preliminary surveys and a progress report see Centro International de Mejoramiento de Maiz y Trigo (1970).

very nearly four times the estimate for the Mexican Labor Intensive Region. Of course, to the extent that farmers are able to obtain employment outside the agricultural sector in cities like Mexico City, Puebla, etc., the estimates here are exagerating the labor allocation problem. Nonetheless, it appears that the mis-allocation of labor within the agricultural sector in Mexico must be considered in addition to the mis-allocation of labor between the agricultural sector and the rest of the economy. This discussion is of course not intended to imply that the solution is as easy to recognize as the problem. The problem of the minifundia is very complex, and Mexican policy makers have perhaps given it more attention than have their counterparts in other countries in Latin America.

Table 10 results for livestock and land are less easily interpreted than those which have so far been discussed. The percentage rate of return to livestock capital in the Northern Plains Region of the United States and Canada is comparable to estimates for regions in Mexico. Estimates for the other two regions in the United States are over twice as large, indicating an extremely high percentage return to livestock capital in 1960. By far the highest returns to livestock capital are therefore in the United States regions

which have feedlot operations as opposed to regions in Mexico and the grazing regions of Canada and the United States.

The returns to livestock feeding operations must have been very high in 1960 because of the rapid expansion of investment during the subsequent period. On the other hand, failure to include costs of buildings and equipment may give a considerable upward bias to present estimates of returns to livestock capital in feedlot areas.[2]

Marginal returns to land appear to vary almost as much as the return to labor. The largest differences for the VMP of land are of course between regions in Mexico and in the United States, although estimates for Canadian plains states are not much different than those for Mexico. The marginal return to land is apparently influenced by complimentary inputs such as fertilizer.[3]

In the United States the Labor Intensive Region has by far the highest VMP for land.

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[2]Prices of beef and hogs in the United States were not particularly high during the period considered. These prices are reported in the U.S. Department of Agriculture, (October and November issues, 1969).

[3]All results for land depend upon the reliability of the assumption that non-hilly pasture in the Mexican Census is comparable to U.S. and Canadian pasture. Since their assumption cannot be tested, results concerning the land input are suspect.

Mexico-United States Regional Growth Accounting

Estimates based on the North America production functions of Chapter 3 assign a substantial portion of agricultural productivity differences between Mexico and the two developed countries to an intercept shift. Thus, a large portion of technological sources of productivity differences in North America were left unexplained or vaguely explained. It was also suggested in Chapter 3 that some of the difficulty in specifying the technological sources of productivity differences stemmed from the failure of Mexican data to separate irrigation specialists from the agricultural scientists who produce new biological technology.

A later section, which presents results of regional growth accounting between two regions within Mexico, will be able to assign most of the productivity differences to differences in quantities of inputs. However, this section's growth accounting results (Table 11) between regions in the United States and Mexico leave most of the productivity differences unexplained.

The share of fertilizer and power in accounting for agricultural productivity differences between states in the Mexican and the United States' Irrigated and Corn Belt Regions is almost the same as estimates for the country level growth accounting of Table 5. But this is not true for the Labor

Table 11: Accounting for Differences in Regional Output/Farm Between Mexico and the United States.

	Mexican Irrigated and Corn Belt Region as a percent of the United States Irrigated and Corn Belt Region		Mexican Labor Intensi Region as a percent of the United States Labor Intensive Region	
Technical Inputs:				
Fertilizer	10.3	(11)*	17.9	(19)
Power	8.9	(10)	10.0	(11)
Human Capital:				
General Education	6.4	(7)	12.7	(13)
Technical Education	-1.0	(-1)	-0.4	(0)
Resource Accumlation:				
Land	-13.7	(-15)	-12.8	(-14)
Livestock	8.8	(10)	12.6	(14)
Labor	-9.2	(-10)	-7.4	(-8)
Total difference in output/farm	90.7	(100)	94.5	(100)
The difference that is explained by the variables listed above	10.5	(12)	32.6	(35)

* The figures in parenthesis are percentages, with the total difference in productivity per farm set equal to 100.

Note: The number of farms for Mexico includes ejido family units where at least half of the income is from the ejido. Production elasticities used in making these estimates were from Regression 2, Table 9.

Intensive Region where 19 per cent of the difference is now accounted for by fertilizer, alone.

The negative result for land in the Irrigated and Corn Belt Region is partly due to the definition of the ejido farm unit which allows the farm size in this large farm region of Mexico to excede farm size in the United States portion of that Region. Although farm size in Mexico's Labor Intensive Region is less than one-fourth that of the five large farm states of the Mexican Northwest, the farm size difference between the same two regions in the United States is also about four to one. Thus, the negative result for land applies to both columns in Table 11. These results are in sharp contrast to the large positive share assigned to land in the Mexico-United States national growth accounting of Chapter 3.[4]

It was expected that growth accounting between regions in the two separate countries would contribute to the understanding of productivity differences between Mexico and the United States. Results for the fertilizer variable seem to be the most useful. In 1960 fertilizer accounted for the largest portion of the measurable agricultural productivity difference between large farm areas in northwest Mexico and the corresponding

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[4]It should be noted that both results are based upon the assumption that the average hectare of pasture in the U.S. is equivalent to the average hectare of non-hilly pasture in Mexico. If, for example, U.S. pasture is better than Mexican pasture land, it could easily account for the negative results in Table 11.

region in the United States. Yet it is between the Mexican and United States Labor Intensive Regions where fertilizer would account for at least 19 percent of the difference in agricultural productivity per farm. This result combined with the fertilizer VMP estimate for Mexico's Labor Intensive Region at over four times the corresponding figure for the Mexican Irrigated and Corn Belt Region again indicates the importance of the failure to use fertilizer on small farms in Mexico.

Chapter 2 described prices of certain commodities raised in the Irrigated and Corn Belt Region which were much lower in Mexico than in the United States. This may explain in small part why the measured inputs fall so far short in accounting for regional output per farm differences measured at country prices. However, price weights are not a major problem for the Labor Intensive Region and the productivity differences left unaccounted for are almost as large for that region. Undoubtably, it is the failure to properly specify technology producing inputs that is making it difficult to account for productivity differences in both regions.

Accounting for Productivity Differences Between Regions in Mexico

Table 11 of the last section provided a partial answer to the question of what it would take to bring Mexico's five large-farm, irrigated states of the Northwest to a level of

productivity comparable to a similar region in the United States. This section will measure what is required to bring Mexico's more traditional small farm states of the Labor Intensive Region to a level of farm productivity comparable to the same five large-farm states of the Irrigated Region.

Since there appears to be no substantial shift in the intercept for these two regions within Mexico, it will be possible to explain much more the productivity difference than was possible for the comparisons between regions in different countries.

According to Table 12, farm size is the most important single variable accounting for productivity differences between Mexico's Labor Intensive Region and Mexico's states in the Irrigated and Corn Belt Region. The land input and livestock inputs together account for over half of the 76 percent difference in productivity per farm between the two regions. Thus, a major share of the productivity gap within Mexico can apparently be closed only by reducing the number of farmers in the Labor Intensive Region. This result is achieved in spite of a definition of the farm unit which excludes ejido family units having less than half of their income from their ejido land.

Yet a substantial portion, over thirty percent, of the productivity gap can be closed by increasing fertilizer consumption per farm on the small farms to levels comparable to that

of the five large farm states. And this could be achieved under existing technology.

These results depend upon the assumption of a homogeneous production function and are only approximate. However, they do add support to the hypothesis that, even under existing technology, application of fertilizer in the small farm areas would provide substantial productivity increase and bring the traditional agricultural states appreciably closer to Mexico's most modern states.

When differences in use of the five other inputs are included in the analysis, slightly more than the 76.5 percent difference in agricultural productivity between the two regions in Mexico are taken into account. This is to be expected because the 0.247 production elasticity for the Labor Intensive Region was used to weight the difference in fertilizer use. If the 0.153 production elasticity for the other regions is used, the productivity difference between the two regions is just taken into account, with fertilizer explaining 20 percent of the productivity gap.

Accounting for Productivity Differences between the Canadian and United States Plains Region

Because the three provinces which make up Canada's Plains Region are so crucial to Canadian agriculture, it's useful to include a separate analysis of that region. In this

Table 12. Growth Accounting Results for two Regions in Mexico, Per Farm

	Mexican Labor Intensive Region as a percent of Mexican Irrigated and Corn Belt Region	
Technical Inputs:		
Fertilizer	22.8	(30)*
Power	7.5	(10)
Human capital:		
General education	8.1	(11)
Technical education	1.0	(1)
Resource accumulation:		
Land	29.6	(39)
Livestock	10.2	(14)
Labor	3.3	(4)
Total difference in output/farm	76.5	(100)
The difference that is explained by the variables listed above	82.5	(109)

* The figures in parenthesis are percentages with the total difference in output per farm set equal to 100.

Note: The number of farms includes ejido family units where at least half of the income is from the ejido. Production elasticities used in making these estimates were from Regression 2, Table 9.

section the Canada-United States growth accounting results of Chapter 3 will be compared with results obtained when the same procedure is applied to just the states and provinces which fall in the Northern Plains Region.

It should be noted that not very much could be learned about whether the human capital production elasticities for the three Canadian provinces might be different from those for United States's states in the Northern Plains Region. It appears from Table 1 that the intercept shift for Canada is smaller than for the United States. This means the regression variables may not be expected to account for all of the regional productivity difference between states and provinces.

The share of the productivity difference accounted for by fertilizer has dropped to less than one-third of what it was for the growth accounting between all Canadian provinces and the United States. This is the most important difference between Table 13 results and those of Table 5, although livestock has also become important as a source of per farm productivity difference in Table 13, and it was not important in Table 5.

Labor remains the most important source of Canada-United States productivity difference, almost as important as it was in Table 5.

Results for the human capital inputs are unsatisfactory again; and that may be one reason why a large portion of the productivity difference is left unexplained.

The result concerning fertilizer is the most revelant; when three of Canada's main agricultural states are compared with a similar region in the United States, fertilizer becomes less important as a source of productivity difference. It is therefore in the other provinces that low fertilizer consumption is a more important problem.

This result is also consistent with the fact that the Table 10 VMP estimate is only 560 dollars for plant nutrients in Canada's Northern Plains Region while the corresponding figure for that region in the United States is 968 dollars. For the country as a whole, Canada's 772 dollar VMP for plant nutrients was comparable to the United States' figure of $762.

Table 13: Growth Accounting Results for the Northern Plains Region, Per Farm

	Canadian Plains Region as a percent of that region in the U.S.	
Technical Inputs:		
Fertilizer	3.0	(5)*
Power	1.7	(3)
Human Capital:		
General education	0.5	(1)
Technical education	0.0	(0)
Resource Accumulation:		
Land	-1.3	(-2)
Livestock	5.1	(9)
Labor	13.3	(23)
Total difference in output/farm	57.2	(100)
The difference that is explained by the variables listed above	22.3	(39)

* The figures in parenthesis are percentages with the total difference in output per farm set equal to 100.

Note: Production estimates used in making these estimates were from Regression 8, Table 9.

Chapter 6

Summary and Conclusions

A major objective of this study was to provide regional estimates of the agricultural production parameters which have been most useful in explaining productivity differences. Considerable attention was given to defining regions in North American and to systematically testing for changes in production parameters across those regions.

The regional divisions were expected to facilitate interesting economic comparisons, especially between traditional and modern regions in Mexico. Because relative scarcities of the main factors of production are found to be important by those who attempt to explain agricultural productivity differences between countries, the large regional differences in the ratios of land productivities to labor productivities were chosen as the basis for identifying regions. Other criteria for identifying regions tended to support this approach.

The functional form employed throughout the study was the Cobb-Douglas production function. There were 89 observations for the North America production functions, and the data included state and province level observations from Canada, Mexico, and the United States.

Results for the North America production function and the country level production elasticity estimates were similar to those obtained by other authors who employed approximately the same techniques. Where differences did exist, it was felt that there were economic conditions which could reasonably be expected to have caused them.

A study such as this one must employ assumptions which cannot be tested; there is also danger of bias in the coefficients and the error term from mis-specifications of the relevant variables or functional form. Because of these problems, the comparability between present estimates and those of other studies was considered important in that it lends support in what is a rather bold undertaking.

In addition to the indication of broad similarities between results for North America and those of production studies from other parts of the world, there is considerable evidence that a large region could be identified within the continent of North America which is not on the same production function as the rest of the continent. The differences in production elasticity estimates appeared to be economically reasonable, although the magnitude of the differences could not always be established with certainty.

Since the regional disparities in production elasticities were small and were confined to one or two variables,

it was not possible to show how the other two regions might differ from each other, if there were any differences. In this respect the somewhat ad hoc methodology for finding significant regional dummy variables provides solutions which are never quite complete. Nonetheless, where the difference in parameters is large enough to affect the economic results, the dummy variables are apparently capable of offering a practical indication of the regional difference in coefficients. (Of course, if there had been fewer observations and several parameters that are different between regions, the problem would become more difficult.)

Present growth accounting results between the United States and Mexico and somewhat similar results obtained by other authors lend broad insights into sources of differences in farm productivities by assigning weights to differences in input use. Regional growth accounting results can provide more specific information needed by policy-makers in a particular country.

Lack of more recent data for Mexico limited the relevance of the regional results for policy purposes and made it impossible to see how results change over time. Nevertheless, the study provided information relevant to the allocation of resources in 1960.

The most interesting regional findings were from the analysis of two groupings of states in Mexico. One consequence of Mexico's dual approach to agricultural development has been that small farm regions have fallen far behind the large farm regions in the adoption of modern inputs and in productivity growth. The differences in farm productivity were quite apparent from state level data used in this study, and the sources of productivity differences between a large farm region (The Irrigated and Corn Belt Region) and what was called the "Labor Intensive Region" were accounted for by inputs representing resource endowments, technical inputs, and human capital.

As might be expected, resource endowments explained over half of the regional productivity difference. Yet increasing fertilizer use per farm in the Labor Intensive Region to the level of use in the Irrigated and Corn Belt Region would close almost one-third of the productivity gap between those two regions. When the Labor Intensive Region's larger production elasticity for fertilizer was used in the accounting formula, just over 100 percent of the regional productivity difference was taken into account.

Comparison of marginal value products for regions in North America also strongly emphasized the mis-allocation of fertilizer among regions in Mexico. For the labor input, the marginal return in the large farm region in Mexico was over

four times as high as the VMP in the Labor Intensive Region, indicating another aspect of the problem of the minifundia.

Other studies were cited which support the main conclusions concerning Mexico's resource allocation problems.

The regional analysis for North America also included the following specific results:

1) Fertilizer was quite important in explaining the productivity difference between the U.S. and Mexican Corn Belt and Irrigated Region but was far more important in accounting for the U.S. and Mexico's productivity difference in the Labor Intensive Region, where a fifth of the productivity is explained by fertilizer.
2) Comparisons of wage ratios with the marginal value product of labor confirm that the problem of excess labor was more severe in Mexican agriculture than in the U.S.
3) Fertilizer is considerably less important in explaining farm productivity differences between Canada's three very important plains states and the U.S. plains states, than it is in explaining the overall Canada - U.S. farm productivity differences.

Directions for Future Work

Knowledge of regional differences in production parameters for North America suggests the need for regional production studies in other parts of the world. The factor scarcity criteria for identifying regions is one alternative, although the best criteria for other studies might depend on the objectives of the particular study and the availability of data.

For the Mexican case, the years between 1960 and 1970 were part of a period of rapid change. When the 1970 Censo becomes available, it will be possible to determine the effects of recent policy and of widely acclaimed technology breakthroughs on the resource allocation problems of Mexico's small farm and large farm states. The cost of bringing in the effects of time will be small compared to the investment in the original project since the difficult decisions concerning variable construction and identification of regions have already been made.

Since some of the results reported here are very relevant to important policy problems concerning the allocation of resources between large farm regions and the small, traditional agricultural regions of Mexico, it would be desirable to redo the Mexico analysis with recent data. This would support present results by removing doubts as to the possibility that they are outdated; in addition, it would permit further tests

of their statistical reliability.

Bringing in the effects of time would also add an important new dimension. The same production parameters used in the country and regional growth accounting might be applied to explaining the increases in productivity between 1960 and 1970. And this could be done at the regional level as well as at the national level. It would be especially interesting to compare the pattern of recent productivity growth in Mexico's very traditional Labor Intensive Region to that of the Irrigated and Corn Belt Region.

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Appendix A

A major challenge of this research effort was to construct variables from data taken from public documents of three different nations. It was necessary to construct units of measurement for each variable from Mexican sources which would mean the same thing as the units obtained from U.S. and Canadian sources. The details of the procedure for doing this and sources of data are presented here for each of the seven input variables and for the output variable.

For some variables alternative specifications were tested in separate regressions. These alternative variable constructions are described along with the discussion of the variable specification which was chosen as being the most accurate.

Table 14, which comes after the variable descriptions, presents all 89 observations for each of the variables constructed for this study.

The following eight sections dealing with each input variable and the output variable include a list of official data sources. In order to avoid needless repetition and in order to present sources in a readable form, census materials for each of the three countries are cited by the title of the

census. The complete reference for Mexican materials can be found in the bibliography under the Secretaria de Industria y Comerico; U.S. census materials are listed under the U.S. Department of Commerce; and Canadian census materials are found under the Ministry of Trade and Finance.

Land

Six categories of farm land in Mexico's Census and five in the United States' Census were weighted according to the value of that land category in each state relative to the value of that state's pastureland. A weight of one was assigned to each hectare of pasture in the United States and each hectare of non-hilly pasture in Mexico. Then the computed pasture equivalents in each state were weighted by that state's price for pasture. Finally, these dollar and peso values of pasture were converted back to pasture equivalents by dividing by the average value of U.S. pasture for all U.S. states or by the average value of non-hill pasture in Mexico.

Since prices of pasture and crop land were not known for Canada, each of five categories of land in each province were weighted relative to pasture by employing weights for each of the five land categories in a state across the border. Washington's land weights were applied to five categories of land in British Columbia; Montana weights to Alberta and Saskatchewan; North Dakota weights to Manitoba and Ontario; Massachusetts weights to Quebec; and Maineland weights were applied to New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland. It was then assumed that improved pasture is worth

the same throughout Canada and that, on the average, pasture in Canada was worth the same as Mexican non-hill pasture and U.S. pasture.

Data for the United States was generously made available by Hans Binswanger and was the same land data used in his dissertation (1973). Binswanger based land weights on 1940 prices as reported by Hoover (1961).

Because of the heavy investments in irrigation in Mexico since 1940, values of land in Mexico were based upon 1960 Census values. This more recent data better reflects the relative value of the six categories of land included for Mexico. It is also the only year for which adequate data is available.

Since the U.S. and Mexican land data is expressed in standard pasture equivalents based upon the average value per hectare of pasture in that state relative to each country's average value for pasture, the crucial assumption is that the typical hectare of pasture in the U.S. and Canada and Mexico is the same. Canada and Mexico both have large areas of brushy pasture which would lower their average value relative to the U.S. value, but fortunately, their Census separates out the low quality pasture. It seems quite reasonable to assume U.S. pasture is similar to Mexican "non-hill pasture" and Canadian "improved" pasture.

Total land and cropland were used as alternative specifications of the land input. Total land includes private and public land which can be used for crops or pasture. In order to make Canadian data comparable to that for the United States and Mexico, improved land and unimproved land, except wood land, was included from the Canadian census. The dry grazing land in much of western United States and in Mexico is expected to be comparable to the brushy, unimproved pasture land in Canada.

In order to eliminate variation in land quality between livestock and crop states, cropland was employed as an alternative to total farm land. Idle or follow cropland was included. Use of this variable assumes that cropland producing livestock feed accounts for most of income from livestock.

Official Data Sources: Census of Canada: 1961, General Review, Bulletin 7.2-5, pp. 5-14, 5-15, 5-64 and 5-65. U.S. Census of Agriculture: 1959, pp. 6 and 43. IV Censos Agricola - Ganadero y Ejidal: 1960, pp. 1-3.

Output

Output was represented as the total value of sales of crops, livestock, and livestock products by the agricultural sector. For Canada figures represent sales during June 1, 1960 to May 31, 1961; U.S. data is, as usual, for 1959; and Mexican data is for 1961.

The Mexican Census does not have sales figures for livestock products, but the value of livestock products must be almost identical to sales of livestock products, so that the sum of Mexico's sales of livestock and crops and the value of livestock production is consistent with sales data employed for the other two countries.

U.S. output data was from Fishelson's dissertation (1968) who based his construction and some of his data on Griliches work. Fishelson's figures have been converted from 1949 to 1959 prices.

Fishelson deflated price weights by twelve commodity groups. Certain states he combined so that he had 39 rather than 48 observations. In assigning the output of one of Fishelson's regions to the states that make up the region, output of each state in the region is constructed according to the Fishelson definition. However, it was assumed that price weights did not vary within these small groupings of states. The Fishelson deflated output of each region was therefore assigned to states

according to their undeflated percentage share of the total regional figure.

Fishelson's own definition of his output is as follows:

Output (Y_{it}) was defined to be the sum of cash receipts from marketing (C_{it}), value of home consumption (HC_{it}), government payments (G_{it}) and the value of the net change in inventories (N_{it}), all measured in 1949 prices.

$$Y_{it} = C_{it1}/ptl + \ldots + \ldots + C_{itj}/I_{ptj} + \ldots$$
$$+ C_{it112} + (HC_{it} + G_{it} + N_{it})/I_{pit},$$

where C_{itj} is cash receipts from marketing the commodities of group j in state i in year t. The 12 commodity groups were: (1) meat animals, (2) dairy products, (3) poultry and eggs, (4) miscellaneous livestock and livestock meats, (5) food grains, (6) feed crops, (7) cotton, (8) tobacco, (9) oil crops, (10) vegetables, (11) fruits and nuts and (12) all other crops. I_{ptj} is same for all i at a given year t. I_{pit} is the price index (1949=100) of total agricultural output of state i in year t...

Official Data Sources: Census of Canada: 1961, General Review, Bulletin 7.2-8, pp. 8-43.
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IV Censos Agricola - Ganadero y Ejidal: 1960, pp. 528-539.
The price index was from the U.S. Dept. of Agriculture (1967, p. 563).

Power

Tractor and draft animal horsepower are used to represent power availabilities for farm operations. It was assumed that tractors in all three countries have the same power. Mexican draft animals were weighed as one horsepower and tractors were assigned thirty horsepower. Reasons for weighing at thirty horsepower are discussed rather thoroughly in Hayami et. al. (1971). The 1 HP weight for draft animals was actually from an estimate for 1,200 lb. horses (Jones, 1938, p. 8).

Official Data Sources: Census of Canada: 1961, General Review, Bulletin 7.2-7, pp. 7-7. U.S. Census of Agriculture: 1959, p. 216. IV Censos Agricola - Ganadero y Ejidal: 1960, pp. 98-100 and 516-18.

Labor

Canadian labor data includes all persons who reported employment in agriculture during 1961. For the U.S. there are persons employed during the last full week ending at least one day before the end of the month; included are farm operators doing one or more hours work, family members who did more than 15 hours work that week, and persons doing one or more hours work for pay.

Mexican labor data presents some problems. Labor was represented as the total of agricultural wage earners, sharecroppers, and ejido and farm operators and working male members of their family, age 15 and older. However, some ejido operators also own private plots and are counted twice in the Censos. In addition, some people who "own" ejido plots do not work those plots as they claim they do. For these two reasons, our labor variable appears to be over-estimated in Mexico's small farm states.

Ejido family labor is even more exagerated because inheritance of ejidos is very uncertain. To make ejido labor figures more consistent with our labor figures, ejido family labor was omitted. Since there are almost as many ejido family workers as there are ejido operators, this decision cuts the labor input from the ejido sector in half. Exclusion of ejido

family labor was partly based upon negative coefficients for family labor obtained by Reed Hertford in his ejido sector regressions (pp. 75 and 79).

Official Data Sources: Census of Canada: 1961, General Review, Bulletin 7.2-7, p. 7-35. Agricultural Statistics, 1959, p. 452. IV Censos Agricola - Ganadero y Ejidal: 1960, pp. 76-8 and 559. Censo de Poblacion, 1960, p. 45.

Livestock

Livestock capital was represented as the value of all varieties of livestock animals and fowl (and bees in the case of Mexico) which are held in significant quantity in each of the respective countries. Each country's animals were valued at prices in that country (converted to dollars).

Draft animals were excluded since they are considered part of the power variable.

Official Data Sources: Census of Canada: 1961, General Review, Bulletin 7.2-8, p. 8.49. U.S. Census of Agriculture: 1959, p. 497. IV Censos Agricola - Ganadero y Ejidal: 1960, pp. 85-9 and 516-519.

Number of Farms

The number of farms is given for states in each country. In Mexico ejidos are regarded here as farms. This assumes that the real decision-making power is held by the ejido authorities rather than by the individual families which are expected to farm individual parcels of land. Treating Mexican farms in this way makes Mexican operating units of a size comparable to those in the U.S.

Official Data Sources: Census of Canada: 1961, General Review, Bulletin 7.2-5, p. 5.4 , U.S. Census of Agriculture: 1959, p. 34. IV Censos Agricola - Ganadero y Ejidal: 1960, pp. 37-9 and 558.

Fertilize.

Weights for primary fertilizer nutrients were based upon 1955 relative prices in the United States. For the U.S. and Canada tons of nitrogen, phosphoric and, potash were assigned weights of 1.62, .93 and .45. (See Griliches, 1964).

Mexico's Census supplied data only for expenditures on fertilizer for the nation and for the states. However, Juvencio Wing has provided figures for Mexico's consumption of N, P, and K. By assuming that each Mexican state consumes fertilizer nutrients mixed in the same proportion, it is possible to convert Mexico's expenditure figures to equivalent tons of plant nutrients which are the same units that were constructed for the other two countries.

From Wing's study entitled Mexican Consumption of Commercial Fertilizer. It was reported under contract with ERS, U.S. Department of Agriculture, 1965, and reproduced by Reed Hertford (p. 146).

Official Data Sources: Dominion Bureau of Statistics, Industry and Merchandising Division, Fertilizer Trade, Catalogue No. 46-207, 1962, p. 14. U.S. Department of Agriculture, ERS, FIS-187 Supplement, Farm Income (A supplement), 1962, p. 60 and Agricultural Statistics, 1961, pp. 491-2, IV Censo Agricola-Ganadero y Ehidal, 1960, pp. 128-30.

Technology

For the United States and Canada technological inputs were represented as numbers of earth scientists and agricultural scientists, including veterinarians. Particularly in Canada, some agricultural scientists are listed in the census under biological scientists which implies that our Canada figures are biased downward.

For Mexico rural technicians served as the corresponding technological input variable. Probably this category includes mainly irrigation engineers, since Mexico has invested large sums in public irrigation projects.

Official Data Sources: Census of Canada: 1961, Labor Force, Bulletin 3.3-7, various pages. National Science Foundation, American Science Manpower, A Report of the National Register of Science and Technical Personnel, Washington: 1960, p. 72. Secretaria de Industria y Commencio, Anuario Estadistico de los Estados Unidos Mexicanos, Government Printing Office: Mexico, D.F., 1969.

Education

Mexico's Anuario Estadistico provides rural literacy ratios for population over 14 years of age. This is the only separate education data for rural Mexico.

Throughout this study U.S. literacy ratios are for the entire population age 14 and above. However, in order to make certain that production function estimates were not biased by using ratios based on both rural and urban population, a separate regression was run with a literacy ratio which was constructed from data for the farm population only. This construction was based upon Department of Commerce figures which indicate 57 percent of the people who have completed no years of school are unable to read. Based upon the same source it was assumed that 30 percent of persons having 1 to 2 years of school cannot read; that 6 percent of those with 3 to 4 years cannot read; that 1 percent of those with 5 to 6 years of school cannot read, and that anyone having completed more than 6 years of school can read. Regression results for the equations with the constructed farm literacy specification for the U.S. variable were essentially the same as results for the education specification which based literacy ratios for U.S. obervations on the total population.

The statistic used in this study for the Canadian population was the percent of the farm population 14 years of age and above who have not attended school.

Official Data Sources: Census of Canada, 1961, Population Bulletin 1.3-6, p. 103-1- 103-14. Secretaria de Industria y Commercio, Anuario Estadistico de los Estados Unidos Mexicanos, Government Printing Office: Mexico, D.F., 1969. U.S. Department of Commerce, "Illiteracy in the United States", Current Population Reports, Population Characteristics Series P-20, No. 217, March 10, 1971.

Table 14. Input and Output Data for the United States, Mexico, and Canada (1959, 1960, and 1961)

United States	Pasture Equivalents (an index)	Land Used for Agriculture (Thousands of hectares)	Fertilizer (Nutrient units)	Income (Thousands of dollars)	Labor (Thousands of workers)	Livestock (Thousands of dollars)
Maine	686200	1324	61694	196171	42	37638
New Hampshire	239507	467	5522	67698	15	20202
Vermont	560849	1280	16447	135397	32	75172
Massachusetts	816301	503	21286	174632	41	41342
Rhode Island	95365	61	3962	23084	4	6058
Connecticut	521963	394	19298	172323	27	37860
New York	7904461	6249	164665	856597	171	450166
New Jersey	1494058	607	59517	317427	49	71425
Pennsylvania	7353597	5056	176944	914612	202	407201
Ohio	19049465	8098	350134	1007690	260	426117
Indiana	22639004	7944	447943	1112050	228	408035
Illinois	54622695	12997	399975	2087860	256	707496
Michigan	9687113	6462	229555	728826	229	297330
Wisconsin	18364329	9051	166750	1172360	299	781785
Minnesota	22594752	12934	224609	1479050	276	652646
Iowa	53597071	13845	303241	2594490	293	236975
Missouri	25927708	14912	295711	1216250	280	606400
North Dakota	21335850	17532	78579	541617	94	292523
South Dakota	29415443	19146	18374	532100	94	549434
Nebraska	41682260	19385	228825	1281970	158	748150
Kansas	37101134	20541	177402	1230900	165	589746
Delaware	521675	316	23732	118392	13	9904
Maryland	2145156	1508	76382	297434	58	88981
Virginia	5082659	5818	176954	520964	210	214726
West Virginia	2192226	3147	18221	145065	75	78018

Table 14--Continued

United States	Agricultural Science Manpower	Literacy	Literacy (Constructed)	Power	Number of Farms	U. S. dummy	Canada dummy	Northern Plains dummy	Corn Belt & Irrigated dummy	Labor Intensive dummy
Maine	121	99	992	17793	17360	1	0	0	0	1
New Hampshire	88	99	991	6605	6542	1	0	0	0	1
Vermont	51	99	993	16669	12099	1	0	0	0	1
Massachusetts	133	98	980	12068	11179	1	0	0	0	1
Rhode Island	26	98	973	1651	1395	1	0	0	0	1
Connecticut	104	98	977	11219	8292	1	0	0	0	1
New York	404	97	990	138670	82356	1	0	0	0	1
New Jersey	138	98	975	24726	15459	1	0	0	0	1
Pennsylvania	370	98	990	144759	100052	1	0	0	0	1
Ohio	233	99	990	204618	140353	1	0	0	1	0
Indiana	214	99	994	186853	128160	1	0	0	1	0
Illinois	332	98	996	290002	154644	1	0	0	1	0
Michigan	498	98	985	169782	111817	1	0	0	1	0
Wisconsin	389	99	991	234387	131215	1	0	0	1	0
Minnesota	343	99	995	275833	145662	1	0	0	1	0
Iowa	214	99	994	327863	174707	1	0	0	1	0
Missouri	190	98	988	191512	168672	1	0	0	1	0
North Dakota	88	99	994	121039	54928	1	0	1	0	0
South Dakota	129	99	995	115639	55727	1	0	1	0	0
Nebraska	145	99	997	175254	96475	1	0	1	0	0
Kansas	112	99	996	173651	104347	1	0	1	0	0
Delaware	27	98	884	8259	5208	1	0	0	1	0
Maryland	243	98	998	37291	25122	1	0	0	0	1
Virginia	249	97	962	75143	97523	1	0	0	0	1
West Virginia	120	97	981	21995	44011	1	0	0	0	1

Table 14--Continued

United States	Pasture Equivalents (an index)	Land Used for Agriculture (Thousands of hectares)	Fertilizer (Nutrient units)	Income (Thousands of dollars)	Labor (Thousands of workers)	Livestock (Thousands of dollars)
North Carolina	5439979	6775	367983	1040930	432	155842
South Carolina	3276802	4593	189575	380647	206	77364
Georgia	4540495	8876	383652	879378	197	181937
Florida	5407528	8727	330369	779100	103	172471
Kentucky	7432806	7669	164048	605316	244	306353
Tennessee	5908103	6921	191316	594336	256	256565
Alabama	3010234	7640	279016	615154	158	184420
Mississippi	4615623	8558	258776	702162	270	227839
Arkansas	5985434	11638	159997	786429	222	153906
Louisiana	4259477	7197	131740	424647	164	197453
Oklahoma	13679903	15593	59304	666199	176	408083
Texas	46420847	63359	437012	2455682	448	1244715
Montana	16045306	32396	22870	401822	50	391958
Idaho	10527885	15334	69820	443715	67	211191
Wyoming	5044635	22036	10144	173356	20	228594
Colorado	13678983	22606	54340	627097	69	339976
New Mexico	7290697	28998	24474	262075	43	166561
Arizona	7999080	25848	94734	398064	51	144798
Utah	3439169	17202	183274	170568	33	124093
Nevada	2162808	24840	2607	54198	5	82278
Washington	21667637	9306	143639	558266	117	182510
Oregon	10297098	17270	79786	337796	96	200546
California	54440626	22390	549014	3059705	382	664538

Table 14--Continued

United States	Agricultural Science Manpower	Literacy	Literacy (Constructed)	Power	Number of Farms	U. S. dummy	Canada dummy	Northern Plains dummy	Corn Belt & Irrigated dummy	Labor intensive dummy
North Carolina	366	96	963	140639	190567	1	0	0	0	1
South Carolina	189	94	946	48637	78172	1	0	0	0	1
Georgia	439	95	959	89392	106350	1	0	0	0	1
Florida	379	97	973	35220	45100	1	0	0	0	1
Kentucky	110	97	970	103415	150986	1	0	0	0	1
Tennessee	190	96	933	97800	157688	1	0	0	0	1
Alabama	237	96	962	67559	115788	1	0	0	0	1
Mississippi	221	95	955	84425	138142	1	0	0	0	1
Arkansas	205	96	980	83852	95007	1	0	0	0	1
Louisiana	274	94	923	53229	74438	1	0	0	0	1
Oklahoma	125	98	987	102323	94676	1	0	1	0	0
Texas	414	96	964	268233	227071	1	0	0	1	0
Montana	311	99	994	59510	28959	1	0	1	0	0
Idaho	302	99	997	56961	33670	1	0	1	0	0
Wyoming	136	99	995	20737	9744	1	0	1	0	0
Colorado	384	99	992	64051	33390	1	0	1	0	0
New Mexico	194	96	942	17146	15919	1	0	0	1	0
Arizona	219	96	874	13443	2233	1	0	0	1	0
Utah	217	99	986	21803	17811	1	0	1	0	0
Nevada	76	99	981	5297	2354	1	0	0	1	0
Washington	572	99	992	63114	51577	1	0	0	0	0
Oregon	885	99	990	56732	42573	1	0	0	1	0
California	106	99	966	147390	99274	1	0	0	1	0

Table 14--Continued

Mexico	Pasture Equivalents (an index)	Land Used for Agriculture (Thousands of hectares)	Fertilizer (Nutrient units)	Income (Thousands of dollars)	Labor (Thousands of workers	Livestock (Thousands of dollars)
Coahuila	11597073	10495	11407	54975	75	55252
Chihuahua	9240713	17105	24113	114275	142	98045
Durango	7882804	8749	10261	64999	135	51287
Nueva Leon	4888391	3310	3861	37982	88	40934
San Louis Potosi	6651435	3635	1065	39579	129	68861
Tamaulipas	11449035	2993	23693	68178	121	59940
Zacatecas	5330252	5712	2282	43277	162	82279
Campeche	2232577	1122	164	8771	16	6056
Quintana Roo	1092713	464	70	4187	13	1341
Tabasco	5159299	1234	842	28312	91	35216
Veracruz	25800669	4397	15982	257808	459	208015
Yucatan	20154622	1601	936	49554	99	19514
Baja California	6763218	1043	38189	45973	27	7557
Baja California T.	1108286	1280	1439	6734	8	6019
Nayarit	3321348	1507	29632	26640	38	28666
Sinaloa	8188106	2248	15818	64284	84	47113
Sonora	21611821	10588	39090	109890	119	104097
Colima	2630630	391	11841	51441	16	5754
Chiapas	9807509	2799	4306	75387	186	50852
Guerrero	10498515	3957	1556	55665	194	44353

Table 14--Continued

Mexico	Agricultural Science Manpower	Literacy	Literacy (constructed)	Power	Number of Farms	U. S. dummy	Canada dummy	Northern Plains dummy	Corn Belt & Irrigated dummy	Labor intensive dummy
Coahuila	744	76	760	4530	13394	0	0	0	0	0
Chihuahua	628	70	700	13667	27957	0	0	0	0	0
Durango	425	76	760	9985	24647	0	0	0	0	0
Neuva Leon	306	73	730	5823	27050	0	0	0	0	0
San Louis Potosi	689	47	470	5457	25412	0	0	0	0	0
Tomaulipas	442	72	620	1346	27063	0	0	0	0	0
Zacatecas	324	67	670	7613	43990	0	0	0	0	0
Campeche	62	58	580	287	1511	0	0	0	0	0
Quintana Roo	39	58	580	186	1837	0	0	0	0	0
Tabasco	128	62	620	865	28128	0	0	0	0	0
Veracruz	960	46	460	8983	133581	0	0	0	0	0
Yucatan	395	54	540	818	15226	0	0	0	0	0
Baja California	197	78	780	3962	5510	0	0	0	1	0
Baja California T.	37	82	820	459	4009	0	0	0	1	0
Nayarit	147	63	630	3388	4368	0	0	0	0	0
Sinaloa	448	61	610	5516	13387	0	0	0	1	0
Sonora	380	20	700	8148	18199	0	0	0	1	0
Colima	86	68	680	1155	2066	0	0	0	0	0
Chiapas	633	36	360	4690	36279	0	0	0	1	0
Guerrero	923	31	310	4559	35042	0	0	0	0	0

Table 14--Continued

Mexico	Agricultural Science Manpower	Literacy	Literacy (constructed)	Power	Number of Farms	U. S. dummy	Canada dummy	Northern Plains dummy	Corn Belt & Irrigated dummy	Labor intensive dummy
Oaxaca	946	38	380	8799	153934	0	0	0	0	0
Aguascalientes	56	71	710	1089	2819	0	0	0	0	0
Guanajuato	598	44	310	979	49360	0	0	0	0	1
Hidalgo	956	37	370	4813	89316	0	0	0	0	1
Jalisco	1319	58	580	11544	63108	0	0	0	0	0
Mexico	810	55	550	8305	156856	0	0	0	0	1
Michoacan	1046	49	490	7972	48722	0	0	0	0	1
Morelos	305	59	590	1299	12492	0	0	0	0	1
Puebla	669	41	410	8056	222834	0	0	0	0	1
Queretaro	341	36	360	2235	15671	0	0	0	0	1
Tlaxcala	218	71	710	3321	12337	0	0	0	0	1

Table 14--Continued

Mexico	Pasture Equivalents (as index	Land Used for Agriculture (Thousands of hectares)	Fertilizer (Nutrient units)	Income (Thousands of dollars)	Labor (Thousands of workers)	Livestock (Thousands of dollars)
Oaxaca	7404762	3561	2211	55443	474	40318
Aguascalientes	1441526	412	2656	9074	18	7996
Guanajuato	8673352	2072	25951	51904	313	36190
Hidalgo	6561431	982	1708	38312	288	28619
Jalisco	10237585	3982	10261	82643	241	150573
Mexico	9992820	1040	5534	77306	534	59895
Michoacan	12646963	3018	7968	65392	208	38609
Morelos	2977625	322	1697	12439	50	12056
Puebla	12420205	1867	3920	58004	636	47278
Queretaro	3551958	719	1041	12079	56	18561
Tlaxcala	2155515	280	2445	10758	122	9515

Table 14--Continued

Canada	Agricultural Science Manpower	Literacy	Literacy (constructed)	Power	Number of Farms	U.S. dummy	Canada dummy	Northern Plains dummy	Corn Belt & Irrigated dummy	Labor intensive dummy
New Foundland	1	99	990	462	1752	0	1	0	1	0
Prince Edward Isle	1	99	990	5713	7335	0	1	0	1	0
Nova Scotia	79	97	970	2074	12518	0	1	0	1	0
New Brunswick	69	97	970	8102	11786	0	1	0	1	0
Quebec	917	99	990	70697	95777	0	1	0	1	0
Ontario	947	99	990	150046	121333	0	1	0	1	0
Manitoba	282	97	970	61463	43306	0	1	1	0	0
Saskatchewan	370	97	970	126613	93924	0	1	1	0	0
Alberta	462	98	980	102624	73212	0	1	1	0	0
British Columbia	217	98	880	16974	19334	0	1	0	1	0

Table 14--Continued

Canada	Pasture Equivalents (an index)	Land Used for Agriculture (Thousands of hectares)	Fertilizer (Nutrient units)	Income (Thousands of dollars)	Labor (Thousands of workers)	Livestock (Thousands of dollars)
New Foundland	24734	14	840	4588	2	2026
Prince Edward Island	511397	269	867	22705	9	17285
Nova Scotia	592565	351	3612	35756	12	26605
New Brunswick	844791	392	794	32821	13	24047
Quebec	10072695	3926	25670	304382	133	315243
Ontario	8922277	6203	166599	776901	172	602047
Manitoba	7744240	6753	50780	190573	60	165770
Saskatchewan	43933444	25311	68648	471842	120	327559
Alberta	30371025	18255	183736	447854	104	460460
British Columbia	2275090	1520	28601	106172	24	79231