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Economic analysis of Peruvian farm households: the production side

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Economic analysis of Peruvian farm households:
The production side

by

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TABLE OF CONTENTS

CHAPTER I.

INTRODUCTION

The agricultural sector in Peru has undergone many changes during the last thirty years. It has been subject to government intervention ranging from price and credit policies to an all encompassing agrarian reform program. Intermittently the agricultural sector was exposed to large variations in rainfall, affecting both rainfed and irrigated production activities. The incidence of these events on the economic welfare of rural households is largely unknown. It requires systematic study of the behavior of rural households. Such knowledge is a prerequisite for the design and application of the cost effective policy measures.

Past studies exclusively dealt with the consumer needs and behavior in relation to the demand for food and fiber. This study emphasizes the dual role of the farm household, that of consumer as well as producer. For that purpose we postulate the basic economic relationships that unify the apparently complex context of the farm household economy.

The following objectives served in organizing this study. First, to provide a characterization of Peruvian farm households, specifically with respect to population, size and sources of income. This will confirm the well known fact that the Peruvian agricultural sector is very heterogeneous creating an obstacle for formulating simple quantitative policy rules. Second, as a first step toward the first objective to develop a model which permits us to estimate regionally disaggregated systems of commodity supply equations. Chapter III develops the corresponding theoretical framework. Chapter IV validates this framework, and finally, Chapter V offers conclusions and suggestions for further research.

CHAPTER II.

ECONOMIC CHARACTERIZATION OF PERUVIAN FARM HOUSEHOLDS

Source of Data and Methodology

The survey

The source of data for this research project is the 1984 socio-economic survey of rural households in Peru "Encuesta Nacional de Hogares Rurales" (ENAHR). This survey covered 7,000 households, classified by geographic regions (Coast, Mountains, Upper and Lower Jungle) and areas (North, Central and South).

The objective of the survey was to get detailed and integrated information of the socio-economic characteristics of those households located in the rural and urban area with at least one of the members of the household involved in agricultural activities.

The unit of study in the survey was the household, defined as a person or a group of people, relatives or not, that live regularly in the house, share main meals, and satisfy commonly other basic needs. The household is constituted by:

a) members that are related by blood, by law or by fact. This includes also persons that the head of the family consider members of the household because of affection or espiritual reasons (godparents, for example).

b) permanent workers of the household that don't receive money for their services, but are given meals, clothes and education.

The head of the household is the person that is recognized by the other members as that.

An agricultural producer is defined as a person or group of people, who has the technical and economic initiative to operate a farm. The producer is the one who makes decisions about what to plant, what to sell, which animals to raise, etc., and also assumes the risk and enjoys the benefits of the farm operation. The producer can operate a farm directly or through a manager.

For ENAHR survey a farm or "explotacion agropecuaria" was considered as an extension of land or group of fields with a minimum of a thousand square meters. The land can be used for agricultural activities totally or partially by one person or a group, regardless of location and tenancy.

The concept of a farm also includes those without land or with less than the minimum, but that reach some of the following limits: 3 cows, 5 pigs, 10 sheeps, 10 goats, 10 auquenidos (llamas or alpacas), 100 chickens, 100 "cuyes" or 100 rabbits.

The survey definition of farm includes in just one area the total extension of small fields or "chacras" that are operated by one or more members of the household. Therefore, a household and a farm or "explotacion agropecuaria" are similar concepts.

The survey divided the regions in rural and urban areas. Urban areas were defined as national territory with populated centers ("Centros Poblados") with 2,000 or more inhabitants. Additionally, they must have 20 percent or more households with one or more persons involve in agricultural activities, as independent workers or direct producers. To determine these characteristics the population and household census of 1981, "Censo de Poblacion y Vivienda", was used.

Rural areas were defined as the national territory with populated centers of less than 2,000 inhabitants, based in the results of the VIII population census and III household census of 1981.

The survey divided the country into four regions, each with substantially different climatic characteristics, available resources, and current levels of physical and economic productivity.

Peru is located between 0° 01' and 18° 21' south latitude and 68° 39' and 81° 19' west longitude Greenwich Meridian, in the western center of South America. Peru has an area of 1,285 thousand squares kilometers, occupying the third place in South America with regard to size. Relative to the State of Iowa, Peru is eight times its size.

The coastal strip climbs from the sea level up to 2,000 meters within a relative short distance. The proximity to the Pacific Ocean creates a climate relatively uniform throughout the year, with only summer and winter seasons perceptible. Daytime summer temperatures average 25 centigrades. The Humboldt current carries cold water southward along the coast, causing little or no precipitation in the coastal plain. The winter season runs from June to November with high humidity.

The Sierra or mountain region, with peaks over 6,500 meters, lies between 2,000 and 5,000 meters above sea level. The Andes Mountains, running from North to South, split into several chains creating numerous valleys. Areas located above the altitude level of 3,500 meters are suitable only for livestock production. Most of the population live in areas between 2,000 and 3,500 meters above sea level because its more appropiate for economic activities.

Temperatures vary considerably throughout the day and between seasons. During the winter, the temperatures range between a high of 20 centigrades and a low of 0 centigrades. Frosting temperatures are not much of a problem for agriculture since this occurs at high altitudes. Summer is the rainy season and lasts from October to April.

The "ceja de selva" or upper forest lies on the Eastern flank of the Oriental Chain of the Andean Mountains at an altitude of 500 meters or more above sea level. The "selva" or lower forest natural region extended east of the Andes at an altitude less than 500 meters above sea level. The selvatic regions comprise about two thirds of Peru. Temperatures average are 29 centigrades. Heavy rainfall, are typical throughout the year, specially during summer months, October to April.

Design of the survey

The survey was conducted in July 1984 by the Instituto Nacional de Estadistica (INE). The institution was responsible for the methodological aspect of the survey like the sampling, questionnaire design, trainning of personnel, preparation of manuals and publication of results. The Oficina Sectorial de Estadistica (OSE) of the Agriculture Ministry participated by doing the field work.

Two different questionnaires were designed and used by the ENAHR survey. One was designed for households with at least one agricultural producer. The other one was designed for households living in rural areas but with no family members involved in agricultural activities. The first type of questionnaire contains 220 questions arranged in eleven sections, as listed below:

Section I : Farm characteristics and land usage.
Section II : Agricultural production and trade.
Section III : Input expenses in crops.
Section IV : Animals and cattle inventory and trade.
Section V : Other expenses and agricultural income.
Section VI : Agricultural credit.
Section VII : Technical assistance.
Section VIII: Miscellaneous.
Section IX : Households characteristics and its members.
Section X : Employment, occupation and income.
Section XI : Training and languages.

The second type of questionnaire contained 45 questions arranged in three sections, as listed below:

Section I : Household characteristics and their members.
Section II : Employment, Occupation and Income.
Section III : Miscellaneous.

The survey divided the country into 24 domains based on natural regions and areas. The population under study was divided into 14 strata. Each stratum was sub divided by departments (political division in Peru) and within them the percentage of households with or without agricultural producer.

The following are the 24 domains (see map 1):

1. Urban coast
2. Urban sierra
3. Urban ceja de selva
4. Urban selva
5. North rural coast with agricultural producer
6. North rural coast without agricultural producer
7. Central rural coast with agricultural producer
8. Central rural coast without agricultural producer
9. South rural coast with agricultural producer
10. South rural coast without agricultural producer
11. North rural sierra with agricultural producer
12. North rural sierra without agricultural producer
13. Central rural sierra with agricultural producer
14. Central rural sierra without agricultural producer
15. South rural sierra with agricultural producer
16. South rural sierra without agricultural producer
17. North rural ceja de selva with agricultural producer
18. North rural ceja de selva without agricultural producer

Map 1: Domains of the study.

19. Central rural ceja de selva with agricultural producer
20. Central rural ceja de selva without agricultural producer
21. South rural ceja de selva with agricultural producer
22. South rural ceja de selva without agricultural producer
23. Rural selva with agricultural producer
24. Rural selva without agricultural producer

The sample size was 7,000 households. Based on previous experiences, it was considered that an average of 300 households per domain would be sufficient to satisfy the objectives of the study.

The sample design consisted of a selection of 30 sample groups in each stratum, with an average of 10 households per group. In rural areas, the groups were defined based on the "area de empadronamiento rural" used in the 1981 Population and Household Census. In the urban areas the sample group has an average of 100 households.

Considering efficiency and cost factors, the survey used a multistage sample. In the case of urban areas, the selection of the sample was developed in three stages, while for rural areas in only two stages. This selection process gave to each farm a selection probability that is proportional to size.

Prices were taken as of July 31st, 1984, so as to avoid the strong inflationary distortions which prevailed throughout the prior twelve months.

Some Descriptive Results of Peruvian Farm Households

Demography

The ENAHR survey represents 1.9 million households. Five percent are households with at least one member classified as an agricultural producer. The two types of rural households had an estimated population equal to 9.4 million, or 49 percent of the total population at that time (Table II-1).

Furthermore, 62 percent of this population is located in the sierra, 17 percent in the coast and 21 percent in the selva.

At the national level, rural households have an average of 4.9 members. At the regional level, the sierra has the smallest average with 4.6 members and the selva having the highest average, equal to 5.6.

Table II-1: Total ENAHR households and population by natural region with and without agricultural producer (ENAHR, 1984).

Natural Regions	Total ENAHR households	Total	POPULATION Male	Female	Average members per Hh.
Country	1,903,862	9,361,516	4,795,695	4,565,821	4.92
w/producer	1,573,747	7,911,598	4,089,612	3,821,986	5.03
w/o producer	330,115	1,449,918	706,083	743,835	4.39
Coast	305,038	1,617,023	825,299	791,724	5.30
Sierra	1,244,274	5,753,864	2,911,254	2,842,610	4.62
Selva	354,550	1,990,630	1,059,143	931,487	5.61

Through the analysis of the published results of the survey we observe that 42 percent of the population is between 0 and 14-years-old. Persons from 15- to 64-years-old, mostly labor force, represent 53 percent of population. The older population, 65 years and over constitutes only 5 percent of the total population of rural households in the country (Table II-2).

The age group 15- to 64-years-old, represent an important fraction of the population specially in the coast and sierra.

The gender distinction is important in relation to agriculturally productive activities. At the national level, we observe a slight majority of males, accounting for 51 percent of the population. In the selva the difference is very marked with 114 males for every 100 females.

Table II-2: Total ENAHR population per age groups by natural regions (ENAHR, 1984).

Natural Regions	Total Population	Age 0-14	Age 15-64	Age 65-...
Country	9,361,517 (100.00%)	3,942,242 (42.11%)	4,986,536 (53.27%)	432,739 (4.62%)
Coast	1,617,023 (100.00%)	665,862 (41.18%)	882,236 (54.56%)	68,925 (4.26%)
Sierra	5,753,864 (100.00%)	2,304,898 (40.06%)	3,125,784 (54.32%)	323,182 (5.62%)
Selva	1,990,630 (100.00%)	971,482 (48.80%)	978,516 (49.16%)	40,632 (2.04%)

The survey defined the Population Economically Active (PEA) as all the persons six or more years old that by the week of the survey were looking for a job because they lost their former, were working, and were looking for a job for the first time.

The total population of 6 or more years old of the rural households was 7.9 million. Thirty seven percent or 2.9 million was economically active. Out of it 98.6 percent was employed and 1.4 percent unemployed.

The PEA is constructed by employed and unemployed people. Employed PEA are those that:

1) do some work for which they received an income
2) don't work because of illness, vacation, license, but have a job.
3) work at least 15 hours in family business, farm, etc., without earning money.

Unemployed PEA are those who didn't work during the week of the survey, but they were looking for a job. The No-PEA is defined as all the people six years or older that during the week of reference didn't work or look for a job. This population is mostly students, housekeepers, retired people, renters and others.

Analyzing the employed PEA, we found that 84.7% of the population work in the Agricultural, Fishing and Hunting Sector; 3.9% in Community, Social and Personal services; 3.6% in Commerce, Restaurants and Hotels; 3.1% in Manufacturing Industry; and 2.4% in the Construction Sector (Table II-3).

Table II-3: Population employed 6 years or older distributed by sex, by natural regions and sectors of the economy (ENAHR, 1984).

Natural Regions	Population Employed		
	6 or more years old	Male	Female
Country	2,910,166	2,321,123	589,043
Agric., Fishing	2,464,401	2,007,353	457,048
Mines explotat.	28,106	26,604	1,502
Manuf. Ind.	90,007	60,000	30,007
Construction	71,096	71,036	60
Others	256,556	156,130	100,426
Coast	478,289	393548	84741
Agric., Fishing	356,315	313,823	42,492
Mines explotat.	2,234	2,234	0
Manuf. Ind.	34,687	19,464	15,223
Construction	15,114	15,114	0
Others	69,939	42,913	27,026
Sierra	1,857,227	1,434,555	422,672
Agric., Fishing	1,591,367	1,238,894	352,473
Mines explotat.	24,135	22,836	1,299
Manuf. Ind.	47,329	34,687	12,642
Construction	49,708	49,648	60
Others	144,688	88,490	56,198
Selva	574,157	493,025	81,632
Agric., Fishing	516,719	454,635	62,084
Mines explotat.	1,738	1,535	203
Manuf. Ind.	7,993	5,850	2,143
Construction	6,274	6,274	0
Others	41,933	24,731	17,202

Out of the employed ENAHR population 16 percent is in the coast, 64 percent in the sierra and the remainder 20 percent in the selva. Three hundred and sixty-five thousands of employed population is involved in agricultural activities, in the coast 75 percent. The sierra and selva also have an important percentage of employed population in this sector, 86 percent and 90 percent, respectively.

Size of farms

Rural households operate 1.6 million farms. Out of these 22 percent operate farms less than one hectare in size, while 48 percent have an area between one and five hectares. It follows that 70 percent of farm households operate farms less than five hectares in size (Table II-4).

Table II-4: Total agricultural households and distribution according to total farm area by natural regions (ENAHR, 1984).

	Total ENAHR farms	Size of Farms (%)				
		less than 1 Ha.	1 - 1.9 Has.	2 - 4.9 Has.	5 - 9.9 Has.	10-more Has.
Country	1,573,748	22.00	22.60	25.00	13.20	15.00
Coast	167,929	32.80	16.70	27.10	15.10	6.60
Sierra	1,087,077	26.10	26.60	24.50	10.60	9.30
Selva	318,742	2.40	12.10	25.60	21.10	38.70

Considering the spatial distribution of farms, one observes that 167 thousands units or 10 percent were located in the coast, 69 percent were in the sierra and 20 percent in the selva.

The ENAHR survey found that the total farming land area is 14.9 million hectares. Out of which, 27 percent or 4.0 million hectares were reported as cultivable land; 7.1 million hectares (48 percent) as natural pasture; 2.9 million hectares as forest and hills; and the rest as other type of land (Table II-5).

The regional distribution of arable land indicated that the Sierra has the biggest area of this type of land, representing 49 percent of the total area. The Coast has 39 percent and the Jungle 12 percent.

At the national level farms with less than five hectares comprised 1.4 million or 36 percent of the cultivable land. In the Coast, 77 percent of the farms represented 39 percent of the area of cultivable land; in the Sierra 82 percent of the farms have 52 percent of the area of cultivated land; and in the Jungle 40 percent of farms have 15 percent of the arable land.

Table II-5: Total number of farms and area used according to the type of land by size of farms (ENAHR, 1984).

Number of farms	Total farms	A R E A (H A S.)			
		Arable land	Pastures	Hills and Forest	Others
Country	1,573,748	4,040,059	7,071,234	2,941,761	840,281
less 1 Ha.	346,243	156,022	7,411	757	5,558
1 to 1.99 Ha.	356,245	412,165	33,257	3,412	10,073
2 to 4.99 Ha.	394,057	881,049	174,610	54,642	39,837
5 to 9.99 Ha.	208,107	825,734	274,942	184,566	74,392
10 to 19.99 Ha.	105,240	655,304	328,782	321,734	88,382
20 to 49.99 Ha.	86,294	691,884	548,568	961,448	134,863
50 or more Ha.	44,706	417,897	5,703,661	1,415,200	487,183

<u>Sources of income</u>

The ENAHR survey data allow us to develop four income definitions:

1) Net farm cash income (NFCI)
2) Net household cash income (NHCI)
3) Net farm income (NFI)
4) Net household income (NHI)

Net farm cash income is calculated by adding off-farm sales minus cash payments for hired labor and cash outlays on purchased inputs. Net household cash income is calculated by adding off-farm earnings in agriculture and non-agriculture activities to net farm cash income. Net farm income is calculated by adding the value of human consumption to net farm cash income. Net household income is calculating by adding off-farm earnings and the value of the human consumption to net farm cash income. It follows that the net household income is the most comprenhensive measure of income.

Net household income is the measure of income which should be used in measuring the material welfare of the farm households.

Table II-6 illustrated the different concepts of income by natural regions. Average annual net household income in

July 1984 prices was 3,065 Intis or 856 U.S. dollars[1] while per capita average net household income was 784 intis or 219 U.S. dollars.

There exist significant variations by regions. Average net households income per capita in the coast and selva are approximate equal to 1,450 Intis or 405 U.S. dollars, whereas the corresponding figure for the sierra is only 488 Intis or 136 U.S. dollars.

Net farm income at the national level contributes 68 percent to net household income. Off-farm income accounts for the remainder, i.e., 32 percent.

Off-farm income constributes approximately 41 percent of net household income in the coast. One reason for this could be that cities offer a wide variety of jobs at better salaries. The corresponding figures for the sierra and selva are 39 percent and 18 percent, respectively. This variability in the composition of net household income shows that opportunities for better income are different between regions (Table II-6).

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[1]The official exchange rate for July 1984 was 3.58 Intis per dollar.

Table II-6: Average net household income per farm and per capita, off-farm income per farm and per capita, average net farm income per farm and per capita by natural regions (ENAHR, 1984).

Income measures	Country	Coast	Sierra	Selva
Average net household income per farm-househ.	3065	6151	1904	5397
Average net household income per capita	784	1482	488	1423
Average off-farm income per farm-household	976	2503	736	986
Average off-farm income per capita	228	545	179	226
Average net farm income per farm-household	2089	3647	1168	4411
Average net farm income per capita	556	937	309	1197

As indicated in Table II-7 net farm income increases with the size of the farm. For farms smaller than five hectares the average net farm income per capita is 317 Intisor 89 U.S. dollars. For farms larger than five hectares the corresponding measure is 1,204 Intis or 336 U.S. dollars. However, the increase in net farm income per farm is not proportional with size. This because average net farm income per hectare decreases with the size of the farm. For farms from 2 to 5 hectares the net farm income

Table II-7: Average net cash farm income and average net farm income per farm, per capita, per hectare and per cultivated hectare by farm-size (ENAHR, 1984).

	SIZE OF FARMS						
	Less 1 Ha	1 to 1.99 Ha	2 to 4.99 Ha	5 to 9.99 Ha	10 to 19.99 Ha	20 to 49.99 Ha	50 or more Ha
Country							
A. Average net cash farm income							
A.1 per farm	137	301	639	1698	2863	4220	3507
A.2 per capita	47	80	177	431	624	1769	984
A.3 per hectare	279	234	219	260	216	156	20
A.4 per cultiv ha	294	343	412	638	654	643	359
B. Average net farm income							
B.1 per farm	623	1129	1693	3036	4629	6246	6426
B.2 per capita	189	297	425	733	999	2176	1642
B.3 per hectare	1270	876	580	465	349	231	36
B.4 per cultv ha	1602	1280	1081	1147	1073	960	822

per hectare is 580 Intis and for farms 20 to 50 hectares it is 231 Intis. The decline in productivity per hectare is less obvious if we consider net farm income per cultivated hectare. Then for farm 2 to 5 hectares, net farm income per cultivated hectare equals 1081 Intis; and for farms 20 to 50 hectares in size, 960 Intis.

Net farm cash income as a percentage of net farm income increases with farm size. For smaller farms, 2 to 5 hectares net farm cash income equals 639 intis or 27 percent of net farm income. For larger farms 20 to 50 hectares net farm cash income equals to 4,220 Intis or 67 percent of net farm income. However, the ratio between net farm cash income and net farm income increases less than proportionally with an increase in farm size.

Table II-8 shows the distribution of households by net household income scale. One observes that in the coast a large proportion of households obtains between 3,000 and 15,000 Intis of net income. Specifically, 49 percent of Urban Coast households and 59 percent of Rural Central Coast households have a net income within this range.

Households in the sierra region are located mostly in the low income portion of the scale. Approximately 40 percent of households obtain between zero to a thousand Intis of net income. This result becomes more significant

Table II-8: Total number of ENAHR households and percentual distribution of households by net household income scale by natural regions and domain at Constant Intis of July 1984 (ENAHR, 1984).

	Total No. Households ENAHR	NET HOUSEHOLD INCOME SCALE (%) Less Than 0	0 to 1000	1001 to 2000	2001 to 3000	3001 to 6000	6001 to 15000	15001 to 30000	30001 or more
Coast									
Dom 1	5832	4.5	8.5	13.1	13.8	25.8	23.6	10.6	0.0
Dom 5	91121	6.5	12.6	21.5	13.2	23.4	18.4	3.7	0.8
Dom 7	57078	4.4	9.6	8.5	9.7	21.7	37.5	7.2	1.3
Dom 9	13898	8.1	4.2	4.8	4.3	19.0	31.0	23.3	5.4
Sierra									
Dom 2	24016	1.7	29.8	20.0	13.1	14.8	14.9	4.0	1.6
Dom 11	230139	8.6	39.7	22.1	9.3	14.1	4.8	1.3	0.0
Dom 13	438438	1.9	44.5	23.5	11.9	12.7	5.3	0.1	0.0
Dom 15	394484	3.7	40.6	24.3	12.8	14.0	3.9	0.7	0.0
Selva									
Dom 3	7073	5.9	14.7	10.7	9.0	23.2	22.3	9.6	4.6
Dom 4	7466	1.2	17.6	12.5	17.6	21.2	24.2	4.6	1.1
Dom 17	106437	7.8	17.2	7.6	13.8	27.2	19.0	4.4	3.1
Dom 19	52532	2.0	7.1	14.4	14.3	29.6	24.7	6.0	1.9
Dom 21	23689	0.3	8.7	12.8	9.3	28.3	30.3	8.1	2.2
Dom 23	121545	1.2	15.2	27.0	19.7	23.4	9.0	3.5	1.1

if one considers the total number of households in the sierra, 1.1 million or six times the number of households in the coast. The 319 thousands of the selva region households follow the pattern of coastal households. Around 40 percent of these in each domain have a net income between 3,000 and 15,000 Intis, with the exception of the lower rural selva households which have a tendency for lower income levels.

Farm income is derived from two sources, cropping or livestock activities. Table II-9 shows the average gross income using this subdivision. At the national level, approximately 74 percent of gross farm income comes from agricultural activities. The selva region has higher returns from agriculture activities. The sierra region which gets the lowest farm income, also gets most of its income from agricultural activities.

Table II-9: Total number of ENAHR households, average gross farm income by activity and net average annual farm income by natural regions and domains (ENAHR, 1984).

Natural Regions and Domains	Total No. ENAHR households	Average gross farm income (intis) Agric.	Livestock	Average net Annual farm income(Intis)
Country	1573748	2492	887	2089
Coast	167929	6844	2349	3647
Dom 1	5833	7600	806	3663
Dom 5	91122	6490	455	2261
Dom 7	57077	6651	3203	4539
Dom 9	13900	9057	11855	9067
Sierra	1087076	1002	675	1168
Dom 2	24016	1902	1036	1823
Dom 11	23140	1425	408	1360
Dom 13	438440	932	651	1138
Dom 15	394484	764	834	1048
Selva	318743	5438	867	4411
Dom 3	7073	6879	1518	4679
Dom 4	7466	3539	1147	2491
Dom 17	106439	6812	895	4657
Dom 19	52532	5772	864	4856
Dom 21	23689	6826	360	7100
Dom 23	121546	3799	888	3575

CHAPTER III.

THEORETICAL FRAMEWORK

The analysis of agricultural households can be approached from many points of view, each relevant in its own way. This chapter summarizes the general model from which we developed the one used for statistical estimation in this study.

The Household

Households are viewed in recent years as "small factories". They combine capital goods, raw materials and labor to produce useful commodities (Becker, 1965).

A farm household plays multiple roles as an economic unit. An agricultural household model is defined as one that combine the producer, consumer and labor supply decision of farm households into a single conceptual framework (Huffman and Lange, 1989; Singh, Lyn and Strauss, 1986a).

The fundamental reason for the traditional separation between firms and households is that firms are usually given control over working time in exchange for market goods, while "discretionary" control over market goods and consumption time is retained by households as they create their own utility.

The neoclassical consumer theory is based on the postulate of rationality. The consumer is assumed to choose among available alternatives in order to get the combination commodities that derives the highest satisfaction. All the information relative to the satisfaction that consumers get from various quantities of commodities is contained in his utility function.

The rational consumer will maximize utility subject to his income constraint, since income is limited and he's not able to purchase unlimited amounts of commodities. The consumer's rate of commodity substitution must equal the price ratio for a maximum or, in other terms, the optimum commodity combination will be given by the point where the consumer's indifferent curve is tangent to its budget line (Henderson and Quandt, 1980).

The neoclassical theory of the firm stipulates that a firm is a technical unit in which commodities are produced. The entrepreneur decides how much and how to produce one or more commodities. An entrepeneur will transform input into outputs, subject to its production function. The difference between revenue from sale of outputs and the cost of inputs is profits if positive or loss, otherwise.

A mathematical expression for this technical relationship between the quantities of inputs used and the quantities of output produced is the production function. The firm will pay for each of the factors of production an established market price. As in the consumer theory, the rational producer will maximize output quantity subject to a cost level, or minimize cost of producing a given output level. The entrepeneur may also allow both output level and cost to vary and maximize his profit. In this case, it is required that the value of the marginal physical product of each input be equated to its price (Henderson and Quandt, 1980).

Traditionally, producers attempt to maximize profits selling goods and services; while consumers try to maximize utility exchanging labor and capital services. Both, households as suppliers of labor and consumers of goods, and firms as producers of goods and users of factors of production are considered to be making their decisions independently.

However, the separability of these two set of theories is vague, specially in developing countries, where production at home is no less important than market production. Most households in agricultural areas consume part of its production, purchase some of their inputs and provide some from their own resources, as labor. It is important to realize the dual nature of the farm household as a production and consumption unit.

The question of which theory is better to use arise. Wharton argued that neither the theory of the firm nor the theory of the consumer are appropiate for farm household studies because of the dual nature mentioned above (Wharton, 1969).

Raj Khrisna argued that the theory of the family farm is essentially the theory of what may be called the "household firm" (Khrisna, 1969). He recognized two specific characteristics of farm households. First, that part of the output goes to the household (own consumption); and second, that part of the input comes from the household (labor). Further theoretical complications are added due to technological characteristics of agriculture.

Nakajima states that family farms can be thought as "firm-household complexes" (Nakajima, 1969). He observes some similarities between firm-household complexes and laborer's household. First, both get income by utilizing their own family labor. Secondly, both seem to have essentially the same objectives: maximization of utility. The differences between them is their way of getting income, or their income equation. The family farm income is a function of the production activities carried out on the farm; then, its income equation contains the production function of the farm while the laborer's household don't.

The economic behavior of farmers is quite "rational" (Schultz, 1964). Each firm-household has its own particular utility function as well as its own particular production function. We say that the economic behavior of a family farm is "rational" when it achieved subjective equilibrium, i.e., when it has realized the maximization of its utility, subject to its income equation (Nakajima, 1969).

Farmers guided their allocational efforts by the aim of maximizing the happiness of the family. The farmers have not heard of difficulties of interpersonal comparisons of utility. Each person's notion of family welfare is given by the net utility from income and effort of all members taken together, attaching the same weight to everyone's happiness (Sen, 1970).

Two methods of implementation of the decision are possible. One is that the head of the family takes the decision on behalf of the entire family, as we'll assume in this study. The second, is that each working member is free to decide how to work, but since he equates his interest of the other members of the family with his own, he will follow the same rule; that is equate marginal product with the real cost of labor.

Models of Household Behavior

As we stated above, farm household plays a multiple role as an economic unit. As a production unit, it has to decide the output mix, technology and resources uses. Its provides also the require level of labor for production activities. Based on this decisions, the household, as a consumption unit will define its consumption bundles and the supply of marketable output.

The degree of integration of these functions will depend on the existence of a market economy. In true subsistence households, these decisions are made simultaneously. Without access to trade, a household can consume only what it produces, and also must rely exclusively on its own labor. However, large proportion of farms are semi-commercial farms in which some inputs are purchased and some outputs are sold. Under these conditions producer, consumer and labor supply decisions are no longer made simultaneously.

The first work about joint-decisions in household models goes back to Chayanov, Nakajima and Krishna. According to them all farms in the world can be classified by two criteria. One is the degree of subsistence production, i.e., proportion of production consumed or sold; and the other is the degree of being a family farm, i.e., the proportion of family or hired labor in total labor input on the farm. The closer these indices are to unity, the more subsistence are these farms. When indices are one, the farm use their own resources to produce what they totally consume. On the other hand, we find a pure commercial farm where indices are zero (Figure 3.1).

Krishna points out that the home input ratio is a much broader concept that labor input ratio. Thus, the proportion of inputs coming from the household is the most appropiate ratio to use for this definition. Also, he adds that most of the farms will be "dual agricultural farms" in the sense that output partially goes home and partially goes to the market (Khrisna, 1969).

Two basic models will be discussed in this section. The first consists of the simplest model used by Nakajima to demonstrate how family farm economy reaches equilibrium. This model with no labor market may not be the most appropiate but it is considered useful for a better understanding of the economic relationship in farmers' behavior. The second model is a more complete and adaptable one. It allows the household to hire in and out labor, and to decide between sell or consume its output. This model was Krishna contribution from a combination of models described earlier by Nakajima.

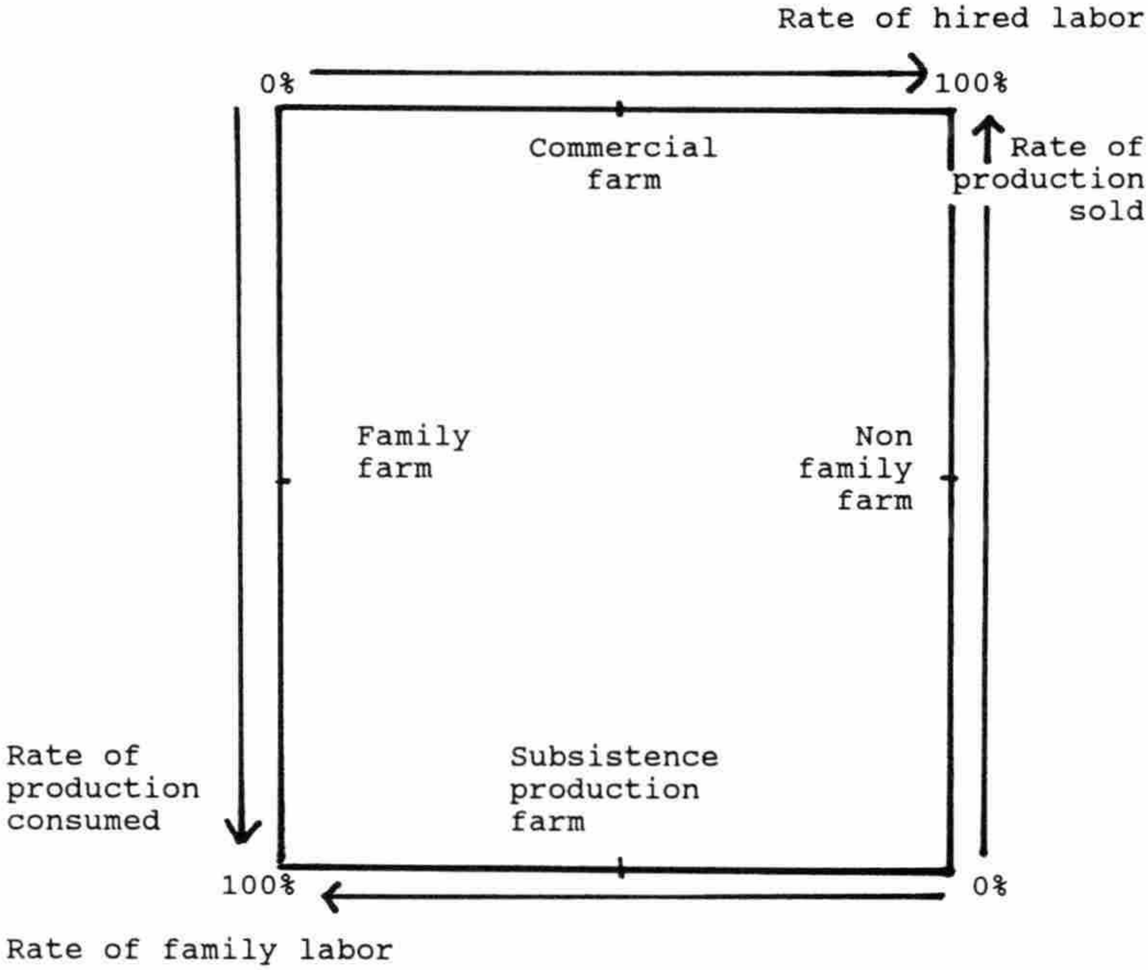

Figure 3.1: Farm classification

Model 1

This is the simplest model of a family farm. A "pure commercial family farm" which operates in a perfectly competitive market for farm products, but no labor market. Then, the family farm will sell all its production and will use only family labor.

The households has an utility function that represents the preference structure of the whole family. The set of assumptions regarding the utility function are:

$$U = U(A,M) \qquad (3\text{-}1)$$

where A represents the family annual labor hours, and M stands for the amount of family's income for the same period. Also,

$$\bar{A} > A > 0 , \qquad M > Mo > 0 \qquad (3\text{-}2)$$

A represents the physiologically possible maximum of labor hours for the whole family, and Mo is the minimum subsistence standard of income for the whole family at a particular level of consumer's price. Also,

$$Ua < 0, \qquad Um > 0 \qquad (3\text{-}3)$$

That is, the marginal utility of labor is negative and the marginal utility of income is positive. Figure 3.2 shows the indifference curve that represent the relationship between income and quantity of family labor used, with slope upward and to the right, due to the assumption (3-3).

An increase in family labor (A) will decrease the level of utility from L_2 to L_1. In order to recover the initial level of utility, M must also increase.

The slope of the indifference curve, expressed by -Ua/Um, represents the valuation of a marginal unit of family labor utilized by the family itself, or the "marginal valuation of family labor" (Nakajima, 1969).

Regarding the production and income of the family farm, the following assumptions were made: (a) the farm produces a single product whose price, Px, is given to the farm as determined on the market; (b) land and labor are the only factors of production; (c) land cannot be leased; (d) the acreage of farm land, B, owned and operated by the family farm is fixed; and (e) the technology of the farm is expressed by a production function, F(A,B).

The following is the equation for the family farm's income:

$$M = Px.\ F(A,B) + E \qquad (3\text{-}4)$$

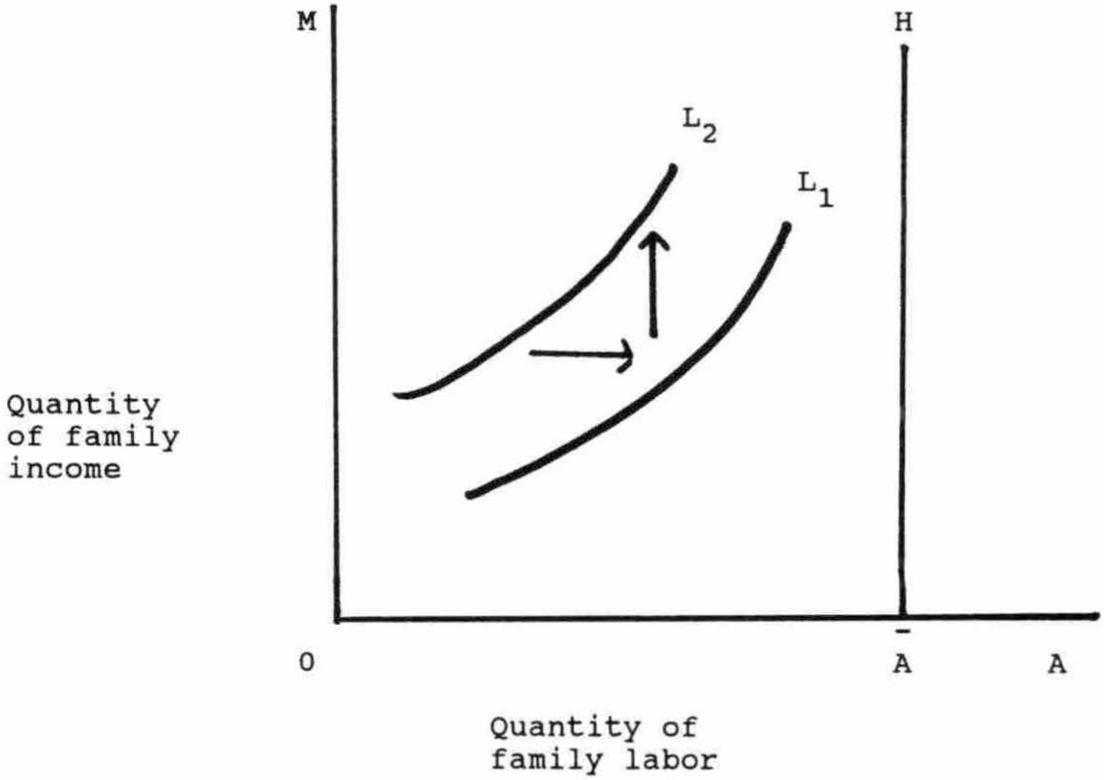

Figure 3.2: Indifference curves

where E stands for other non-farm income. For the production function it is assumed that marginal productivity of labor is non-negative and decreasing, i.e.,

$$Fa > 0, \qquad Faa < 0 \tag{3-5}$$

Then, maximizing the utility function (3-1) subject to income equation (3-4) we get:

$$Px.Fa = -Ua/Um \tag{3-6}$$

This implies that for a family farm in equilibrium the "marginal productivity of labor" equals the "marginal valuation of family labor". The equilibrium values of A and M are determine by the simultaneous equations (3-4) and also (3-6). Then the amount of output, F, is determined by the production function (Nakajima, 1969).

This equilibrium is showed graphically in figure 3.3. OE represents a given amount of E, non-farm income from assets. EL1 is the production possibility curve. Since any point along this curve can be chosen by the family farm, it is called "family income curve".

The family farm will reach a subjective equilibrium, Q, in the sense that utility is maximized when the indifference curve touches L1 (Figure 3.3a). Curve L3 in Figure 3.3b is the marginal productivity of labor curve and L2 the marginal valuation of family labor curve. At the point of equilibrium Q' the marginal productivity of labor intersects the rising marginal valuation curve.

Without a labor market, the marginal productivity of labor in subjective equilibrium tends to be different in each family farm. The causes of these differences depend on the quantities of nonlabor resources, the number of workers in farms and the number of dependents in the farms.

Model 2

The assumptions of this model are that a perfectly competitive labor market exists. The family can hire in and hire out labor. Also, the output produced can be partly sold and partly retained. Then, we maximize:

$$U = U(A,X,M) \qquad (3\text{-}7)$$

where A, as before, represents the total amount of family labor used; X stands for the amount of product consumed in

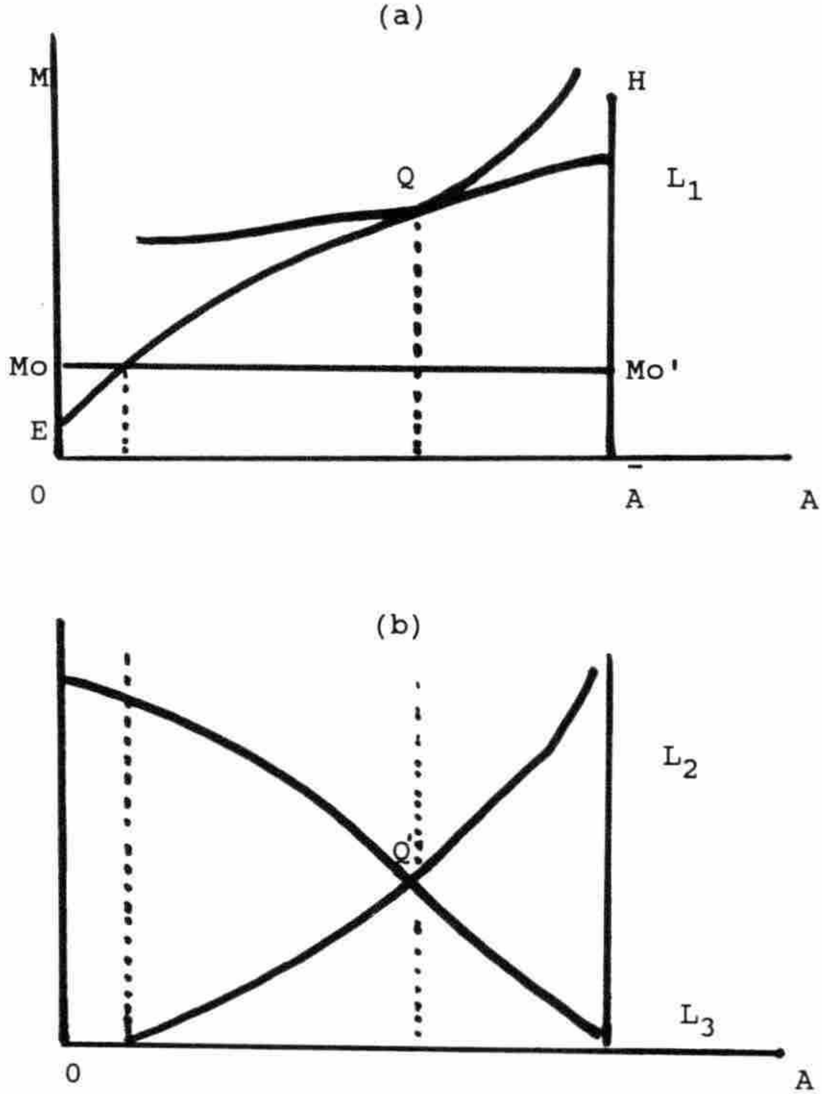

Figure 3.3: Subjective equilibrium

the household; and M is the portion of output that is sold in the market. Also,

$$Ua < 0, \qquad Ux > 0, \qquad Um > 0 \tag{3-8}$$

which means that the marginal utility of labor is negative, and the marginal utility of income in both forms monetary (M) and in kind (X) are positive. The income equation is:

$$M = P\,[F(A',B)-X] + (A - A') \tag{3-9}$$

A is the total quantity of family labor that could be grater, equal to or less than A', the labor input on the farm. A' is determined by the equality of its value of the marginal product with the wage rate. The labor input of the family farm is determined similarly by the equality of the marginal valuation of family labor with the wage rate. The retained output X is determined by the equality of the marginal valuation of retained output with the price (Khrisna, 1969). These conditions are represented by the first order conditions:

$$P.Fa' = W \tag{3-10}$$

$$-Ua/Um = W$$

$$Ux/Um = P$$

The Empirical Model

Based on the preceding section a more complex theoretical model was constructed. Although, it was not possible to apply it to the specific data set, it is useful to describe it and show how the assumptions made and the restrictions of the data set implyed a modification of the model.

Suppose the household consumes three commodities; a market purchased good (Xm), part of the farm output (Xh), and leisure time (Xl). The decision unit is a family farm and there exist a utility function that represents the preferences of the whole family.

$$U = U (Xm, Xh, Xl) \qquad Uxi > 0 \quad i=h,m,l. \qquad (3\text{-}11)$$

The utility function is assumed to be constant overtime, continuous, twice differentiable and quasi-concave. The household utility depends on, the consumption goods and the inputs of leisure or home time of husband and wife (Xl). These two time endowments are distinguished from each other because they are heterogeneous. Each of them receives an endowment of time which can be allocate to work on own farm, work off farm and free time. This free time is a residual category that includes leisure and work at home.

The household gets satisfaction out of the consumption of these goods, thus they maximize utility subject to the constraint of the human time endowment, net household cash income and the production function for farm output.

Time constraint

$$T = Tf + Tm + Xl \qquad (3\text{-}12)$$

where

Tf : Time available for farm work

Tm : Time available for off-farm work

Xl : Leisure time

T : Total time available

The farmer can increase their total time availability by hiring-in labor. The Tm can be positive in the case of hiring-in or negative in the case of hiring-out labor.

The total time available (T) is a (2x1) vector of husband and wife time endowment. The gender distinction exists because endowed and acquired skills of males and females are different. An adjusted factor is needed to get an homogeneous measure of time.

Farm technology constraint

$$G\ (\ Q;\ Tf\ ;\ Zf\ ;\ D\ ;\ \gamma\ )\ =\ 0 \qquad (3\text{-}13)$$

$$Gl > 0 \qquad Gz > 0$$

where

Q : Output

Tf : Labor demand for farm work

Zf : Land used

D : Other variable inputs

γ : Productivity parameter

The technology represented by the implicit function[1] G is assumed to be continuous, twice differentiable and a well behaved concave function.

[1]The advantage of using the implicit function form of the production function is that we can incorporate multiple crops,linking inputs and outputs. Provided the household is a price taker in the relevant markets, the introduction of multiple outputs does not affect the recursive property of the model.

We are implicity considering that family labor and hired labor are homogeneous. In general, farm labor supply from outside the farm household might be considered heterogeneous because of different skills and incentives to work.

Another variable that affect production is land used in crop production (Zf). Many studies consider land as a fix resource, but we're assuming that a market for land exists. Renting land in and out is then, possible.

The farmer can increase the total amount of land available (Z) by renting. Then, land rented (Zm) can be positive if we're renting land for our own used, or negative if we're renting land out. The amount of land available is,

$$Z = Zf + Zm \qquad (3\text{-}14)$$

where

Z : Total land used in crop production

Zf : Own property land

Zm : Land rented

Here we are assuming again homogeneity in both lands. Usually land can be distinguished by its quality.

Finally, we have also incorporate the productivity parameter γ.

Net household cash income constraint

The farm household receives its income from the sales of farm products, of wage labor and also from other assets. The household spends the net income on the purchase of goods.

$$I = Pq.Q + V + w.Tm + r.Zm = Pm.Xm + Ph.Xh + Pd.D \tag{3-15}$$

where

I : Net household income

Pq : Output price

V : Nonfarm and nonwage income

w : Market wage rate

r : Market land rate

D : Other variable inputs

Pd : Price of other variable inputs

Ph : Price of purchased goods

We can combine now the constraints to get the full income equation (Y).

$$Y = Pq.Q + V + w(T-Tf-Xl) + r(Z-Zf) = Pm.Xm + Ph.Xh + Pd.D$$

$$Y = Pq.Q + wT + rZ + V = Pm.Xm + Ph.Xh + w(Tf+Xl) + rZf + Pd.D \qquad (3\text{-}16)$$

Equation (3-16) shows that the full income received is the sum of the total value of farm production, the total time available, the total land available and the asset income. This income is spent on the purchase of final goods for consumption (Xm and Xh) and variable inputs for farm production (D).

The farm household will maximize the following Lagrangian function:

$$L = U(Xh,Xm,Xl) + \lambda\,[Pq(Q,Tf,\ Z-Zm;\ D;\ \gamma) + w.(T-Tf-Xl) + r.Zm + V - Pm.Xm - Ph.Xh - Pd.D] \qquad (3\text{-}17)$$

The first order conditions for interior solutions are the following:

i) $\delta L/\delta Xh = Uh - \lambda.Ph = 0$

ii) $\delta L/\delta Xm = Um - \lambda.Pm = 0$

iii) $\delta L/\delta Xl = Ul - \lambda.W = 0$

iv) $\delta L/\delta Tf = \lambda[Ph.Gtf - W] = 0$

v) $\delta L/\delta Zm = \lambda[-Ph.Gzm + r] = 0$

vi) $\delta L/\delta D = \lambda[Ph.Gd - Pd] = 0$

vii) $\delta L/\delta \lambda = [Pq(Q, Tf, Z-Zm; D; \gamma) + w.(T-Tf-Xl) + r.Zm + V - Pm.Xm - Ph.Xh - Pd.D] = 0$

The model contains eight endogenous variables Xm, Xh, Xl, Tm, Zm, D, Tf, Q. There are eight independent variables Ph, Pm, Pd, T, Zf, w, V, γ. Since the relevant market prices are considered exogenously determined, meaning that the household has no influence in the determination of prices, the model can be solved in two steps. The first step considers the farm household as a production unit, and the second step considers its decision as a consumption unit.

The first order conditions from i) to iii) are the standard results of the consumer theory, in which each household equates the marginal utility of the final goods consumed to their market price. These three equations combine with the constraint give us the demands for these commodities.

Equations iv) from vi) are the profit maximization conditions for input use. The value of the marginal product of each input is set equal to the market factor price. These equations will determine the quantity of farm labor (tf), the quantity of rented land (Zm) and the quantity of variable inputs (D) needed to produce. The rest of the variables Tm, Zf, Q are determined within the system. Using equation (3-12) we can determine Tm* since Tf* and Xl* are determined by the model. Similarly, using equation (3-14) we can determine Zf* since Zm are determine in the model. Finally, output Q, can be determined using the production function equation (3-13) since Tf*, Zf*, D* were determined in the model.

Other results can also be derived: marketable output which is the difference between Q and Xh, net farm income Y, value of home consumption, among others.

The model stated above is a block recursive model that can be expressed in matrix notation, this means that the household can make its consumption decision independent of production and vice versa. But this doesn't mean that changes in some parameters don't affect the elements in the other block. This can be demonstrated by showing some comparative static results (see Appendix A for detailed explanation of comparative static analysis).

Table III-1 shows us the expected signs of the corresponds elasticities, defined as the percentage change in the dependent variable due to a percentage change in the independent variable.

From the comparative static results we conclude that any change in the parameters of the model require the household to make simultaneous consumption and production decisions. The main linkage between them is the income equation.

The choice of estimating the model depends on two factors, the theoretical model and the existing data set. The preceding theoretical model involved the use of eight independent and dependent variables. Even though the ENAHR data survey contains some of this information, a close analysis of it forces us to make major adjustments of the theoretical model.

Specific assumptions were made with respect to the following areas.

Table III-1: Summary of expected signs of the correspondent comparative static results.

	Price commod produc	Price market commod	Daily wage rate	Other indep var	Land rent rate	Asset incom	Price var input	Total time endow	Land used
	Ph	Pm	w	Ψ	r	V	Pd	T	Zf
Xh	?	+	?	+	-	-	+	0	0
Xm	+	?	?	?	?	?	?	0	0
Xl	?	?	?	?	?	?	?	+	0
λ	+	?	?	-	+	+	-	0	0
Tf	+	0	-	0	?	0	?	+	0
Zm	+	0	+	0	-	0	?	0	-
Tm	?	0	?	0	?	0	?	+	0
D	+	0	?	0	?	0	-	0	0
Q	+	0	-	0	?	0	?	0	0

Xh = own consumption commodity
Xm = marketed purchased goods
Xl = leisure time
λ = marginal revenue
Tf = farm work
Zm = own land
Tm = off-farm work
D = other variable inputs
Q = total output

Farm technology

An implicit assumption in the empirical model is that all the farm households have the same production function. Since the analysis is made on domain basis this assumption is reasonable. The model is based on the behavioral characteristics of a single farm, and these are assumed to be common for all the firms in each domain.

In the agricultural sector it is common to find farmers producing more than one type of crop for many reasons: cash flow, risk reduction and others. Then, it is perfectly possible to assume a single farm producing n products.

The output and factors of production can be represented in many different ways.

$$Q_i = f\ (K_j, L_l) \tag{3-18}$$

$$h(Q_i) = X \tag{3-19}$$

$$g(Q_i,\ K,\ L) = 0 \tag{3-20}$$

Equation (3-18) is the most common type of representation of the production function. The physical amount of production, Q, is a function of a variable and fixed factor of production. Equation (3-20) represents an implicit function technology with multiple output. Both forms require specific input allocations for each crop, since that information is not available in the survey, this is not an adequate form to used.

Equation (3-19) allows the possibility of no explicit difference between variable and fixed factors of production, grouping all together as one composite factor of production. The relationship is a multiple output production function, which gives the maximum feasible output combination Qi associated with the composite factor X. This is the approach used for the study.

The choice of this form of production function implies a diferent treatment of the input allocation. The composite factor X will be seen as an intermediate output, and it will be a function of a number of factor of production as well.

$$h(Q_i) = X = f(K, L) \tag{3-21}$$

Time endowment

The theoretical model requires that the total time endowment for the household is divided in time work in the farm, time work out of the farm and leisure time. This type of disaggregation was not able to obtain from the survey data. The data available only include work outside the farm and hired labor. It however does not contain the minimal data set required to measure the number of days the family worked, and hence presumably was willing and able to work. The data are not sufficient to statistically determine the farm household labor supply. Similarly, the specification of crop labor requirements or demand for labor per crop is not available.

These findings along with the empirical tests of significance explained in Chapter IV, lead us to the conclusion that supply of labor is perfectly elastic at a given level of wage rate. Also, the results of Table III-2 show that lack of workers is not relative major problem relative to price, for example.

Land

The model in principle assumes a perfectly competitive market for land rented in or out. Existing legislation, however, gives property rights in those who actually cultivate the land, creating a substantial imperfection in the land rental market. The decision to rent land in or out was therefore seen as essentially exogenous. This implies

TABLE III-2 : Survey response to questions about problems in the production process.

	Have you had problems that affect your production?		What do you think caused		
Domains	Yes	No	Lack of Credit	Lack of Water	Low Prices
1	193	164	21	92	51
2	225	102	13	85	33
3	120	246	2	14	22
4	148	246	20	12	17
5	202	224	55	97	34
7	188	186	15	119	60
9	261	114	27	154	65
11	207	152	41	50	39
13	226	216	25	99	41
15	302	136	37	114	25
17	209	190	23	90	30
19	185	138	35	5	129
21	231	152	14	57	99
23	183	266	34	15	68
Total	2880	2532	362	1003	713

the problems in the agriculture production?

Far Markets	Lack of Workers	Erosion, Fertilit	Lack of Seed, Man	Others
0	2	42	6	122
13	3	24	31	173
3	16	2	3	96
5	4	12	37	91
4	2	52	21	91
3	2	22	2	91
12	10	32	18	141
27	2	37	35	150
30	7	26	54	143
8	0	45	88	224
15	3	4	16	148
65	36	53	32	60
43	54	45	51	85
55	8	14	56	127
283	149	410	450	1742

that the area of cultivated land per household in a given year must be taken as exogenous.

Consumption

A major assumption in the model is that the household members get satisfaction from the consumption of goods and leisure. The survey collected data for home consumption, production and marketed surplus. The latter two were established by direct questions. On farm use was establish residually. For on farm use four questions disaggregated that total into output used for seed, for feeding animals, for barter and for household consumption itself.

Surprisingly the survey revealed no tendency toward price self-sufficiency of rural households. The percentage of home consumption was low enough to justify the assumption that rural households had at all times access at competitive prices to the commodities they themselves also produced. With competitive commodity markets the production and consumption divisions of the rural households can be analyzed separately, taking the prices of commodities as exogenous to the rural household.

If we analyze Table III-3 we will find that for the crop selection there is a higher percentage of total output that is marketed. We might also notice that in the Sierra region, own consumption seems to have more importance.

TABLE III-3: Percentual distribution of total production in own consumption and marketed surplus by crops (ENAHR, 1984).

Crops	% Marketed Output	% Own Consumpt	% For Seed	% Animal Consumpt	% Trade	% Other
COUNTRY						
Banana	52.7	36.0	0.0	5.9	2.2	3.2
Barley	20.7	53.5	13.4	6.4	2.4	3.4
Cotton seed	71.7	0.0	0.0	0.0	0.0	28.3
Dried peas	31.8	44.1	16.6	6.4	0.8	1.1
Lima beans	4.5	70.5	17.5	0.8	1.8	4.8
Manioc	25.9	60.0	0.0	10.5	1.4	2.1
Orange	46.5	2.8	0.0	0.4	0.0	50.3
Potatoes	25.9	34.6	15.8	10.5	1.4	2.1
Rice	46.5	2.8	0.0	0.4	0.0	50.3
Sweet potatoes	88.0	3.5	0.0	1.3	0.2	7.0
Wheat	23.4	58.2	11.0	2.1	2.7	2.7
White corn	21.9	60.2	6.2	6.1	2.8	3.0
Yellow corn	72.8	10.1	1.2	14.3	0.5	1.1
COAST						
Rice	93.3	2.2	0.4	0.1	0.4	3.5
Sweet potatoes	89.2	2.1	0.0	1.3	0.0	7.1
Yellow corn	94.3	1.1	0.2	3.2	0.0	1.2

SIERRA						
Barley	20.7	53.5	13.4	6.4	2.4	3.4
Lima beans	4.5	70.4	17.6	0.8	1.8	4.8
Potato	38.3	35.3	16.3	0.6	1.2	8.3
Wheat	23.1	58.6	11.1	2.1	2.7	2.7
White corn	20.8	61.5	6.3	5.6	3.0	3.0
SELVA						
Rice	87.5	9.5	1.7	0.7	0.1	0.5
Yellow corn	58.7	14.1	1.7	23.7	0.9	1.0
Banana	68.3	21.0	0.0	10.6	0.0	0.0
Manioc	25.3	60.2	0.0	11.0	1.4	2.1

Expenditure in inputs

The model considers input requirements per crop as endogenously determine. The survey did not collect the required detail information. However, information on total expenditure on off farm required inputs is available. Since this measure is more exact, it was chosen.

The Lagrangian equation (3-17) must be modified by the restrictions mentioned above. This essentially yields a model of the production decision of the rural household. We emphasize that farmers can produce more than one crop. We start with a two commodity model. The expansion to more than two crops can be done without modifying the analysis.

Total output produced Q_a and Q_b will be considered as endogenous but we take C_a and C_b, on farm use as exogenous. This assumption allow us to formulate the problem in terms of the endogenous variable Q_a^s and Q_b^s, the marketed surplus of commodity A and B respectively.

The maximization problem can be formulated by using the following Lagrangian function,

$$L = Pa.Q_a^s + Pb.Q_b^s - \lambda[h(Q_a^s, Q_b^s) - f(K,EXP,L)] \quad (3-22)$$

where

Q_i = output surplus of product i.

K = land.

EXP = expenditure in inputs.

L = labor

Equation (3-22) represents the maximization of the gross value of marketed surplus subject to a technological constraint. In this case due to the fact that the production function form (3-19) was chosen, the constraint reflects that all the inputs are used in the production of both outputs. In the output space this relationship denotes a transformation surface, which gives the maximum amount that can be produced of a certain output, holding the rest constant. The negative of the slope of this curve is called the marginal rate of transformation between pairs of products, which describes that the resources used on the production of one can be transferred to the production of the other. The system of supply equations will be derived under the assumption that the farm household maximize output sold given its technology constraint.

Solving the Lagrangian equation with respect to the endogenous variables, one obtains the first order conditions,

(i) $\delta L/\delta Q_a^s = P_a - \lambda h_a = 0$

(ii) $\delta L/\delta Q_b^s = P_b - \lambda h_b = 0$

(iii) $\delta L/\delta \lambda = h(Q_a^s , Q_b^s) - f(K,EXP,L) = 0$

Totally differentiate the F.O.C.

$$dPa - \lambda[haa\ dQ_a^s + hab\ dQ_b^s] + ha\ d\lambda = 0$$
$$dPb - \lambda[hba\ dQ_a^s + hbb\ dQ^s{}_b] + hb\ d\lambda = 0$$
$$ha\ dQ_a^s + hb\ dQ_b^s - fk\ dK - fexp\ dEXP - fl\ dL = 0$$

In matrix form,

$$\begin{bmatrix} \lambda haa & \lambda hab & ha \\ \lambda hba & \lambda hbb & hb \\ ha & hb & 0 \end{bmatrix} \begin{bmatrix} dQ_a^s \\ dQ_b^s \\ d\lambda \end{bmatrix} = \begin{bmatrix} -dPa \\ -dPb \\ \varphi \end{bmatrix}$$

where

$\varphi = f_k\ dK + f_{exp}\ dEXP + f_l\ dL$

Following the same procedure to find the comparative statics we end up with the following expected signs

Table III-4: Summary of comparative static results.

		Price commd A	Price commd B	Land	Expendit in inputs	Labor
		Pa	Pb	K	EXP	L
Marketed surplus A	Q_a^s	+	-	+	+	-
Marketed surplus B	Q_b^s	-	+	+	+	-
Marginal product	λ	?	?	?	?	?

The previous model can be analyzed graphically. One observes an input and an output side linked by the composite factor or intermediate product. On the input side we have markets of labor, land and expenditure in inputs.

The demands of those markets are the normal downward sloping curves, and are not a subject of analysis in this study. On the labor market an elastic supply curve is assumed, meaning that the household can find an infinite amount of labor at a given wage rate. The case of land and expenditure are the opposite, in the sense that totally inelastic supply curves are assumed, i.e., the equilibrium quantities supplied are given. As to expenditure its endogenously determined equilibrium price can be thought as the shadow price of circulating capital (Figure 3.4). If some of circulating capital is borrowed the shadow price equals unity plus the implicit rate of return to circulating capital.

Since all the inputs have to be used in the production of outputs, we have an equilibrium in the intermediate product market (Figure 3.5), where X_s and X_d are the composite factor supplied and demanded, respectively. On the output side farmers faced infinitely price elastic demand curves for their products. The derived supply response of rural households then becomes the principal objective, both theoretically and empirically.

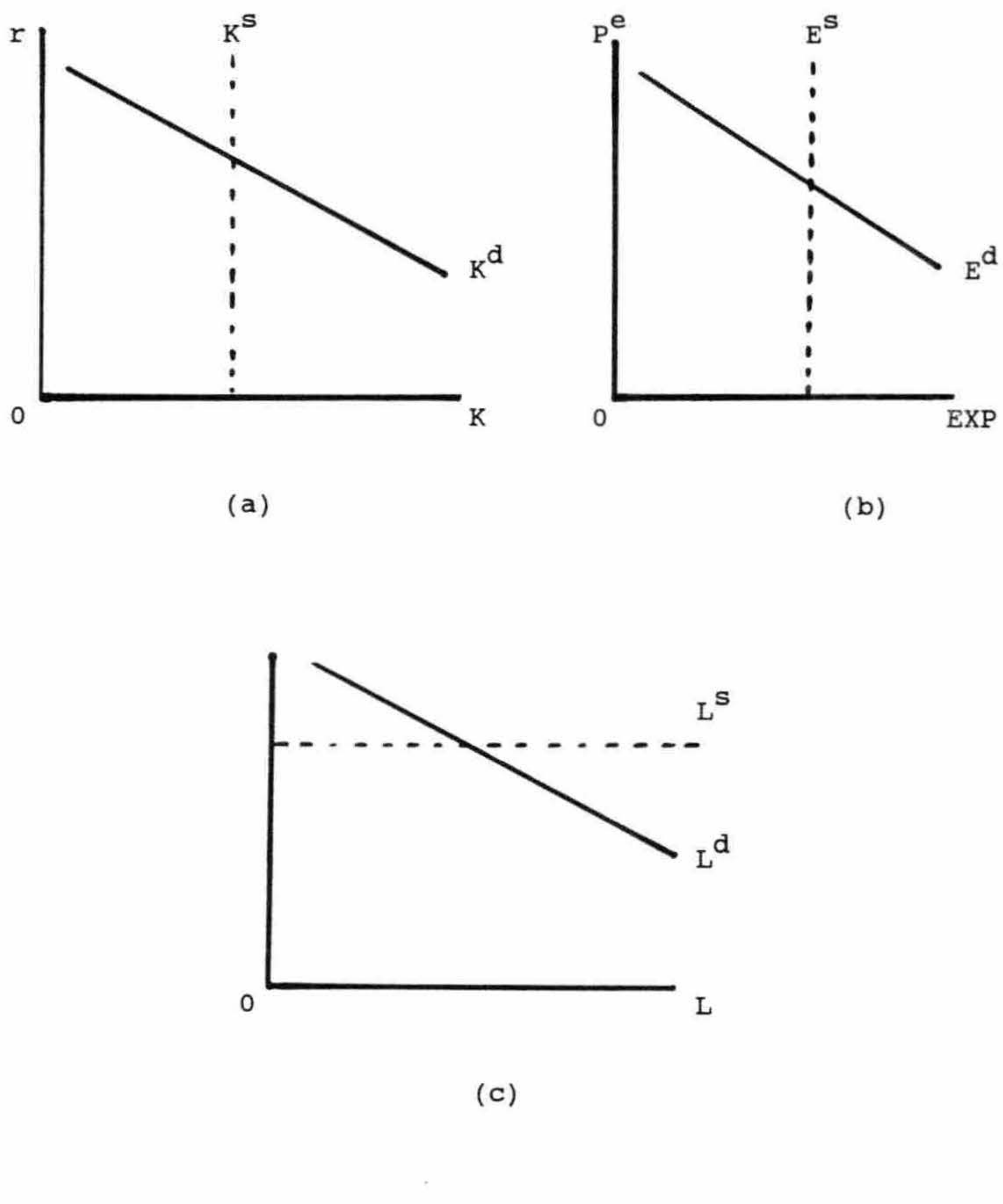

Figure 3.4 : Input markets

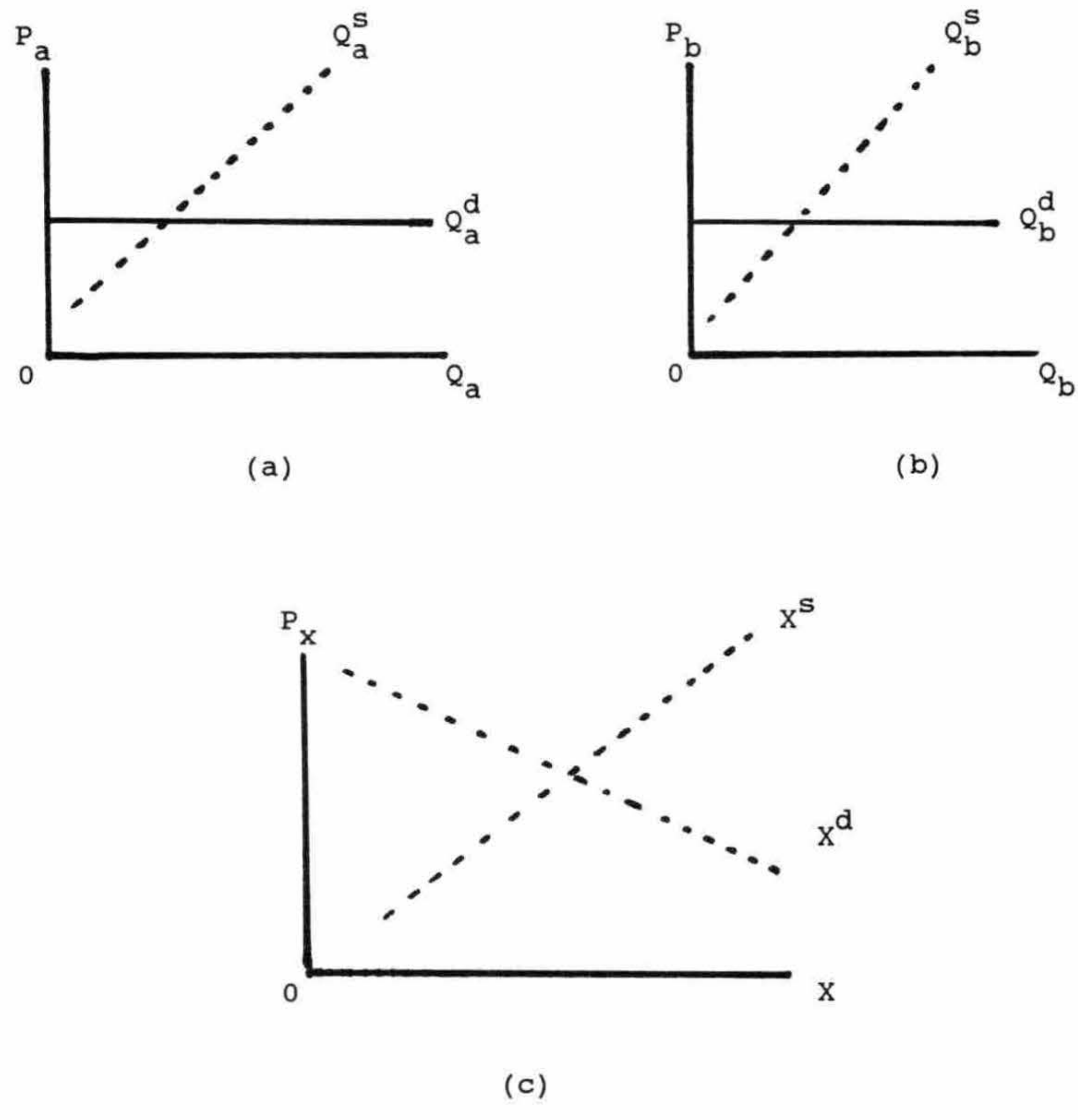

Figure 3.5: Output markets

CHAPTER IV.

THE ESTIMATION PROCEDURE AND STATISTICAL RESULTS

This chapter reviews efforts made to estimate different parameters that enter in the derivation of the model discussed in Chapter III. The basic assumption is that producers maximize their gross revenue subject to a production function, separable in outputs and inputs.

The Estimation Procedure

The functional form

The derived supply relationships can be estimated by using linear, semi-logarithmic or double logarithmic statistical models. The supply equations can be expressed as follows,

Linear: (4-1)

$$Q_i = B_{io} + \sum_{i=1}^{n} B_{ij} P_j + B_{ie} EXP + B_{iw} W + B_{il} L \qquad i,j = 1,2,\ldots.n$$

Semi-log: (4-2)

$$Q_i = B_{io} + \sum_{i=1}^{n} B_{ij} LnP_j + B_{ie} LnEXP + B_{iw} LnW + B_{il} LnL$$

Double log: (4-3)

$$\text{Ln } Q_i = B_{io} + \sum_{i=1}^{n} B_{ij} \text{ LnP}_j + B_{ie} \text{ LnEXP} + B_{iw} \text{ LnW} + B_{il} \text{ LnL}$$

where:

Q_i = output surplus of the ith commodity.

P_i = price received by the producer of the ith commodity.

EXP = total expenditure in variable inputs.

W = wage rate expressed in daily wage or "jornales".

L = area of cultivated land available.

The decision of which form to use in the estimation of the supply equations was made based on the efficiency of the parameters estimated. Along with the multiple regression analysis performed, a t-test for the parameters was carried out. The hypothesis consists of

$$\text{Ho: } B_i = 0 \qquad (4\text{-}4)$$

$$\text{Ha: } B_i \neq 0$$

If the t-value is larger than the tabled value of t at the desired probability level, the true hypothesis is accepted. Also, the standard deviation for each estimated parameter gives us some idea of the relevance of that parameter in the explanation of the dependent variable.

In addition, the adequacy of the overall production function or the accuracy of the production equations are assessed through the analysis of the R^2 coefficient of determination. This coefficient reflects the proportion of variation of the dependent variable that is explained by variations of the independent variable.

To determine the adequacy of these functional forms, each of them were used for the estimation in three domains of the study, domain 3 (Selva), domain 5 (Coast) and domain 11 (Sierra). We will take the case of domain 3 to show in detail how the criteria above mentioned were applied. The Table IV-1 reflects the results of the estimation of the system of equations obtained applying the Seemingly Unrelated Least Squares procedure described in the next section. A first look at these results indicates that the semi-logarithmic form provides a better fit than the linear form, as shown by the R^2 coefficients of determination. As expected the standard errors of some of the critical parameters are smaller. Table IV-6 details the double logarithmic coefficients corresponding to the form. The much better fit is reflected in the increase of the coefficients of determination, and as before, in the reduction of the corresponding standard errors. The final selection of this form has the additional advantage that the results of the regression procedure yield directly own and cross price elasticities.

Table IV-1: Estimated parameters for domain 3 using the linear and the semi-logarithmic forms.

Linear:

	Price Banana	Price Manioc	Price Rice	Price Yell corn	Expend	R^2
Q sold Banana	4.099 (0.411)	-0.098 (0.246)	0.124 (0.242)	-0.415 (0.310)	0.021 (0.044)	0.721
Q sold Manioc	-1.211 (0.920)	1.555 (0.550)	-0.652 (0.542)	-0.347 (0.705)	0.031 (0.098)	0.242
Q sold Rice	-3.571 (3.051)	0.353 (1.831)	3.479 (1.800)	-0.120 (0.023)	0.521 (0.327)	0.782
Q sold Yell corn	0.544 (0.774)	0.077 (0.068)	1.178 (1.040)	2.026 (1.362)	0.023 (0.019)	0.635

Semi-log:

	Price Banana	Price Manioc	Price Rice	Price Yell corn	Expend	R^2
Q sold Banana	2.210 (0.415)	-0.079 (0.024)	0.100 (0.230)	-0.492 (0.310)	0.045 (0.024)	0.731
Q sold Manioc	-1.041 (0.937)	1.260 (0.641)	-0.385 (0.221)	-0.172 (0.610)	0.021 (0.058)	0.454
Q sold Rice	-2.371 (6.240)	-0.091 (0.139)	2.189 (0.973)	-0.620 (0.752)	0.216 (0.082)	0.454
Q sold Yell corn	0.585 (0.831)	0.099 (0.059)	0.992 (1.032)	1.820 (1.023)	0.058 (0.044)	0.654

The theoretical discussion in Chapter III, emphasized the existence of more than one endogenous or decision variable. The statistical estimation procedure must mirror the farm household economy as a system of simultaneous relations among several dependent and independent variables.

This system of derived supplies can be written in the following way, using the implicit function theorem,

$$Q_i = f(P_1, P_2, \ldots P_n, X) \qquad (4\text{-}5)$$

and are homogeneous of degree zero in output prices (Henderson and Quandt, 1980).

The estimation method

The statistical estimation procedure to be applied on the supply system is the Seemingly Unrelated Least Squares (S.U.L.S.) by which the coefficients in all equations are estimated simultaneously. Although this statistical procedure is usually described in the context of estimating a number of equations using time-series data, it is equally relevant for cross-sectional data (Judge et al., 1988).

The advantages of this procedure is that it allows for making linear restrictions across equations which are taken into account on the simultaneous estimated coefficients. The gain in efficiency of the estimates appears whenever the independent variable are not highly correlated and if the disturbance term in different equations are highly correlated.

We will explain this statistical method in detail using the following example. Let's consider a set of three log-linear supply equations:

(4-6)

$$Ln\ Q_1 = B_{10} + B_{11}\ LnP_1 + B_{14}\ LnX + e_1$$

$$Ln\ Q_2 = B_{20} + B_{22}\ LnP_2 + B_{24}\ LnX + e_2$$

$$Ln\ Q_3 = B_{30} + B_{33}\ LnP_3 + B_{34}\ LnX + e_3$$

It's assumed that the quantity produced of the ith output depends in its own price P_i and a composite factor X. In order to be clear, we have excluded the other prices in each equation.

The three supply equations can be written in matrix notation as,

(4-7)

$$Y_1 = X_1\ \beta_1 + e_1$$

$$Y_2 = X_2\ \beta_2 + e_2$$

$$Y_3 = X_3 \beta_3 + e_3$$

where Y_1 and X_1 will contain all T observations on the dependent and explanatory variables in the supply equation for output 1. Similarly, Y_2 and X_2 contain all T observations on the dependent and explanatory variables of output 2. Same thing for Y_3 and X_3. Also, β_1, β_2 and β_3 are the (3x1) coefficient vectors for each of the equations, and e_1, e_2 and e_3 are the (Tx1) disturbance vectors of each equations.

The assumptions behind this statistical procedure are the following:

a. All disturbances have a zero mean

$$E\,[e_i] = 0 \qquad i=1,2,3$$

b. Each equation can have different variance

$$Var\,(e_1) = E[e_1^2] = \sigma_1^2$$
$$Var\,(e_2) = E[e_2^2] = \sigma_2^2$$
$$Var\,(e_3) = E[e_3^2] = \sigma_3^2$$

c. Two disturbances in different equations but corresponding to the same time period[1] are

---

[1]In most applications Yi and Xi will contain observations on variables for T different time periods, and the subscript i corresponds to particular economic unit as a household, specially if we're using cross sectional data.

correlated (contemporaneous correlation)

$$\text{Covar}\ (e_i e_j) = E[e_i\ e_j] = \sigma_{ij}$$

d. Disturbances in different time periods, whether they are in the same equation or not, are uncorrelated (autocorrelation does not exist)

$$\text{Covar}\ (e_{it}\ e_{js}) = E[e_{it}\ e_{is}] = 0 \quad \text{for } t]s$$

In matrix notation this assumption can be written as

$$E[e_i] = 0 \qquad E[e_i e_j'] = \sigma_{ij}\ I$$

If we take as an example, $E[e_1 e_1'] = \sigma^2{}_1\ I$, least squares applied to this first equation is the best linear unbiased estimator in the sense that it is the best estimator that is a linear unbiased function of Y_1. But, because of the existence of contemporaneous correlation it's possible to obtain a better linear unbiased estimator that is function of Y_1, Y_2 and Y_3.

Using matrix notation we can rewrite (4-8) as

$$Y = X\beta + e$$

the disturbance covariance matrix ϕ is of dimension (3Tx3t) with each (TxT) sub matrix being equal to a scalar multiplied by a T-dimensional identity matrix.

$$\phi = \begin{bmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_2^2 & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_3^2 \end{bmatrix} \quad x \quad It$$

Thus, the generalized least squares estimator $\hat{\beta}$ = $(X'\phi^1 X)^1 X\phi^1 Y$ is the best linear unbiased estimator for ß. It has a lower variance than the least squares estimator for ß because it takes into account the contemporaneous correlation between the disturbances in different equations (Judge et al., 1988).

There exists two cases under which least squares is identical to generalized least squares and, in those cases there is nothing to gained by treating the equations as a system. The first case, is when all contemporaneous correlations are zero. That is,

$$\sigma_{12} = \sigma_{13} = \sigma_{23} = 0$$

The second case, occurs when the explanatory variables in each equation are identical. That is,

$$X_1 = X_2 = X_3$$

Then, if ϕ is a diagonal matrix or if the set of independent variables is the same for each equation then this estimator will yield exactly the same results as the single OLS estimator.

Statistical Results

The statistical method described above is now applied to obtain all price elasticities for each group of products for the selected domains comprising the totality of the ENAHR survey.

Specific production characteristics per domain

As mentioned in Chapter II, the ENAHR survey data are divided in 24 domains out of which 14 included households with agricultural producers.[2] These 14 domains are going to be the focus of the study.

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[2]Households with agricultural producer are those which have at least one member of the family operating a farm. For more details refer to Chapter II, p. 4.

Domains Code	Areas
1	Urban Coast
2	Urban Sierra
3	Urban Ceja de Selva
4	Urban Selva
5	North rural coast
7	Central rural coast
9	South rural coast
11	North rural sierra
13	Central ruarl sierra
15	South rural sierra
17	North rural ceja de selva
19	Central rural ceja de selva
21	South rural ceja de selva
23	Rural selva

The ENAHR survey anticipated and collected data pertaining to the production of more than one hundred crops. It confirms that Peru has many different micro-climates given rise to a wide variety of products.[3] In order to

[3]For a complete detailed list of crops see Appendix C.

restrict the study to major crops only the following criteria were used.

First of all, to provide a natural complement for existing studies of the demand side, specifically De las Casas (De las Casas, 1977) and Amat y Leon (Amat y Leon, 1973) yielded a selection of 45 crops.

The second step was to determine the number of households per domain with production of these crops. Those crops produced by less than 20 households overall were removed from the list, leaving us with 17 main crops (see Table IV-2). Within domains we selected only those crops that were produced by at least 20 households.

Table IV-3 provides final selection of crops per domain. One observes that the domains in the coast (Domain 1,5,7 and 9) have an average of four crops. The most important are yellow corn, sweet potatos and rice. The domains in the sierra have a much wider diversity of crops, with an average of 7 crops. The most important are white corn, wheat, potatoes, oca and barley. Similarly to the coast, the domains in the selva present an average of five crops per domain. The most important in this case are yellow corn, rice, manioc and bananas. For domains 11 and 13 a further selection was made since prices of manioc and wheat for domain 11 and oca for domain 13 were not reported in the survey.

TABLE IV-2: Number of farms with production per domain.

	Costa	Sierra	Selva		Costa		
	DOM 1	DOM 2	DOM 3	DOM 4	DOM 5	DOM 7	DOM 9
Banana	19	2	114	130	40	7	4
Barley	1	120					1
Cotton Seed	11		7	5		45	6
Dried Peas	1	27			2	1	
Lima Beans		62			1		
Manioc	13	3	45	113	12	32	8
Oca		17					
Onions	3	9		4		4	42
Oranges	4	2	6	7		4	3
Potatoes	12	182	1			1	61
Quinua		15					
Rice	81	1	143	110	124	7	69
Sugar	1	1	6	4	4		
Sweet Potato	27		2	1	11	48	40
Wheat	1	120					11
White Corn	19	224	1		20	13	66
Yellow Corn	94	4	121	143	80	68	70

Sierra			Selva				
DOM 11	DOM 13	DOM 15	DOM 17	DOM 19	DOM 21	DOM 23	TOTAL
13			101	127	41	162	760
47	133	125					427
			12	1			87
16	34	11	1				93
7	58	89			31		248
21		2	115	101	109	186	760
23	21	48			17		126
	2						64
			1	27	42		96
80	182	304		3	144		970
	3	97			1		116
4			81	14	2	117	753
11			27				54
6	5	3	1	6			150
83	136	61					412
138	242	132	10	7	80		952
29	9	3	137	113	81	150	1102

TABLE IV-3: Distribution of crop production per domain.

	Costa	Sierra	Selva		Costa		
	DOM 1	DOM 2	DOM 3	DOM 4	DOM 5	DOM 7	DOM 9
Banana			X	X	X		
Barley		X					
Cotton Seed						X	
Dried Peas		X					
Lima Beans		X					
Manioc			X	X		X	
Oca							
Onions							X
Oranges							
Potatoes		X					X
Quinua							
Rice	X		X	X	X		X
Sugar							
Sweet Potato	X					X	X
Wheat		X					
White Corn		X			X		X
Yellow corn	X		X	X	X	X	X

Sierra			Selva			
DOM 11	DOM 13	DOM 15	DOM 17	DOM 19	DOM 21	DOM 23
			X	X	X	X
X	X	X				
	X					
	X	X			X	
			X	X	X	X
X		X				
				X	X	
X	X	X			X	
		X				
			X			X
			X			
	X	X				
X	X	X			X	
X			X	X	X	X

Analysis of results

The supply response was estimated for the 14 domains of the study including the more representative crops produced. Tables IV-4 to IV-17 shows the results in detail. They consist of the own and cross-price elasticities of substitution or complementarity between crops, and the expenditure elasticity, wage rate elasticity and the cultivated land elasticity.

The model was run first with the correspondent crop selection for each domain plus the expenditure variable. Then we substitute the latter for the wage rate variable; and finally, we included all these together with cultivated land as a final additional variable. Either one of these approaches are quite satisfactory in the sense of good fit (coefficient of determination). We cannot tell definitively which one is better because the introduction of an additional explanatory variable does not uniformly reduce the standard errors of the already included explanatory variables. Nevertheless, the most complete specification yields supply response signs consistent with theoretical expectations, they are statistically significant and the coefficient of determination increases, if only marginally.

For each of the 14 domains two important conclusions emerge. First, the own price elasticities are strongly positive, falling between 0.4 to 1.4. This means that a one percent increase in the price of crop i will increase the quantity marketed of that crop on the average by more than one percent. Policies that depress prices received by farmers apparently lead to a proportionately large reduction in marketed surplus.

Second, cross price elasticities indicate the degree of substitutability or complementarity between crops. Crops that are substitutes will carry a negative elasticity sign, while those that are complements will have a positive sign. Generally cross price elasticities are small relative to direct price elasticities. This implies, that if the intersectoral terms of trade were to move in favor of agriculture then the marketed surplus of all crops would increase.

Analysis of those results by regions reconfirm these findings. Analyzing the domains that correspond to the Coast, we observe repeatedly sustitutability between rice, potatoes, and bananas. The same pattern holds for yellow corn, potatoes, rice and white corn. On the other hand, rice, onions, and sweet potatoes appear as complementary crops.

The Sierra shows more frequently complementarity among products. This can be explained if one considers that on farm use represents a higher proportion of output in this region. Farmers of necessity must diversify their production. We find complementarity between barley and white corn, wheat and barley and lima beans and oca.

The Selva region shows sustitutability between rice and manioc, and bananas and manioc; and to some extent also bananas and yellow corn.

The expenditure elasticity, wage labor elasticity and land elasticity have similar signs and sizes in most domains. Expenditure elasticities are positive as expected, and wage rate elasticities are negative. The elasticity pertaining to cultivated land is positive and proportionately large.

As expenditure on inputs increases, the marketed output increases. These results are important in the sense that they are consistent with neo-classical economic postulates. We therefore conclude that Peruvian households behave in a rationally economic fashion as predicted by the model developed in pages 54 to 60.

In order to show the results in greater descriptive detail, we will analyze the results of domain 13: the central rural Sierra region. Farmers in this region produce six major crops: barley, dried peas, lima beans, potatoes, wheat and white corn. We find that own price elasticities are positive going from 0.5 in case of dried peas to 1.0 for white corn.

This result shows a proportionally great responsiveness to prices. A policy considering an increase in prices received by the farmers in this region, will increase the marketed surplus of these crops substantially. Furthermore, considering that this region produces an important percentage of potatoes and wheat, the highest pay off of an Inti or Dollar used to increase this price will have two major effects. First, it will increase the farm household income; and second, it will provide more of these commodities to the market.

In general the domains in the Sierra are characterize by a frequently complementarity among products. We find complementarity between lima beans, barley and white corn, and substitutability between potatoes and wheat.

The expenditure elasticities are positive for all crops, indicating that they are normal goods. An increase in expenditure of off farm inputs will increase the quantity sold. This elasticities fluctuate from 0.01 to 0.04. Surprisingly, the effect of this variable is not as significant as we thought. The need for cash or credit in order to get input is not as important in this region.

The wage rate elasticities are negative throughtout. They go from -0.01 to -0.06. We expected the relationship between marketed surplus and daily wage rate to be as it is; but somehow the decision of hired labor at an increasing wage rate doesn't seem to affect the marketed output a whole lot.

Cultivated land elasticity is positive as expected. One observes that the central sierra region doesn't require urgently an expansion of land. This would indicate that may be a requirement for increase in productivity is more necessary in this case.

We can conclude that the central Sierra farmers are sensitive at prices more than anything else. The policy design then has to consider that in this region, an increase in prices received by farmers is the most efficient way to increase marketed surplus and farmers income. Money directed to subsidies for farmers producing this crop will have higher pay off.

Table IV-4: Estimated supply coefficients.
DOMAIN 1 (94 Obs.)

	Price Rice	Price Swpotato	Price Yell corn	Expend	Wage rate	R ** 2
Q sold Rice	-0.233 (0.115)a	1.243 (0.067)	0.071 (0.097)	0.031 (0.031)		0.951
Q sold Swpotato	1.069 (0.104)	0.057 (0.061)	-0.107 (0.089)	0.112 (0.055)		0.867
Q sold Yell corn	-0.108 (0.161)	-0.025 (0.094)	0.823 (0.137)	0.292 (0.084)		0.750

	Price Rice	Price Swpotato	Price Yell corn	Expend	Wage rate	R ** 2
Q sold Rice	1.228 (0.072)	-0.230 (0.109)	0.062 (0.098)		-0.077 (0.10)	0.951
Q sold Swpotato	0.147 (0.069)	1.167 (0.105)	-0.013 (0.094)		-0.132 (0.098)	0.854
Q sold Yell corn	-0.070 (0.106)	-0.026 (0.162)	0.822 (0.144)		-0.458 (0.150)	0.730

	Price Rice	Price Swpotato	Price Yell corn	Expend	Wage rate	Cultivate land	R ** 2
Q sold Rice	1.262 (0.076)	-0.123 (0.134)	0.111 (0.100)	0.054 (0.065)	-0.053 (0.100)	0.296 (0.181)	0.957
Q sold Swpotato	0.102 (0.066)	1.057 (0.117)	-0.078 (0.091)	0.133 (0.053)	-0.193 (0.091)	0.089 (0.160)	0.893
Q sold Yell corn	-0.074 (0.093)	0.006 (0.164)	0.815 (0.127)	0.283 (0.079)	-0.330 (0.127)	0.392 (0.224)	0.837

[a] Numbers in parentheses are standard errors.

Table IV-5: Estimated supply coefficients.
DOMAIN 2 (224 Obs)

	Price barley	Price dr peas	Price lima bean	Price potato	Price wheat	Price wh corn	Expend	R ** 2
Q sold barley	0.822 (0.394)a	0.257 (0.044)	-0.006 (0.043)	-0.002 (0.057)	-0.000 (0.004)	0.004 (0.048)	0.021 (0.019)	0.962
Q sold dr peas	0.022 (0.044)	0.790 (0.043)	0.012 (0.057)	-0.062 (0.034)	0.005 (0.045)	0.023 (0.048)	0.014 (0.002)	0.953
Q sold lima bean	0.011 (0.010)	-0.003 (0.011)	0.628 (0.015)	0.010 (0.009)	0.022 (0.011)	-0.006 (0.0012)	0.006 (0.0052)	0.981
Q sold potato	0.089 (0.100)	-0.114 (0.090)	-0.079 (0.129)	0.751 (0.071)	-0.027 (0.101)	-0.095 (0.109)	0.002 (0.040)	0.872
Q sold wheat	0.012 (0.016)	0.006 (0.017)	0.032 (0.024)	-0.003 (0.014)	0.771 (0.018)	-0.016 (0.020)	0.010 (0.0084)	0.990
Q sold wh corn	-0.016 (0.040)	-0.003 (0.038)	0.018 (0.052)	0.040 (0.03)	-0.015 (0.004)	0.750 (0.044)	-0.020 (0.0196)	0.951

	Price barley	Price dr peas	Price lima bean	Price potato	Price wheat	Price wh corn	Wage rate	R ** 2
Q sold barley	0.816 (0.040)	0.027 (0.038)	-0.016 (0.0052)	-0.007 (0.031)	0.007 (0.041)	0.012 (0.044)	-0.103 (0.046)	0.968
Q sold dr peas	0.012 (0.044)	0.780 (0.042)	-0.000 (0.058)	-0.059 (0.034)	0.003 (0.045)	0.023 (0.039)	-0.023 (0.015)	0.952
Q sold lima bean	0.013 (0.010)	-0.000 (0.011)	0.630 (0.015)	0.008 (0.0092)	0.024 (0.01)	-0.005 (0.001)	-0.007 (0.0013)	0.990
Q sold potato	0.086 (0.099)	-0.116 (0.090)	-0.083 (0.128)	0.751 (0.077)	-0.025 (0.010)	-0.093 (0.0109)	-0.026 (0.110)	0.872

Q sold wheat	0.010 (0.0189)	0.002 (0.017)	0.030 (0.0201)	-0.001 (0.014)	0.769 (0.019)	-0.018 (0.020)		-0.018 (0.021)		0.990
Q sold wh corn	-0.026 (0.041)	-0.015 (0.038)	0.005 (0.005)	0.043 (0.031)	-0.019 (0.014)	0.750 (0.045)		-0.012 (0.017)		0.948

	Price barley	Price dr peas	Price lima bean	Price potato	Price wheat	Price wh corn	Expend	Wage rate	Cultivate land	R ** 2
Q sold barley	0.828 (0.044)	0.035 (0.031)	-0.017 (0.055)	-0.018 (0.034)	0.002 (0.015)	0.009 (0.005)	0.014 (0.016)	-0.137 (0.068)	0.021 (0.030)	0.969
Q sold dr peas	0.025 (0.047)	0.796 (0.043)	0.005 (0.0058)	-0.073 (0.037)	0.008 (0.048)	0.027 (0.050)	0.039 (0.028)	-0.096 (0.073)	0.012 (0.032)	0.957
Q sold lima bean	0.011 (0.010)	-0.004 (0.011)	0.628 (0.015)	0.010 (0.010)	0.022 (0.013)	-0.006 (0.013)	0.009 (0.007)	-0.008 (0.002)	0.001 (0.0087)	0.991
Q sold potato	0.199 (0.107)	-0.100 (0.090)	-0.091 (0.137)	0.720 (0.048)	-0.056 (0.010)	-0.114 (0.110)	0.011 (0.004)	-0.079 (0.016)	0.074 (0.065)	0.880
Q sold wheat	0.014 (0.002)	0.007 (0.0019)	0.031 (0.025)	-0.005 (0.0016)	0.768 (0.021)	-0.017 (0.002)	0.010 (0.012)	-0.003 (0.0023)	0.005 (0.0014)	0.990
Q sold wh corn	-0.021 (0.024)	-0.000 (0.039)	0.013 (0.059)	0.035 (0.033)	-0.004 (0.004)	0.762 (0.045)	0.044 (0.025)	-0.085 (0.065)	0.008 (0.028)	0.956

[a] Numbers in parentheses are standard errors.

Table IV-6: Estimated supply coefficients.
DOMAIN 3 (143 Obs)

	Price banana	Price manioc	Price rice	Price yell corn	Expend	R ** 2
Q sold banana	1.113 (0.041)a	0.058 (0.040)	0.039 (0.038)	-0.077 (0.041)	0.004 (0.025)	0.953
Q sold manioc	-0.063 (0.062)	1.044 (0.062)	-0.000 (0.5911)	0.051 (0.630)	0.014 (0.039)	0.888
Q sold rice	-0.049 (0.068)	0.025 (0.067)	1.093 (0.065)	-0.098 (0.069)	0.093 (0.043)	0.899
Q sold yell corn	0.127 (0.051)	0.075 (0.050)	0.037 (0.047)	1.073 (0.051)	0.068 (0.032)	0.938

	Price banana	Price manioc	Price rice	Price yell corn	Wage rate	R ** 2
Q sold banana	1.130 (0.039)	0.035 (0.040)	0.029 (0.036)	-0.106 (0.038)	-0.165 (0.079)	0.958
Q sold manioc	-0.091 (0.069)	1.077 (0.062)	0.013 (0.056)	0.104 (0.060)	-0.236 (0.122)	0.897
Q sold rice	-0.060 (0.074)	0.018 (0.075)	1.115 (0.068)	-0.045 (0.073)	-0.032 (0.149)	0.887
Q sold yell corn	0.119 (0.054)	0.069 (0.055)	0.054 (0.050)	1.109 (0.053)	-0.030 (0.109)	0.930

	Price banana	Price manioc	Price rice	Price yell corn	Expend	Wage rate	Cultivate land	R ** 2
Q sold banana	1.134 (0.041)	0.033 (0.041)	0.040 (0.038)	-0.098 (0.041)	0.014 (0.026)	-0.184 (0.085)	0.022 (0.036)	0.958
Q sold manioc	-0.089 (0.063)	1.084 (0.063)	0.004 (0.059)	0.086 (0.063)	0.043 (0.040)	-0.282 (0.131)	0.001 (0.056)	0.900
Q sold rice	-0.035 (0.070)	0.036 (0.071)	1.123 (0.067)	-0.082 (0.071)	0.102 (0.045)	-0.065 (0.147)	0.102 (0.063)	0.906
Q sold yell corn	0.099 (0.049)	0.081 (0.049)	0.053 (0.041)	1.071 (0.050)	0.072 (0.031)	-0.059 (0.1038)	0.115 (0.044)	0.947

[a] Numbers in parentheses are standard errors.

Table IV-7: Estimated supply coefficients.
DOMAIN 4 (143 Obs)

	Price banana	Price manioc	Price rice	Price yell corn	Expend	Wage rate	R ** 2
Q sold banana	1.217 (0.030)a	-0.068 (0.033)	0.011 (0.030)	0.023 (0.020)	0.042 (0.016)		0.980
Q sold manioc	-0.058 (0.035)	1.115 (0.038)	-0.063 (0.039)	0.054 (0.034)	0.028 (0.019)		0.753
Q sold rice	0.001 (0.042)	0.004 (0.0047)	1.013 (0.048)	0.016 (0.024)	0.072 (0.023)		0.984
Q sold yell corn	-0.024 (0.038)	0.010 (0.0099)	-0.038 (0.048)	1.030 (0.038)	0.070 (0.021)		0.799
Q sold banana	1.224 (0.031)	-0.062 (0.034)	0.028 (0.034)	0.027 (0.031)		-0.040 (0.015)	0.939
Q sold manioc	-0.056 (0.035)	1.114 (0.039)	-0.047 (0.037)	0.051 (0.035)		-0.065 (0.060)	0.892
Q sold rice	0.015 (0.044)	0.020 (0.049)	1.038 (0.050)	0.029 (0.004)		-0.019 (0.007)	0.809
Q sold yell corn	-0.012 (0.039)	0.020 (0.004)	-0.009 (0.004)	1.036 (0.040)		0.870 (0.060)	0.870

	Price banana	Price manioc	Price rice	Price yell corn	Expend	Wage rate	Cultivate land	R ** 2
Q sold banana	1.215 (0.029)	-0.079 (0.032)	0.009 (0.033)	0.008 (0.030)	0.027 (0.010)	-0.058 (0.049)	0.071 (0.025)	0.947
Q sold manioc	-0.062 (0.035)	1.102 (0.032)	-0.059 (0.039)	0.038 (0.035)	0.017 (0.020)	-0.082 (0.052)	0.051 (0.030)	0.897
Q sold rice	-0.000 (0.043)	0.001 (0.048)	1.014 (0.049)	0.013 (0.004)	0.069 (0.023)	-0.017 (0.073)	0.015 (0.037)	0.825
Q sold yell corn	-0.027 (0.038)	-0.002 (0.042)	-0.035 (0.031)	1.014 (0.031)	0.058 (0.039)	-0.077 (0.022)	0.056 (0.032)	0.886

[a] Numbers in parentheses are standard errors.

Table IV-8: Estimated supply coefficients.
DOMAIN 5 (124 Obs)

	Price banana	Price rice	Price wh corn	Price yell corn	Expend	R ** 2
Q sold banana	1.167 (0.230)a	-0.104 (0.030)	0.017 (0.009)	0.002 (0.051)	0.412 (0.400)	0.980
Q sold rice	-0.475 (0.281)	1.230 (0.201)	0.023 (0.011)	-0.360 (0.06)	0.028 (0.012)	0.756
Q sold wh corn	0.006 (0.074)	-0.015 (0.031)	0.837 (0.055)	-0.211 (0.170)	0.008 (0.0033)	0.985
Q sold yell corn	0.555 (0.607)	0.043 (0.091)	-0.206 (0.050)	-0.053 (0.034)	0.046 (0.0165)	0.790

	Price banana	Price rice	Price wh corn	Price yell corn	Wage rate	R ** 2
Q sold banana	1.167 (0.300)	-0.106 (0.030)	-0.014 (0.040)	-0.013 (0.010)	-0.432 (0.280)	0.980
Q sold rice	-0.429 (0.240)	1.250 (0.208)	0.055 (0.050)	-0.226 (0.075)	-0.169 (0.083)	0.756
Q sold wh corn	0.009 (0.063)	-0.018 (0.054)	0.829 (0.032)	-0.297 (0.091)	-0.077 (0.049)	0.985
Q sold yell corn	0.607 (0.110)	0.049 (0.094)	-0.196 (0.050)	-0.124 (0.034)	-0.016 (0.0165)	0.790

	Price banana	Price rice	Price wh corn	Price yell corn	Expend	Wage rate	Cultivate land	R ** 2
Q sold banana	1.167 (0.280)	0.007 (0.030)	0.009 (0.040)	0.009 (0.020)	0.176 (0.100)	-0.416 (0.200)	0.198 (0.198)	0.980
Q sold rice	-0.468 (0.079)	1.230 (0.057)	0.078 (0.037)	-0.239 (0.200)	0.002 (0.036)	-0.174 (0.100)	0.119 (0.041)	0.766
Q sold wh corn	-0.007 (0.079)	-0.019 (0.057)	0.814 (0.037)	-0.287 (0.200)	0.023 (0.003)	-0.098 (0.010)	-0.034 (0.014)	0.986
Q sold yell corn	0.512 (0.120)	0.022 (0.057)	-0.187 (0.086)	-0.126 (0.300)	0.041 (0.005)	-0.052 (0.034)	0.130 (0.062)	0.855

[a] Numbers in parentheses are standard errors.

Table IV-9: Estimated supply coefficients.
DOMAIN 7 (68 Obs)

	Price cotton se	Price manioc	Price sw potato	Price yell corn	Expend	R ** 2
Q sold cotton se	0.974 (0.070)a	0.049 (0.018)	-0.013 (0.010)	-0.206 (0.150)	0.029 (0.006)	0.902
Q sold manioc	0.036 (0.130)	0.903 (0.136)	-0.131 (0.105)	-0.454 (0.257)	0.013 (0.011)	0.689
Q sold sw potato	-0.204 (0.141)	0.412 (0.150)	1.220 (0.201)	-0.121 (0.290)	0.101 (0.120)	0.698
Q sold yell corn	0.140 (0.092)	-0.037 (0.096)	0.116 (0.102)	1.050 (0.181)	0.139 (0.079)	0.588

	Price cotton se	Price manioc	Price sw potato	Price yell corn	Wage rate	R ** 2
Q sold cotton se	0.952 (0.063)	0.058 (0.007)	-0.008 (0.007)	-0.223 (0.149)	-0.063 (0.010)	0.903
Q sold manioc	0.030 (0.100)	0.910 (0.130)	-0.109 (0.016)	-0.460 (0.240)	-0.053 (0.018)	0.690
Q sold sw potato	-0.272 (0.123)	-0.374 (0.150)	1.297 (0.180)	-0.176 (0.280)	-0.220 (0.120)	0.691
Q sold yell corn	0.041 (0.079)	0.012 (0.006)	0.194 (0.102)	0.968 (0.185)	-0.076 (0.013)	0.544

	Price cotton se	Price manioc	Price sw potato	Price yell corn	Expend	Wage rate	Cultivate land	R ** 2
Q sold cotton se	0.932 (0.083)	-0.020 (0.030)	-0.066 (0.107)	-0.176 (0.130)	0.113 (0.101)	-0.012 (0.009)	0.374 (0.126)	0.913
Q sold manioc	0.042 (0.139)	0.762 (0.156)	-0.212 (0.170)	-0.376 (0.250)	0.199 (0.020)	-0.146 (0.130)	0.624 (0.360)	0.725
Q sold sw potato	-0.082 (0.143)	-0.175 (0.150)	1.381 (0.180)	-0.210 (0.206)	0.166 (0.103)	-0.001 (0.020)	1.135 (0.370)	0.785
Q sold yell corn	0.178 (0.100)	0.040 (0.040)	0.167 (0.167)	1.013 (0.180)	0.051 (0.010)	-0.007 (0.014)	0.368 (0.260)	0.621

[a] Numbers in parentheses are standard errors.

Table IV-10: Estimated supply coefficients.
DOMAIN 9 (70 Obs)

	Price onions	Price potato	Price rice	Price sw potato	Price wh corn	Price yell corn	Expend	R ** 2
Q sold onions	1.207 (0.097)a	-0.191 (0.100)	-1.085 (0.930)	0.071 (0.031)	-0.027 (0.072)	-0.084 (0.079)	0.152 (0.066)	0.844
Q sold potato	-0.088 (0.082)	1.367 (0.085)	-1.297 (0.790)	-0.020 (0.068)	-0.034 (0.016)	0.236 (0.083)	0.148 (0.059)	0.891
Q sold rice	0.012 (0.007)	-0.148 (0.080)	0.398 (0.760)	0.028 (0.077)	-0.000 (0.0047)	0.014 (0.005)	0.007 (0.005)	0.134
Q sold sw potato	0.076 (0.070)	-0.140 (0.080)	-0.945 (0.760)	1.040 (0.066)	-0.081 (0.010)	0.040 (0.080)	0.106 (0.054)	0.894
Q sold wh corn	-0.019 (0.050)	0.003 (0.099)	0.475 (0.045)	0.017 (0.047)	1.019 (0.042)	0.013 (0.057)	0.057 (0.039)	0.949
Q sold yell corn	-0.029 (0.007)	-0.225 (0.070)	-0.730 (0.670)	0.056 (0.050)	0.017 (0.052)	0.992 (0.070)	0.068 (0.040)	0.887

	Price onions	Price potato	Price rice	Price sw potato	Price wh corn	Price yell corn	Wage rate	R ** 2
Q sold onions	1.228 (0.101)	-0.194 (0.101)	-0.769 (0.099)	0.044 (0.089)	-0.050 (0.080)	-0.088 (0.010)	-0.158 (0.101)	0.828
Q sold potato	-0.070 (0.089)	1.357 (0.094)	-1.079 (0.080)	-0.034 (0.017)	-0.046 (0.070)	0.223 (0.091)	-0.860 (0.0105)	0.870
Q sold rice	0.008 (0.072)	-0.158 (0.075)	0.259 (0.076)	0.052 (0.063)	0.027 (0.059)	0.003 (0.0073)	-0.101 (0.080)	0.170
Q sold sw potato	0.092 (0.081)	-0.138 (0.084)	-0.675 (0.078)	1.012 (0.071)	-0.110 (0.060)	0.041 (0.029)	-0.147 (0.094)	0.8[illegible]0

Q sold wh corn	-0.013 (0.058)	-0.003 (0.006)	0.537 (0.350)	0.016 (0.015)	1.018 (0.048)	0.006 (0.0059)		0.017 (0.018)		0.946
Q sold yell corn	-0.018 (0.007)	-0.221 (0.07)	-0.527 (0.068)	0.034 (0.061)	-0.010 (0.061)	0.995 (0.071)		-0.116 (0.08)		0.887

	Price onions	Price potato	Price rice	Price sw potato	Price wh corn	Price yell corn	Expend	Wage rate	Cultivate land	R ** 2
Q sold onions	1.173 (0.095)	-0.199 (0.090)	-1.098 (0.240)	0.091 (0.083)	0.005 (0.0079)	-0.064 (0.540)	0.243 (0.090)	-0.085 (0.144)	0.421 (0.195)	0.865
Q sold potato	-0.068 (0.070)	1.366 (0.081)	-1.486 (0.770)	-0.013 (0.017)	-0.029 (0.006)	0.211 (0.079)	0.119 (0.063)	-0.056 (0.076)	0.346 (0.160)	0.908
Q sold rice	0.017 (0.0137)	-0.154 (0.075)	0.156 (0.710)	0.053 (0.046)	0.024 (0.071)	-0.006 (0.0061)	0.008 (0.007)	-0.117 (0.011)	0.192 (0.151)	0.061
Q sold sw potato	0.085 (0.083)	-0.136 (0.085)	-0.858 (0.800)	1.026 (0.073)	-0.099 (0.073)	0.041 (0.083)	0.073 (0.030)	-0.066 (0.123)	0.061 (0.170)	0.896
Q sold wh corn	-0.026 (0.059)	-0.002 (0.0061)	0.360 (0.571)	0.033 (0.005)	1.038 (0.049)	0.010 (0.005)	0.088 (0.057)	-0.077 (0.009)	0.025 (0.012)	0.214
Q sold yell corn	-0.007 (0.007)	-0.217 (0.072)	-0.617 (0.069)	0.032 (0.006)	-0.016 (0.059)	0.986 (0.071)	0.003 (0.068)	-0.110 (0.100)	0.214 (0.140)	0.896

[a] Numbers in parentheses are standard errors.

Table IV-11: Estimated supply coefficients.
DOMAIN 11 (138 Obs)

	Price barley	Price oca	Price potato	Price yell corn	Price wh corn	Expend	R ** 2
Q sold barley	0.333 (0.240)a	-0.123 (0.110)	0.016 (0.023)	0.027 (0.045)	0.036 (0.025)	0.013 (0.022)	0.980
Q sold oca	-0.100 (0.085)	0.666 (0.263)	0.049 (0.018)	-0.064 (0.130)	-0.029 (0.015)	0.217 (0.098)	0.980
Q sold potato	-0.041 (0.154)	-0.076 (0.011)	0.847 (0.078)	-0.090 (0.091)	-0.123 (0.091)	0.083 (0.057)	0.983
Q sold yell corn	-0.005 (0.068)	0.019 (0.049)	-0.037 (0.035)	1.069 (0.041)	0.007 (0.004)	0.005 (0.025)	0.925
Q sold wh corn	0.004 (0.064)	-0.036 (0.046)	0.038 (0.030)	-0.010 (0.008)	0.884 (0.038)	0.020 (0.020)	0.974

	Price barley	Price oca	Price potato	Price yell corn	Price wh corn	Wage rate	R ** 2
Q sold barley	0.333 (0.017)	0.231 (0.16)	0.034 (0.056)	0.022 (0.011)	0.042 (0.078)	-0.062 (0.031)	0.980
Q sold oca	0.036 (0.038)	0.666 (0.230)	0.035 (0.017	0.063 (0.027)	-0.088 (0.231)	-0.133 (0.313)	0.980
Q sold potato	-0.031 (0.160)	-0.146 (0.100)	0.894 (0.076)	-0.067 (0.095)	-0.113 (0.100)	-0.057 (0.013)	0.916
Q sold yell corn	-0.006 (0.068)	0.023 (0.044)	-0.041 (0.030)	1.067 (0.040)	0.006 (0.004)	-0.001 (0.005)	0.983

Q sold wh. corn	0.002 (0.065)	-0.018 (0.024)	0.026 (0.013)	-0.017 (0.033)	0.879 (0.041)		-0.004 (0.005)		0.973

	Price barley	Price oca	Price potato	Price yell corn	Price wh corn	Expend	Wage rate	Cultivate land	R ** 2
Q sold barley	0.333 (0.038)	0.049 (0.035)	0.031 (0.041)	0.063 (0.034)	0.010 (0.021)	0.015 (0.014)	-0.129 (0.100)	0.056 (0.048)	0.980
Q sold oca	-0.099 (0.028)	0.660 (0.024)	-0.005 (0.04)	-0.002 (0.015)	0.018 (0.017)	0.057 (0.028)	-0.014 (0.012)	0.270 (0.012)	0.980
Q sold potato	-0.030 (0.016)	-0.065 (0.014)	0.839 (0.090)	-0.088 (0.021)	-0.011 (0.160)	0.087 (0.068)	-0.022 (0.075)	0.011 (0.028)	0.925
Q sold yell corn	-0.020 (0.064)	-0.047 (0.055)	-0.014 (0.0024)	1.012 (0.047)	-0.009 (0.006)	0.002 (0.002)	-0.042 (0.027)	0.061 (0.029)	0.987
Q sold wh corn	0.013 (0.066)	-0.002 (0.005)	0.028 (0.036)	0.023 (0.049)	0.889 (0.042)	0.047 (0.066)	-0.027 (0.030)	0.033 (0.026)	0.97[illegible]

[a] Numbers in parentheses are standard errors.

Table IV-12: Estimated supply coefficients.
DOMAIN 13 (242 Obs)

	Price barley	Price dried pe	Price lima bean	Price potato	Price wheat	Price wh corn	Expend	R ** 2
Q sold barley	0.857 (0.340)a	0.038 (0.0317)	0.038 (0.088)	0.098 (0.025)	0.155 (0.005)	-0.004 (0.003)	0.056 (0.002)	0.980
Q sold dried pe	0.033 (0.085)	0.463 (0.033)	0.064 (0.040)	-0.118 (0.041)	-0.016 (0.038)	0.004 (0.003)	0.047 (0.023)	0.902
Q sold lima bean	0.024 (0.054)	0.020 (0.023)	0.669 (0.027)	-0.010 (0.003)	-0.018 (0.020)	0.052 (0.023)	0.007 (0.016)	0.970
Q sold potato	0.078 (0.095)	0.024 (0.003)	-0.004 (0.004)	0.856 (0.046)	-0.079 (0.042)	-0.036 (0.038)	0.016 (0.024)	0.953
Q sold wheat	0.134 (0.055)	0.029 (0.021)	0.057 (0.026)	-0.016 (0.025)	0.715 (0.026)	-0.053 (0.022)	0.009 (0.015)	0.978
Q sold wh corn	0.012 (0.069)	0.031 (0.027)	0.029 (0.032)	-0.032 (0.033)	0.012 (0.030)	0.956 (0.002)	0.022 (0.019)	0.980

	Price barley	Price lima bean	Price oca	Price potato	Price wheat	Price wh corn	Wage rate	R ** 2
Q sold barley	0.857 (0.026)	0.088 (0.014)	0.000 (0.018)	-0.007 (0.012)	0.000 (0.000)	0.009 (0.0107)	-0.007 (0.0107)	0.980
Q sold dried pe	0.022 (0.089)	0.478 (0.034)	0.034 (0.029)	-0.081 (0.037)	-0.027 (0.035)	0.002 (0.035)	-0.054 (0.051)	0.892
Q sold lima bean	0.037 (0.056)	0.017 (0.022)	0.671 (0.025)	-0.019 (0.023)	-0.017 (0.012)	0.055 (0.022)	-0.051 (0.032)	0.972
Q sold potato	0.080 (0.095)	0.026 (0.037)	-0.015 (0.014)	0.864 (0.040)	-0.083 (0.042)	-0.036 (0.038)	-0.039 (0.055)	0.954

Q sold wheat	0.133 (0.055)	0.028 (0.021)	0.064 (0.024)	-0.022 (0.023)	0.717 (0.024)	-0.053 (0.024)		-0.023 (0.022)		0.978
Q sold wh corn	0.008 (0.069)	0.034 (0.027)	0.014 (0.030)	-0.016 (0.029)	0.006 (0.009)	0.955 (0.028)		-0.034 (0.028)		0.980

	Price barley	Price lima bean	Price oca	Price potato	Price wheat	Price wh corn	Expend	Wage rate	Cultivate land	R ** 2
Q sold barley	0.857 (0.016)	-0.002 (0.028)	0.019 (0.010)	-0.013 (0.013)	-0.026 (0.012)	0.046 (0.011)	0.018 (0.071)	-0.013 (0.085)	0.033 (0.010)	0.980
Q sold dried pe	0.033 (0.088)	0.465 (0.034)	0.060 (0.042)	-0.111 (0.043)	-0.016 (0.038)	0.004 (0.035)	0.040 (0.025)	-0.022 (0.026)	0.016 (0.003)	0.904
Q sold lima bean	0.034 (0.057)	0.018 (0.022)	0.660 (0.027)	-0.009 (0.008)	-0.022 (0.025)	0.055 (0.023)	0.015 (0.006)	-0.065 (0.021)	0.016 (0.017)	0.974
Q sold potato	0.080 (0.099)	0.026 (0.039)	-0.007 (0.047)	0.863 (0.048)	-0.078 (0.044)	-0.036 (0.039)	-0.029 (0.006)	-0.009 (0.003)	0.015 (0.037)	0.954
Q sold wheat	0.129 (0.058)	0.030 (0.022)	0.060 (0.027)	-0.016 (0.028)	0.717 (0.027)	-0.054 (0.023)	0.007 (0.035)	-0.019 (0.017)	0.006 (0.021)	0.978
Q sold wh corn	0.026 (0.066)	0.023 (0.026)	0.023 (0.031)	-0.045 (0.032)	0.003 (0.029)	0.961 (0.040)	0.027 (0.019)	-0.028 (0.024)	0.054 (0.026)	0.984

[a] Numbers in parentheses are standard errors.

Table IV-13: Estimated supply coefficients.
DOMAIN 15 (304 Obs)

	Price barley	Price lima bean	Price oca	Price potato	Price wheat	Price wh corn	Expend	R ** 2
Q sold barley	0.681 (0.340)a	0.006 (0.0317)	0.049 (0.088)	0.053 (0.025)	0.022 (0.005)	-0.001 (0.003)	0.008 (0.002)	0.941
Q sold lima bean	0.017 (0.110)	0.428 (0.230)	0.199 (0.080)	-0.270 (0.090)	0.351 (0.078)	0.145 (0.005)	0.505 (0.078)	0.980
Q sold oca	0.004 (0.016)	0.006 (0.046)	0.610 (0.027)	0.004 (0.003)	0.031 (0.020)	0.000 (0.064)	0.000 (0.011)	0.942
Q sold potato	-0.009 (0.023)	-0.006 (0.006)	0.006 (0.003)	0.881 (0.039)	-0.003 (0.030)	-0.001 (0.029)	0.011 (0.002)	0.933
Q sold wheat	0.041 (0.023)	0.013 (0.004)	-0.056 (0.038)	-0.019 (0.030)	0.644 (0.089)	0.003 (0.028)	0.023 (0.016)	0.943
Q sold wh corn	-0.237 (0.056)	0.029 (0.014)	0.360 (0.038)	-0.029 (0.083)	0.093 (0.036)	0.571 (0.009)	0.043 (0.036)	0.980

	Price barley	Price lima bean	Price oca	Price potato	Price wheat	Price wh corn	Wage rate	R ** 2
Q sold barley	0.679 (0.030)	0.010 (0.089)	0.048 (0.052)	0.045 (0.045)	0.030 (0.040)	0.030 (0.012)	-0.019 (0.079)	0.941
Q sold lima bean	-0.071 (0.031)	0.426 (0.098)	0.075 (C.054)	0.027 (0.054)	-0.072 (0.043)	0.029 (0.012)	-0.144 (0.067)	0.980
Q sold oca	0.007 (0.016)	0.013 (0.006)	0.060 (0.028)	-0.009 (0.008)	0.038 (0.021)	0.040 (0.021)	-0.047 (0.041)	0.443
Q sold potato	-0.008 (0.022)	0.008 (0.006)	-0.000 (0.038)	0.854 (0.039)	0.018 (0.019)	-0.078 (0.008)	-0.087 (0.058)	0.938

Q sold wheat	0.048 (0.023)	0.009 (0.065)	-0.055 (0.039)	-0.011 (0.039)	0.632 (0.040)	0.026 (0.030)		-0.007 (0.005)		0.940
Q sold wh corn	-0.021 (0.047)	0.024 (0.0138)	0.060 (0.081)	0.027 (0.084)	-0.024 (0.006)	0.571 (0.019)		-0.080 (0.012)		0.980

	Price barley	Price lima bean	Price oca	Price potato	Price wheat	Price wh corn	Expend	Wage rate	Cultivate land	R ** 2
Q sold barley	0.678 (0.032)	0.013 (0.009)	0.036 (0.054)	0.043 (0.035)	0.022 (0.041)	-0.009 (0.012)	0.011 (0.002)	-0.037 (0.028)	0.027 (0.022)	0.943
Q sold lima bean	-0.027 (0.021)	0.428 (0.098)	0.069 (0.043)	0.098 (0.009)	-0.013 (0.010)	0.029 (0.009)	0.020 (0.009)	-0.044 (0.032)	0.320 (0.120)	0.980
Q sold oca	0.006 (0.017)	0.014 (0.007)	0.596 (0.028)	-0.010 (0.028)	0.034 (0.021)	0.052 (0.046)	0.011 (0.001)	-0.019 (0.012)	0.011 (0.013)	0.945
Q sold potato	0.005 (0.022)	0.002 (0.061)	0.017 (0.037)	0.860 (0.028)	0.017 (0.048)	0.011 (0.005)	0.084 (0.056)	-0.013 (0.015)	0.043 (0.017)	0.948
Q sold wheat	0.046 (0.022)	0.005 (0.061)	-0.036 (0.037)	-0.009 (0.007)	0.646 (0.028)	0.016 (0.065)	0.026 (0.006)	-0.035 (0.016)	0.043 (0.017)	0.951
Q sold wh corn	-0.094 (0.024)	-0.095 (0.071)	0.020 (0.023)	0.361 (0.034)	-0.089 (0 010)	0.571 (0.087)	0.142 (0.056)	-0.037 (0.032)	0.168 (0.087)	0.980

[a] Numbers in parentheses are standard errors.

Table IV-14: Estimated supply coefficients.
DOMAIN 17 (137 Obs)

	Price banana	Price manioc	Price rice	Price sugar cane	Price yell corn	Expend	R ** 2
Q sold banana	0.967 (0.068)a	0.022 (0.135)	-0.069 (0.102)	-0.126 (0.135)	0.023 (0.017)	0.075 (0.045)	0.940
Q sold manioc	0.014 (0.006)	1.143 (0.012)	0.005 (0.0093)	-0.099 (0.012)	0.005 (0.005)	0.005 (0.004)	0.999
Q sold rice	-0.109 (0.091)	-0.163 (0.180)	1.167 (0.106)	0.194 (0.180)	-0.039 (0.076)	0.071 (0.050)	0.874
Q sold sugar	0.115 (0.051)	-0.199 (0.102)	0.041 (0.070)	1.510 (0.102)	0.044 (0.040)	0.030 (0.034)	0.937
Q sold yell corn	0.157 (0.087)	0.075 (0.174)	-0.109 (0.132)	-0.089 (0.174)	0.989 (0.074)	0.003 (0.058)	0.934

	Price banana	Price manioc	Price rice	Price sugar cane	Price yell corn	Wage rate	R ** 2
Q sold banana	0.986 (0.069)	0.104 (0.127)	0.035 (0.037)	-0.121 (0.087)	0.044 (0.058)	-0.083 (0.080)	0.935
Q sold manioc	0.011 (0.0058)	1.135 (0.011)	0.001 (0.0007)	-0.106 (0.012)	0.001 (0.0004)	-0.011 (0.007)	0.999
Q sold rice	-0.092 (0.090)	-0.087 (0.166)	1.266 (0.113)	0.197 (0.176)	-0.020 (0.075)	-0.082 (0.111)	0.869
Q sold sugar	0.092 (0.048)	-0.265 (0.089)	0.009 (0.061)	1.450 (0.100)	0.007 (0.040)	-0.094 (0.050)	0.942

Q sold yell corn	0.179 (0.079)	0.123 (0.140)	-0.118 (0.100)	-0.015 (0.164)	1.029 (0.066)		-0.173 (0.097)		0.943

	Price banana	Price manioc	Price rice	Price sugar can	Price yell corn	Expend	Wage rate	Cultivate land	R ** 2
Q sold banana	0.966 (0.071)	0.020 (0.144)	-0.057 (0.112)	-0.137 (0.104)	0.017 (0.062)	0.068 (0.053)	-0.042 (0.090)	0.004 (0.005)	0.941
Q sold manioc	0.013 (0.005)	1.143 (0.011)	0.010 (0.009)	-0.105 (0.012)	0.004 (0.005)	0.007 (0.0044)	-0.015 (0.007)	0.001 (0.005)	0.990
Q sold rice	-0.105 (0.093)	-0.191 (0.180)	1.161 (0.147)	0.222 (0.194)	-0.054 (0.081)	0.085 (0.070)	-0.049 (0.110)	0.068 (0.076)	0.880
Q sold sugar	0.107 (0.049)	-0.196 (0.099)	0.084 (0.077)	1.458 (0.103)	0.028 (0.042)	0.056 (0.037)	-0.124 (0.064)	0.011 (0.040)	0.949
Q sold yell corn	0.165 (0.085)	0.088 (0.171)	-0.162 (0.133)	-0.040 (0.018)	1.019 (0.074)	0.028 (0.068)	-0.198 (0.107)	0.029 (0.068)	0.945

[a] Numbers in parentheses are standard errors.

Table IV-15: Estimated supply coefficients.
DOMAIN 19 (127 Obs)

	Price banana	Price manioc	Price orange	Price yell corn	Expend	R ** 2
Q sold banana	1.115 (0.051)a	-0.112 (0.054)	-0.510 (0.24)	-0.046 (0.044)	0.013 (0.026)	0.966
Q sold manioc	-0.103 (0.085)	0.797 (0.092)	-0.390 (0.230)	0.009 (0.070)	0.070 (0.040)	0.848
Q sold orange	0.105 (0.080)	-0.165 (0.095)	0.788 (0.431)	0.023 (0.007)	0.009 (0.050)	0.355
Q sold yell corn	0.014 (0.070)	-0.120 (0.070)	-0.051 (0.340)	0.890 (0.060)	0.056 (0.036)	0.916

	Price banana	Price manioc	Price orange	Price yell corn	Wage rate	R ** 2
Q sold banana	1.109 (0.047)	-0.188 (0.054)	-0.510 (0.250)	-0.046 (0.040)	-0.031 (0.070)	0.966
Q sold manioc	-0.042 (0.080)	0.820 (0.095)	-0.480 (0.400)	0.004 (0.007)	-0.056 (0.013)	0.831
Q sold orange	0.101 (0.080)	-0.169 (0.090)	0.790 (0.430)	0.022 (0.007)	-0.023 (0.012)	0.355
Q sold yell corn	0.072 (0.060)	-0.106 (0.075)	-0.160 (0.150)	0.890 (0.060)	-0.121 (0.100)	0.913

	Price banana	Price manioc	Price orange	Price yell corn	Expend	Wage rate	Cultivate land	R ** 2
Q sold banana	1.128 (0.054)	-0.131 (0.060)	-0.498 (0.250)	-0.056 (0.046)	0.007 (0.094)	-0.056 (0.030)	0.046 (0.052)	0.967
Q sold manioc	-0.084 (0.087)	0.750 (0.096)	-0.440 (0.400)	-0.015 (0.070)	0.106 (0.150)	-0.243 (0.049)	0.074 (0.080)	0.866
Q sold orange	0.106 (0.096)	-0.169 (0.106)	0.784 (0.450)	0.021 (0.080)	0.066 (0.160)	-0.019 (0.055)	0.006 (0.090)	0.355
Q sold yell corn	0.025 (0.060)	-0.163 (0.070)	-0.133 (0.080)	0.880 (0.050)	0.099 (0.081)	-0.287 (0.037)	0.047 (0.060)	0.936

[a] Numbers in parentheses are standard errors.

Table IV-16: Estimated supply coefficients.
DOMAIN 21 (144 Obs)

	Price banana	Price manioc	Price lima bean	Price orange	Price potato	Price wh corn	Price yell corn	Expend	R ** 2
Q sold banana	1.012 (0.087)a	-0.220 (0.097)	-0.151 (0.160)	-0.168 (0.126)	-0.150 (0.084)	0.124 (0.077)	-0.073 (0.142)	0.080 (0.039)	0.917
Q sold manioc	0.084 (0.034)	1.014 (0.038)	-0.049 (0.036)	0.007 (0.049)	-0.041 (0.033)	-0.054 (0.030)	0.066 (0.050)	0.020 (0.015)	0.975
Q sold lima bean	-0.009 (0.007)	0.001 (0.007)	0.660 (0.010)	-0.007 (0.001)	0.002 (0.0068)	0.003 (0.006)	0.002 (0.0011)	0.009 (0.003)	0.986
Q sold orange	0.328 (0.079)	-0.046 (0.0089)	-0.166 (0.104)	1.215 (0.077)	0.010 (0.015)	-0.071 (0.013)	-0.106 (0.070)	0.253 (0.023)	0.871
Q sold potato	-0.069 (0.073)	-0.066 (0.028)	-0.411 (0.131)	0.045 (0.017)	0.982 (0.120)	-0.099 (0.065)	0.270 (0.120)	0.021 (0.030)	0.919
Q sold wh corn	0.001 (0.054)	-0.078 (0.060)	0.011 (0.011)	-0.023 (0.023)	0.107 (0.090)	0.796 (0.051)	-0.034 (0.0086)	0.038 (0.027)	0.934
Q sold yell corn	0.001 (0.010)	0.020 (0.010)	0.111 (0.019)	-0.030 (0.015)	-0.012 (0.010)	0.009 (0.009)	0.878 (0.017)	0.003 (0.004)	0.997

	Price banana	Price manioc	Price lima bean	Price oranges	Price potato	Price wh corn	Price yell corn	Wage rate	R ** 2
Q sold banana	1.083 (.086)	-0.220 (0.100)	-0.211 (0.170)	-0.131 (0.140)	0.014 (0.091)	0.086 (0.080)	0.032 (0.015)	-0.023 (0.0121)	0.902
Q sold manioc	0.066 (0.031)	1.010 (0.039)	-0.044 (0.065)	0.014 (0.0053)	-0.044 (0.033)	-0.040 (0.020)	0.053 (0.035)	-0.033 (0.004)	0.974

	Price banana	Price manioc	Price lima bean	Price orange	Price potato	Price wh corn	Price yell corn	Expend	Wage rate	Cultivate land	R ** 2
Q sold lima bean	-0.009	0.005	0.661	-0.000	0.002	0.003	0.003		-0.001		0.871
	(0.006)	(0.0007)	(0.013)	(0.0010)	(0.006)	(0.006)	(0.001)		(0.004)		
Q sold orange	0.054	-0.038	-0.166	1.194	0.010	-0.091	-0.097		-0.070		0.918
	(0.073)	(0.089)	(0.140)	(0.122)	(0.007)	(0.063)	(0.0126)		(0.0101)		
Q sold potato	-0.051	-0.070	-0.440	0.069	0.990	-0.107	0.308		-0.041		0.931
	(0.055)	(0.068)	(0.100)	(0.011	(0.070)	(0.063)	(0.110)		(0.094)		
Q sold wh corn	-0.032	-0.087	0.018	-0.004	0.104	0.823	-0.055		-0.076		0.997
	(0.055)	(0.068)	(0.011)	(0.009)	(0.058)	(0.052)	(0.096)		(0.070)		
Q sold yell corn	-0.002	0.019	0.110	-0.021	-0.012	-0.011	0.878		-0.012		
	(0.0094)	(0.011)	(0.019)	(0.015)	(0.009)	(0.008)	(0.016)		(0.013)		

	Price banana	Price manioc	Price lima bean	Price orange	Price potato	Price wh corn	Price yell corn	Expend	Wage rate	Cultivate land	R ** 2
Q sold banana	0.996	-0.241	-0.199	-0.094	-0.028	0.137	-0.038	0.095	-0.083	0.051	0.921
	(0.090)	(0102)	(0.170)	(0.014)	(0.094)	(0.080)	(0.149)	(0.043)	(0.017)	(0.071)	
Q sold manioc	0.094	1.027	-0.015	-0.033	-0.008	-0.051	0.051	0.026	-0.022	0.061	0.981
	(0.031)	(0.035)	(0.060)	(0.052)	(0.003)	(0.028)	(0.050)	(0.015)	(0.041)	(0.024)	
Q sold lima bean	-0.010	0.001	0.662	-0.002	0.002	0.003	0.002	0.001	-0.001	0.000	0.990
	(0.007)	(0.0008)	(0.014)	(0.0012)	(0.007)	(0.006)	(0.001)	(0.0036)	(0.009)	(0.0058)	
Q sold orange	0.043	-0.032	-0.135	1.167	0.024	-0.079	-0.128	0.015	-0.055	0.032	0.874
	(0.084)	(0.049)	(0.016)	(0.109)	(0.087)	(0.074)	(0.100)	(0.019)	(0.040)	(0.065)	
Q sold potato	-0.053	-0.046	-0.357	-0.014	1.039	-0.092	0.248	0.011	-0.062	0.102	0.931
	(0.027)	(0.081)	(0.136)	(0.011)	(0.075)	(0.062)	(0.118)	(0.034)	(0.093)	(0.056)	
Q sold wh corn	-0.010	-0.092	-0.020	0.024	0.093	0.804	-0.011	0.029	-0.053	0.033	0.937
	(0.0062)	(0.070)	(0.012)	(0.0101)	(0.064)	(0.055)	(0.102)	(0.020)	(0.080)	(0.038)	
Q sold yell corn	-0.001	0.019	0.108	-0.021	-0.012	0.012	0.881	0.002	-0.011	0.001	0.997
	(0.010)	(0.012)	(0.020)	(0.017)	(0.011)	(0.0097)	(0.018)	(0.005)	(0.014)	(0.0058)	

[a] Numbers in parentheses are standard errors.

Table IV-17: Estimated supply coefficients.
DOMAIN 23 (186 Obs)

	Price banana	Price manioc	Price rice	Price yell corn	Expend	R ** 2
Q sold banana	1.210 (0.033)a	0.006 (0.032)	0.010 (0.036)	0.052 (0.031)	0.043 (0.017)	0.926
Q sold manioc	0.022 (0.026)	1.134 (0.027)	0.077 (0.028)	-0.042 (0.024)	0.013 (0.013)	0.947
Q sold rice	-0.009 (0.033)	0.045 (0.031)	1.042 (0.037)	0.029 (0.032)	0.062 (0.017)	0.894
Q sold yell corn	0.029 (0.041)	0.005 (0.041)	-0.048 (0.042)	1.045 (0.039)	0.030 (0.021)	0.866

	Price banana	Price manioc	Price rice	Price yell corn	Wage rate	R ** 2
Q sold banana	1.198 (0.034)	0.005 (0.033)	0.026 (0.003)	0.037 (0.030)	-0.069 (0.039)	0.924
Q sold manioc	0.020 (0.020)	1.134 (0.026)	0.084 (0.028)	-0.044 (0.025)	-0.006 (0.030)	0.947
Q sold rice	-0.025 (0.035)	0.044 (0.034)	1.066 (0.037)	0.008 (0.033)	-0.096 (0.004)	0.888
Q sold yell corn	0.017 (0.041)	0.002 (0.004)	-0.042 (0.043)	1.029 (0.038)	-0.085 (0.047)	0.868

	Price banana	Price manioc	Price rice	Price yell corn	Expend	Wage rate	Cultivate land	R ** 2
Q sold banana	1.199 (0.034)	0.004 (0.003)	0.007 (0.036)	0.047 (0.030)	0.030 (0.040)	-0.025 (0.0021)	0.044 (0.026)	0.928
Q sold manioc	0.021 (0.027)	1.134 (0.025)	0.076 (0.029)	-0.040 (0.025)	0.012 (0.016)	-0.011 (0.035)	0.015 (0.012)	0.948
Q sold rice	-0.013 (0.034)	0.043 (0.031)	1.042 (0.037)	0.023 (0.033)	0.036 (0.020)	-0.056 (0.045)	0.009 (0.027)	0.895
Q sold yell corn	0.027 (0.042)	0.001 (0.041)	-0.046 (0.045)	1.034 (0.040)	0.072 (0.051)	-0.022 (0.024)	0.045 (0.033)	0.870

[a] Numbers in parentheses are standard errors.

CHAPTER V.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The general objective of the preceding study has been to analyze the behavior of Peruvian farm households. The aim of the study is to increase the knowledge of how these economic entities operate as well as the constraints that they face. It is our belief that a better understanding of the sector will help policy makers in designing more cost effective policies in order to improve the well-being of Peruvian farmers.

A review of theoretical studies reveal that agricultural households play a multiple role as economic units, with characteristics that combine both consumer's and producer's behavior. As producers, the households produce goods and supply labor; and as consumers, households consume goods and services. The degree of integration will depend on the existence of a market economy. The theory of the household firm or the theory of firm-household complexes, as stated by Khrisna and Nakajima respectively, are the ones which take into account this duality of farm households.

An important issue stated by the theory is that farm households are rational agents, that maximize utility subject to their income equation. The new aspect is that the income equation contains the production function of the farm.

The analysis of the ENAHR survey data identified main features of the Peruvian farm households. The survey includes the responses of approximately 7,000 households along the Peruvian territory, which was divided in 24 domains. The main aspects about Peruvian farm households were reviewed in Chapter II. It's important then to remember the main characteristics of Peruvian households: Most of the population surveyed, 62%, is located in the sierra region, 85% of the PEA work in the Agricultural and Fishing sector. There is an average of 4.9 member per household. With respect to the size of farms, 70% of them have less than 5 hectares; and the sierra region has the biggest area of cultivable land.

A model of the farm household production was constructed considering the complexity of Peruvian households. However, the degree of applicability of the theoretical model to the real world depends on the availability of the data, and further, the reliability of it. The data base did not permit the testing of the more complex model. We therefore simplified the model as shown at the end of Chapter III. The estimation of the supply response of farmers gave us some interesting conclusions.

1) It seems that Peruvian farm households have a rational behavior as economic units. Households marketed surpluses are positively sensitive to an increase in their own prices, expenditures and cultivable land, and negatively sensitive to an increase in wage rates. This finding confirms the theoretical thought that even small farmers behave rationally.

2) A follow-up to the first conclusion, drive us to think that Peruvian farm households are involved in a market economy. Even though, a more in-depth and detailed study of household behavior would give us the precise conclusion, this rational behavior seems to indicate that farmers are articulated to the market mostly via prices. If that is so, we have to be aware that even small farmers are affected by price policies, and in general, for the whole economic policy governal by market mechanisms.

3) A close look at the results of the elasticities of output surplus lead us to derive some specific conclusions for each domain. In general, prices are the most significant variable for farmers followed by expenditure in inputs. The latter indicates that a need for cash, read as credit, would have a positive

impact in output surplus. On the other hand, some domains indicate a negative response to an increase in the daily wage rate, while a positive response to an increase in cultivable land. We cannot have a conclusive response of the effect in the daily wage rate, since more study of the agricultural labor market is needed. About cultivable land, its impact has to be taken into consideration, meaning that policy directed to increase land availability or what is called increase of the agriculture frontier would have a positive impact in output surplus in various domains.

Recommendations for Future Reseach

The study has identified many issues related to the structure of the farm household decision process: the separability of decisions and jointness, the resource availability, the factors of production, and the sources of income. As long as the data permitted some of these issues has been empirically established.

The results, however, are tentative. A more detailed data set would be necessary to estimate simultaneously the production and consumption models. This would require building a more precise and reliable data base at the household level. Even though the ENAHR survey data provides a wealth of detailed information, we found some problems, specially in two areas. First, the production data doesn't seem to be reliable and this has a lot to do with the fact that farmers, specially small units, rarely keep records. The reliance on memory or recall approach can not always bring good results. Second, the questionnaire design doesn't permit the identification of uses of factors of production per crop, only per household. A detailed model of household production would require this kind of disaggregation.

Future reseach should analyze more closely the labor issue. A wide variety of interesting topics can be developed with the data available. Going beyond farm household systems, a better understanding of Peruvian agricultural labor market can be addressed to help policy makers.

Another point is that the model used in this study does not distinguish crops and livestock, specifically we assume only crop production as the main activity of Peruvian farmers. However, many farm households included in the survey produce both crops and livestock. It's recommended, therefore, that future research incorporate both activities.

Finally, we recommend that any future research on Peruvian farm households economy should adopt and utilize the conceptual framework of farm household production models. It not only provides a useful insight into the understanding of the farm household economy but also can be used as an input into developing policy models.

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APPENDIX A. THE COMPARATIVE STATIC ANALYSIS OF THE GENERAL MODEL

The comparative statics analysis for the model presented in Chapter III is developed in this section. We totally differentiate the first order conditions. The differential equations are the following:

i) $Uhh.dXh + Uhm.dXm + Uhl.dXl - Ph.d\lambda - \lambda.dPh = 0$

ii) $Umh.dXh + Umm.dXm + Uml.dXl - Pm.d\lambda - \lambda.dPm = 0$

iii) $Ulh.dXh + Ulm.dXm + Ull.dXl - W.d\lambda - \lambda.dW = 0$

iv) $Gtf.dPh + Ph\ [Gtftf.dTf - Gtfzm.dZm + Gtfd.dD] - dW = 0$

v) $-Gzm.dPh - Ph\ [Gzmtf.dTF + Gzmzm.dZm + Gzmd.dD] + dr = 0$

vi) $Gd.dPh + Ph\ [Gdtf.dTf - Gdzm.dZm + Gdd.dD] - dPd = 0$

vii) $G.dPh + Ph\ [Gtf.dTf - Gzm.dZm + Gd.dD] + (T - Tf - Xl)$
$dW + W(-dTf - dXl) + Zm.dr + r.dZm + dV - Pm.dXm -$
$Xm.dPm - Ph.dXh - Xh.dPh - Pd.dD - D.dPd = 0$

Arranging terms in matrix notation:

$$
\begin{vmatrix}
Uhh & Uhm & Uhl & -Ph & 0 & 0 & 0 \\
Umh & Umm & Uml & -Pm & 0 & 0 & 0 \\
Ulh & Ulm & Ull & -W & 0 & 0 & 0 \\
-Ph & -Pm & -W & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & Gtftf & -Gtfzm & Gtfd \\
0 & 0 & 0 & 0 & -GzmTf & -Gzmzm & -Gzmd \\
0 & 0 & 0 & 0 & Gdtf & -Gdzm & Gdd
\end{vmatrix}
\begin{vmatrix}
dXh \\ dXm \\ dXl \\ d\lambda \\ dTf \\ dZm \\ dD
\end{vmatrix}
=
\begin{vmatrix}
\lambda dPh \\ \lambda dPm \\ \lambda dW \\ \varphi \\ dW/Ph- W/Ph)dPh \\ -dr/Ph + r/Ph)dPh \\ dPd/Ph - (Pd/Ph)dPh
\end{vmatrix}
$$

A B C

Where: $\varphi = Xm.dPm - (G - Xh)dPh - (T - Tf - Xl)dW - dV + DdPd - Zm.dr$

In order to get the comparative static results we need to get $B = A^1C$

The method to get the inverse of matrix A is using the cofactor matrix and then the adjoint of A. The determinant of the matrix is the following:

$$|A| = Ph^2 . Uml^2 . Gdtf^2 . Gzmzm < 0$$

As we see above, matrix A is a block diagonal partitioned matrix. Each block is a symmetric matrix. The cofactor elements of matrix A are the following:

$A11 = + [Pm^2\ Ull\ Gzmzm\ Gdtf^2]$

$A12 = + [Pm\ Ph\ Ull\ Gzmzm\ Gtf^2]$

$A13 = + [Pm\ Ph\ Ulm\ Gzmzm\ Gdtf^2]$

$A14 = - [Ph\ Ulm^2\ Gzmzm\ Gdtf^2]$

$A22 = + [Ph^2\ Ull\ Gzmzm\ Gdtf^2]$

$A23 = + [Ph^2\ Ulm\ Gzmzm\ Gdtf^2]$

$A24 = - [Ph\ Uhl\ Ulm\ Gzmzm\ Gdtf^2]$

$A33 = + [Ph^2\ Umm\ Gzmzm\ Gdtf^2]$

$A34 = - [Ph\ Umm\ Uhl\ Gzmzm\ Gdtf^2]$

$A44 = + [Umm\ Ulh^2\ Gzmzm\ Gdtf^2]$

$A55 = - [Ph^2\ Uml^2\ Gdzm^2]$

$A56 = + [Ph^2\ Uml^2\ Gdtf\ Gzmd]$

$A57 = + [Ph^2\ Uml^2\ Gzmzm\ Gdtf]$

$A66 = - [Ph^2\ Uml^2\ Gdtf^2]$

$A67 = + [Ph^2\ Uml^2\ Gtfzm\ Gdtf]$

$A77 = - [Ph^2\ Uml^2\ Gzmtf^2]$

$$\begin{vmatrix} dXh \\ dXm \\ dXl \\ d\lambda \\ dTf \\ \\ dZm \\ \\ dD \end{vmatrix} = \frac{\begin{vmatrix} A11 & -A12 & A13 & -A14 & 0 & 0 & 0 \\ -A12 & A22 & -A23 & A24 & 0 & 0 & 0 \\ A13 & -A23 & A33 & -A43 & 0 & 0 & 0 \\ -A14 & A24 & -A34 & A44 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & A55 & -A56 & A57 \\ 0 & 0 & 0 & 0 & -A56 & A66 & -A67 \\ 0 & 0 & 0 & 0 & A57 & -A67 & A77 \end{vmatrix} \begin{vmatrix} \lambda dPh \\ \lambda dPm \\ \lambda dW \\ \varphi \\ -dW/Ph + (W/Ph^2)dPh \\ -dr/Ph + (r/Ph^2)dPh \\ -dPd/Ph + (Pd/Ph^2)dPh \end{vmatrix}}{|A|}$$

The following are some expected results.

<u>Changes in Ph</u>

(1) $dXh = [A11.©.dPh + A14\ (G - Xh)dPh]/|a|$

$\delta Xh/\delta Ph = U11/U1m^2 - (G - Xh)/Ph$

(-) (?)

Change in the Ph have two effects on the consumption of Xh. The substitution effect, first term, is negative as in the consumer theory; but there exists an additional effect that depends on the quantity sold of that commodity. If the difference (G - Xh) is positive then the household income should increase due to the increase in Ph. This effect can change the sign of the equation. (2) $dXm = [-A12.\ \lambda.dPh]/ |A|$

$\delta Xm/\delta Ph = -\ (Pm\ Ull\ Gtf^2\ \lambda)/(Ph\ Uml^2\ Gdtf^2)\ > 0$

An increase in the price of commodity Xh will increase the consumption of the substitute commodity Xm.

(3) $dXl = [A13.\lambda.dPh + A43(G - Xh).dPh]/|A|$

$\delta Xl/\delta Ph = Pm/Ulm.Ph - [Umm\ .\ Uhl\ (G - Xh)]/Ph.Uml^2$

(?) (?)

We cannot sign a priori this result because the cross price effect has an ambiguous sign. Also when (G - Xh) is equal to zero, the demand for leisure is determine by the cross price effect only.

(4) $d\lambda = [-A14.\lambda.dPh - A44\ (G - Xh).dPh]/|A|$

$\delta\lambda/\delta Ph = \lambda/Ph\ - Umm\ Ulh^2\ (G - Xh)/Ph^2\ Uml^2\ > 0$

If (G - Xh) is greater than zero the sign of the result is positive, meaning that an increase in Ph will increase the marginal revenue of the household.

(5) $dTf = [\ (A55.W/Ph^2)dPh\ ]/|A|$

$\delta Tf/\delta Ph = -\ Gdzm^2.W/Ph^2\ Gdtf^2\ Gzmzm\ > 0$

An increase in farm output price Ph increases the demand for farm labor.

(6) $dZm = [(A66.r/Ph^2).dPh]/|A|$

$\delta Zm/\delta Ph = -\ r/Ph^2 Gzmzm\ > 0$

An increase in farm output price will increase the demand for land.

(7) $dD = [\ (A77.Pd/Ph^2)dPh\ ]/|A|$

$\delta D/\delta Ph = -\ (Gzmtf^2.\ Pd)/(Ph^2\ Gdtf^2\ Gzmzm \quad > \quad 0$

An increase in output price produce by the farm will increase the demand for variable inputs.

Using the identities equations we can get the response of the other endogenous variables.

(8) $Tm = T - Tf - Xl$

$\delta Tm/\delta Ph = -[\delta Tf/\delta Ph + \delta XL/\delta Ph]$

$\qquad\qquad (+) \qquad\qquad (?)$

The supply of labor off-farm can be found by the equation of time allocation. We know that the demand for farm labor increase as Ph increases, but the household is not require to meet this demand from its own family labor. Then, the result is ambiguous.

(9) $G(Q;\ Tf,\ Zf, D, \gamma) = 0$

$\delta Q/\delta Ph = \delta G/\delta Tf\ .\ \delta Tf/\delta Ph \quad > \quad 0$

The level of farm output increases as farm price rises in a single input case, maintaining the productivity parameter constant.

<u>Changes in Pm</u>

The most relevant comparative static results are the following:

(10) $dXh = (-A12.dPm - A14\ Xm\ dPm)/|A|$

$\delta Xh/\delta Pm = (-Pm\ Ull\ Gtf^2)/(Ph\ Uml^2\ Gdtf^2) + Xm/Ph > 0$

As the price of the marketed output increases we consume more of the substitute commodity Xh produce by the household.

(11) $dXm = (A22.\lambda dPm + A24Xm\ dPm)/|A|$

$\delta Xm/\delta Pm = Ull/Uml^2 - Uhl\ Xm/Ph\ Ulm$?

The common result doesn't hold here. An increase in price of commodity m will have an ambiguous effect on Xm.

(12) $dXl = [-A23\ \lambda dPm - A43\ Xm\ dPm]/|A|$

$\delta Xl/\delta Pm = -\lambda/Ulm + (Umm\ Uhl)/Ph\ Uml^2$?

The effect of an increase in price of commodity Xm will have an ambiguous effect in the demand of leisure.

(13) $d\lambda = [A24\ dPm + A44\ Xm\ dPm]/|A|$

$\delta\lambda/\delta Pm = -\ Uhl/Ph\ Ulm + Umm\ Ulh^2 Xm/Ph\ Uml^2$?

Change in W

(14) $dXh = [A13\ \lambda\ dW + A14\ (T - Tf - Xl)\ dW]/|A|$

$\delta Xh/\delta W = Pm\ \lambda/Ph\ Ulm - (T - Tf - Xl)/Ph$?

The change in the wage rate would have an ambiguous effect in the consumption of Xh.

(15) $dXm = [-A23.dW - A24\ (T - Tf - Xl)dW]/|A|$

$\delta Xm/\delta W = -\ 1/Ulm + Uhl\ (T - Tf - Xl)/Ulm\ Ph$?

(16) $dXl = [\ A33.dW + A43\ (T - Tf - Xl)\ dW\ ]/|A|$

$\delta Xl/\delta W = Umm/Uml^2 - Umm\ Uhl\ (T - Tf - Xl)/Ph\ Ulm^2$?

The result is ambiguous since there is more than one way to allocate time.

(17) $dTf = [(-A55/Ph)dW]/|A|$

$\delta Tf/\delta W = Gdzm^2/Ph\ Gdtf^2 Gzmzm < 0$

As wage rate increases the opportunity cost of farm labor increases, so farm labor switches to other uses.

(18) $dZm = [(A56/Ph)dW]/|A|$

$\delta Zm/\delta W = Gzmd/Ph\ Gdtf\ Gzmzm$?

(19) $dD = [(-A57/Ph)dW]/|A|$

$\delta D/\delta W = -1/Ph\ Gdtf$?

(20) $d\lambda = [\ -A34\ \lambda\ dW - A44(T - Tf - Xl)dW\ ]/|A|$

$\delta\lambda/\delta W = Umm\ Uhl^2/Ph\ Uml^2 - Umm\ Ulh^2(T-Tf-Xl)/Ph^2 Uml^2$?

<u>Changes in r</u>

(21) $dXh = A14\ Zm\ dr/|A|$

$\delta Xh/\delta r = -Zm/Ph < 0$

As land rate increases the consumption of the commodity produced by the household declines.

(22) $dXm = -A24\ Zm\ dr/|A|$

$\delta Xm/\delta r = Uhl^2 Zm/Ph\ Ulm$

The effect of an increase in land rate on the consumption of commodity Xm is ambiguous.

(23) $dXl = A43\ Zm\ dr/|A|$

$\delta Xl/\delta r$ = -Umm Ulh Zm / Ph Uml^2 ?

(24) dTf = (A56/Ph)dr/¦A¦

$\delta Tf/\delta r$ = Gzmd/Ph Gdtf Gzmzm ?

(25) dZm = (-A66/Ph)dr/¦A¦

$\delta Zm/\delta r$ = 1/Ph Gzmzm < 0

(26) dD = (A67/Ph)dr/¦A¦

$\delta D/\delta r$ = Gtfzm/Ph Gzmzm Gdtf ?

(27) Tm = Tf + Tm + Xl

$\delta Tm/\delta r = -\delta Tf/\delta r - \delta Xl/\delta r$?

(28) $G(Q; Tf, Zf, D, \gamma) = 0$

$\delta Q/\delta r = \delta Q/\delta Tf \, . \, \delta Tf/\delta r$?

(29) $d\lambda$ = -A44 Zm dr

$\delta\lambda/\delta r$ = -Umm $Ulh^2/Ph^2 Uml^2$ > 0

Changes in V

(30) dXh = A14 dV/¦A¦

$\delta Xh/\delta V = -1/Ph < 0$

(31) dXm = -A24 dV/¦A¦

$\delta Xm/\delta V$ = Uhl/Ph Ulm ?

(32) dXl = A34 dV/¦A¦

$\delta Xl/\delta V$ = Umm Uhl/Ph Uml^2 ?

(33) $d\lambda$ = -A44 dV/¦A¦

$\delta\lambda/\delta V$ = -Umm Ulh^2/Ph^2 Ulm^2 > 0

<u>Change in Pd</u>

(34) $dXh = -A14\ D\ dPd/|A|$

$\delta Xh/\delta Pd = D/Ph \quad > \quad 0$

(35) $dXm = A24\ D\ dPd/|A|$

$\delta Xm/\delta Pd = -Uhl\ D/Ph\ Ulm \quad ?$

(36) $dXl = -A43\ D\ dPd/|A|$

$\delta Xl/\delta Pd = Umm\ Uhl\ D/Ph\ Uml \quad ?$

(37) $dTf = (-A57/Ph) dPd/|A|$

$\delta Tf/\delta pd = -\ 1/\ Ph\ Gdtf \quad ?$

(38) $dZm = (A67/Ph)\ dPd/|A|$

$\delta Zm/\delta Pd = Gtfzm/Ph\ Gzmzm\ Gdtf \quad ?$

(39) $dD = (-A77/Ph) dPd/|A|$

$\delta D/\delta Pd = Gzmtf^2/Ph\ Gzmzm\ Gdtf^2 \quad < \quad 0$

(40) $d\lambda = A44\ D\ dPd/|A|$

$\delta \lambda/\delta Pd = Umm\ Ulh^2 D/Ph^2 Uml^2 \quad < \quad 0$

<u>Change in Zf</u>

(41) $Z = Zm + Zf$

$\delta Zf/\delta Zf = \delta Z/\delta Zf - \delta Zm/\delta Zf$

<u>Change in T</u>

(42) $T = Tf + Tm + Xl$

$1 = \delta Tf/\delta T + \delta Tm/\delta T + \delta Xl/\delta T$

<u>Change in Ψ</u>

(43) $dXh = -A14\ d\Psi\ /|A|$

$\delta Xh/\delta\Psi = 1/Ph \quad > \quad 0$

(44) $dXm = A24\ d\ /|A|$

$\delta Xm/\delta\Psi = \ -Uhl/Ph\ Uml \quad ?$

(45) $dXl = -A43\ d\ \ /|A|$

$\delta Xl/\delta\Psi = \ Umm\ Uhl/Ph\ Uml^2 \quad ?$

(46) $d\lambda = \ A44\ d\Psi\ /|A|$

$\delta\lambda/\ \delta\Psi = Umm\ Ulh^2/\ Ph^2Ulm^2 \quad < \quad 0$

APPENDIX B. THE COMPARATIVE STATICS OF THE MODIFIED MODEL

In order to get the comparative statics results we need to find the inverse of matrix A. The determinant of A

$$|A| = 2\lambda\ hab\ ha\ hb - \lambda[haa\ hb^2 + hbb\ ha^2] > 0$$

The cofactor elements of the matrix are the following:

$A11 = -\ hb^2$

$A12 = -\ ha\ hb$

$A13 = \lambda\ hb\ hab - \lambda\ ha\ hbb$

$A21 = -\ ha\ hb$

$A22 = -\ ha^2$

$A23 = \lambda\ hb\ haa - \lambda\ ha\ hab$

$A31 = \lambda\ hb\ hab - \lambda\ ha\ hbb$

$A32 = \lambda\ hb\ haa - \lambda\ ha\ hba$

$A33 = \lambda^2\ haa\ hbb - \lambda^2\ hab^2$

$$\begin{vmatrix} dQa \\ dQb \\ d\lambda \end{vmatrix} = \frac{\begin{vmatrix} A11 & -A12 & A13 \\ -A21 & A22 & -A23 \\ A31 & -A32 & A33 \end{vmatrix}}{|A|} \begin{vmatrix} -dPa \\ -dPb \\ \varphi \end{vmatrix}$$

<u>Change in Pa</u>

$dQa/dPa = hb^2/|A| \quad > \quad 0$

$dQb/dPa = -ha\ hb/|A| \quad < \quad 0$

$d\lambda/dPa = -[\lambda hb\ hab - \lambda ha\ hbb]/|A| \quad ?$

<u>Change in Pb</u>

$dQa/dPb = -\ ha\ hb/|A| \quad < \quad 0$

$dQb/dPb = ha^2 \quad > \quad 0$

$d\lambda/dPb = [\lambda hb\ haa - \lambda ha\ hba]/|A| \quad ?$

<u>Change in k</u>

$dQa/dk = \lambda[hb\ hab - ha\ hbb]\ fk/|A| \quad > \quad 0$

$dQb/dk = \lambda[hb\ haa - ha\ hab]\ fk/|A| \quad > \quad 0$

<u>Change in EXP</u>

$dQa/dEXP = \lambda[hb\ hab - ha\ hbb]\ fe/|A| \quad > \quad 0$

$dQb/dEXP = \lambda[hb\ haa - ha\ hab]\ fe/|A| \quad > \quad 0$

Change in L

$dQa/dL = -\lambda[hb\ hab - ha\ hbb]\ fl/|A| \quad < \quad 0$

$dQb/dL = -\lambda[hb\ haa - ha\ hab]\ fl/|A| \quad < \quad 0$

Summary:

	Pa	Pb	K	EXP	L
Qa	+	_	+	+	-
Qb	-	+	+	+	-
λ	?	?	?	?	?

APPENDIX C. LIST OF CROPS

Type	Code Number	Name
Pastures:		
	2001	Alfalfa
	2003	Elefante
	2011	Sudan
	2014	Other patures
Permanent:		
In production:		
	3001	Achiote
	3007	Cacao
	3008	Cafe
	3014	Ciruelas
	3015	Coca
	3017	Cocotero
	3018	Chirimiyo
	3020	Granado
	3023	Guayabo
	3024	Higuera
	3025	Humari
	3028	Limon
	3029	Limon dulce
	3030	Lucuma
	3032	Mandarina
	3033	Mango
	3034	Manzana
	3037	Melocotonero
	3038	Membrillo
	3040	Naranjo
	3041	Nispero
	3043	Olivo
	3044	Pacae
	3047	Palto
	3049	Peral
	3050	Pijuayo
	3051	Pimienta
	3052	Pomarrosa
	3056	Te
	3059	Vid

Growing:		
	3114	Ciruela
	3121	Guanabano
Temporal:		
Cereals:		
	4002	Arroz
	4003	Avena Grano
	4004	Canahua o Canihua
	4005	Cebada Grano
	4007	Maiz Amarillo Duro
	4008	Maiz Amilaceo
	4009	Quinua
	4010	Sorgo
	4011	Trigo
Fruits:		
	4101	Cana de Azucar
	4103	Fresas o frutilla
	4104	Granadilla
	4105	Mani fruta
	4106	Melon
	4107	Papaya
	4108	Pepino
	4109	Pina
	4110	Platano
	4111	Sandia
	4113	Tuna
Vegetables:		
	4202	Aji o Pimiento
	4203	Ajo
	4204	Alabahaca
	4206	Apio
	4208	Beterraga
	4209	Caigua
	4210	Calabaza
	4211	Cebolla
	4212	Col o repollo
	4213	Coliflor
	4215	Culantro
	4217	Espinaca
	4219	Lechuga
	4220	Maiz Choclo
	4221	Nabo
	4222	Pepinillo

	4223	Perejil
	4225	Rabano
	4226	Tomate
	4228	Zanahoria
	4229	Zapallo
	4230	Zapallito Italiano
Fresh Vegetables:		
	4301	Arveja
	4302	Caupi o frijol chiclayo
	4303	Frijol chileno
	4304	Frijol de palo
	4305	Frijol
	4307	Frijol vainita
	4308	Habas
	4309	Lenteja
	4310	Pallar
	4311	Zarandaja
	4312	Otras legumbres frescas
Beans:		
	4401	Arveja
	4402	Caupi o frijol chiclayo
	4403	Chocho o tarwi
	4404	Frijol
	4405	Frijol de palo
	4407	Haba
	4408	Lacyao
	4409	Lenteja
	4411	Pallar
	4412	Zarandaja
Tubers:		
	4502	Arracacha
	4503	Camote
	4505	Mashua o Izano
	4507	Oca
	4508	Olluco
	4509	Papa
	4511	Sanchapapa
	4512	Uncucha
	4514	Yuca
For feed:		
	4601	Avena forrajera

	4603	Cebada forrajera
	4606	Maiz chala
	4609	Yunya Forrajera
Industrial:		
	4703	Algodon
	4707	Cana de Azucar para ahcohol
	4709	Cana de azucar para chancaca
	4712	Cube o barbasco
	4717	Linaza
	4718	Lino
	4719	Mani para aceite
	4723	Palillo
	4728	Sorgo escobero
	4729	Soya
	4731	Tabaco rubio
	4732	Urena lobaya
	4733	Yute
	4734	Otros industriales
Others temporal:		
	4803	Carrizo
	4805	Flores Ornamentales