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TRAINING MANUAL

for

AGRICULTURAL POLICY WORKSHOP

Prepared for

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by

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Preface

The advent of computer technology has permitted policy analysts to simulate complex social issues in a manner somewhat similar to controlled experiments performed by physical and biological scientists. Unfortunately, policy simulation models have generally not been well received. In spite of their potential contribution to the analytical process, these models have been critized for being: too dependent on main-frame computers; too complicated to be used jointly by decisionmakers and analysts; too demanding in the type and quantity of data required; too inflexible to handle changing policy situations; and too unrealistic to satisfy decisionmakers' need for relevance to the present policy environment.

This manual has been designed to be used as source material in a food and agricultural policy workshop devoted to an analysis of the interrelationships of key food, agriculture, and nutrition policy issues. The major objectives of the manual are:

1. Demonstrate the Relevance of Food, Agriculture, and Nutrition Policy Analysis to Overall Agricultural Development Planning and Evaluation.

2. Present a Unified Economic Framework for Analyzing Major Agricultural Policy Issues.

3. Present a Practical Application of Policy Analysis that Allows Agricultural Development Specialists with Various Levels of Training in a Wide Range of Disciplines to Interact Effectively.

The manual is divided into six sections. The first section presents an overview of the relevance and nature of policy analysis to the agricultural development process. The second

section presents a simple, yet precise overview of consumer behavior and its role in the policy process. The third section presents a similar overview of producer behavior. The fourth section discusses the unification of consumer and producer behavior into a market system and its relevance to policy analysis. The fifth section summarizes a policy simulation model that has been adapted for implementation on microcomputers. The final section presents selected applications of the simulation model to current issues in food, agriculture, and nutrition policy.

CHAPTER 1

THE ROLE OF POLICY ANALYSIS IN AGRICULTURAL DEVELOPMENT

The process of developing a country's agricultural sector involves a continual resolution of conflicting goals. The identification of goals and the choice of actions to accomplish those goals lie at the heart of the policy process. Public policy decisionmakers have a need to evaluate alternative goals and actions and thus have special information requirements for the analysts who assist them in the policy formulation process.

The Nature of the Policy Process

The following questions are examples of typical conflicts that policy analysts and decisionmakers must ponder:

> Should the country be self-sufficient in their own food production or should they seek food security thru the international markets?
>
> Should the prices farmers recieve and consumers pay be "improved"?
>
> Can the efficiency of the food processing and distribution industries be increased?
>
> How will a particular food policy affect households according to income leval and location?
>
> What will be the nutritional consequences of a proposed new agricultural policy or project?

These questions, although familiar to policymakers and policy analysts, require a distinction to be made about the knowledge and actors that are relevant to the issue. Knowledge may be either positive or normative. Positive knowledge is an objective statement or description of "the way things are in the real world." In contrast, normative knowledge is a subjective view of

"the way things should be." Positive knowledge is used to describe the situation as accurately as possible, while normative knowledge reflects the goals, values, and beliefs that the policy actors deem relevant to the situation.

The policy actors are the persons and organizations that have some self-interest in a particular policy issue. Lawmakers, policy analysts, farmers, consumers, farm organizations, and consumer organizations are typical agricultural policy actors. The composition of policy actors will vary with the issue. A livestock policy issue will attract relatively little interest from crop farmers, particularly farmers who produce crops unrelated to the livestock sector. Lawmakers choose an appropriate policy option from the alternatives evaluated by the policy analyst. The analyst evaluates each policy alternative for its political, social, administrative, and economic feasibility in solving the current policy problem.

Any policy issue involves policy actors interacting in five distinct phases of the policy process. Table 1.1 presents a summary of the policy process.

The first phase of the policy process consists of the identification of the goals, values, and beliefs that constitute the nation's sense of character and identity. Goal identification involves a broad description of social welfare standards such as attitudes toward employment, poverty, medical care, nutritional status, and social and economic justice. This activity should establish a clear understanding of society's vision of "the way things should be", or normative assumptions. These assumptions

Table 1.1 The Policy Process

Phase	Description	Knowledge	Actors
1.	Goal Identification	Normative	Citizens Public Officials Philosophers Policy Analysts
2.	Problem Identification	Normative, Positive	Citizens Public Officials Interest Groups Policy Analysts
3.	Formulation and Analysis of Policy Options	Positive	Policy Analysts
4.	Selection of Policy Option	Normative, Positive	Public Officials
5.	Evaluation of Implemented Policy Option	Positive	Policy Analysts

should be recognized as central ingredients in assessing the political and social feasibility of a particular policy.

The second phase involves the identification of policy problems, or situations where there is a strong indication that positive knowledge (facts) on "the way things are" is significantly different from the normative assumptions. Evidence that the present situation deviates from society's norms can come from several sources. In most cases, problems are identified through citizen complaints to public officials or in evaluations conducted by policy analysts.

In the third phase of the policy process, analysts attempt to produce information and data (positive knowledge) about the extent of the problem. Issues identified in the second phase may still

be valid, but the policy analyst must strive to separate normative interpretations of the situation from a relatively objective survey of the relevant facts. Policy analysts assess the present difference between normative and positive views of the problem. If there is general agreement that a genuine policy problem exists, the analysts can then formulate a series of policy options and estimate the likely consequences or impacts of each. Finally, the analyst must analyze the impacts of each option for political, social, administrative, and economic feasibility.

If policy analysts prepare positive assessments of several policy options, their measures might include financial costs and returns, crop yields, income levels, and nutritional status. Each assessment should also include a description of the major policy actors who have interests in that particular option. At a minimum, the actors should be classified according to whether they will primarily benefit from the option or pay most of the program costs necessary to implement the option. In many cases, the policy actors who are primarily beneficiaries of a particular policy option do not pay a proportionate share of the program costs.

In the fourth phase, key decisionmakers in the executive and legislative branches of the government review the analysts' positive assessments of the problem and proposed options, then select the option that best serves their interpretation of normative assumptions. This selection process involves an intricate mix of economics, politics, sociology, and psychology that remains largely uncomprehendable to researchers. However, regardless of the decisionmaking method, these judgements will be

more fruitful if they are the result of a deliberate evaluation of facts, or a relatively objective assessment of "the way things are", in light of the society's prevailing norms. If for a particular policy issue, the analysis results in favorable assessments of two or more policy options, the decisionmakers' choice will depend on how each compares to the desired goal. The government's decision on a particular policy issue will be more effective if all of the options can be compared on the basis of a careful assessment of their respective costs and benefits. Decisionmakers are often forced by circumstances to make decisions based on very limited information. If positive information is available, the decisionmakers will quickly translate it into values that reflect normative equalivalents. The decisionmakers need to know the estimated burden of program costs on beneficiaries and nonbeneficiaries in order to assess the policy option's compatibality with prevailing norms for social and economic justice. For every option chosen, the decisionmakers will consider its positive assessment, in normative equilivalents, compared to a similar evaluation of the other options.

Once a policy option has been chosen and implemented, the final phase of the policy process involves a positive assessment of the new policy's effectiveness in solving problems identified in the second phase. The evaluation should offer an objective assessment of the policy's achievements, which can be entered into the next round of the policy process (phases two and three).

It should be emphasized that policy analysts have roles in all phases of the policy process except the selection of the

appropriate policy option, which is an essentially political act that requires decisionmakers to make both normative and positive judgements about the effacy of each option. The policy process operates as a feedback system. Policy analysts collect normative and positive information about a particular policy issue and develop an objective analysis of options. After a new policy has been adopted, the analysts again provide the framework within which information on the effectiveness of the programs implemented in support of the policy can be evaluated. Evaluations by policy analysts, along with critiques by citizens and decisionmakers, provide a new set of knowledge for a second iteration of phase two. If the original problem has only been partially solved by the new policy, then the process continues in an effort to develop effective solutions.

Decisionmakers' Information Needs

In phase four of the policy process, decisionmakers use normative and positive information to choose an appropriate policy option. Their normative information is supplied mainly through the political process. Their interpretations of prevailing political and social norms become major criteria in the evaluation of analysts' policy options. By virtue of their positions of trust and responsibility, public officials who must select a policy option for implementation are in the best position to process normative information. However, they will be more effective in choosing new policies if they also receive relevant positive information from the analysts.

What kind of information should the policy analyst produce for the decisionmaker? The information should be positive, that

is, reasonably objective in interpreting "the way things are now" and "the way things would be if a particular policy option were implemented."

The information should systematically describe all relevant aspects of a particular policy option and make the same analysis of all other options for the problem. The decisionmakers will be confused if each option analysed uses a different frame of analytical reference.

Decisionmakers need positive information on parameters that are important to citizens and are reflected in citizen evaluation of political effectiveness. Consumers, farmers, and food processors and distributors are the key actors who will feel the market impact of food and agriculture policy. Prices, employment, income, taxes, mortality rates, wage rates, interest rates, and literacy rates are of common interest to these citizens and politicians. Decisionmakers will choose the policy option that maximizes net political benefits. There is as yet no calculus to measure political costs and benefits, but they surely exist and decisionmakers are relatively expert practitioners of the art of transforming positive information about policy parameters into a normative assessment.

Decisionmakers also need disaggregated estimates of policy impacts on relevant parameters in terms of gains to the selected subpopulations that are prime or desired beneficiaries, and costs to the subpopulations that either finance most of the public expenditures under the policy or lose benefits enjoyed under pre-existing policies. These classifications of policy impacts are

important because they allow decisionmakers to assess the effectiveness of the policy in reaching subpopulations that have been targeted for public assistance.

Role of the Policy Analyst

The policy analyst has the responsibility for interpreting relevant facts about policy options with a strong sense of scientific detachment from the normative judgements that are best made by decisionmakers. A decisionmaker risks political repudiation if he dictates the answers to be supplied by the policy analyst, for in doing so, he denies himself the very information that will be most useful in his normative judgements.

The analyst should not feel dismayed if decisionmakers' choose policy options that differ from his recommendations. It is not the analyst's job to make the kind of normative judgements that are required of decisionmakers.

The analyst's chief contribution to the policy process lies with his efforts to interpret the existing policy situation and proposed policy changes from an objective viewpoint. The analyst's job is challenging because he must take a multidisciplinary approach to each policy issue. He must understand the production and marketing techniques of each commodity affected by a particular policy option. He must possess a practical understanding of economic theory and its empirical application to the current problem, and he must cope with the constant pressure to produce extensive analyses with insufficient data. Above all, he must render analyses that can be comprehended by decisionmakers, yet retain the essential empirical attributes of the issue.

The policy analyst has major responsibility for maintaining a data base appropriate for policy analysis. The data may be drawn from censuses and other published, or secondary sources that are usually aggregated. The analyst should also collect primary data on household consumption, farm production, and market commodity processing activities. The analyst must use available data to construct a model of each policy option. Econometric models can be powerful analytical tools for demonstrating the linkages between the policy actors and the differential impacts of policy modifications.

Much of policy analysis involves clarifying the roles of demand and supply behavior and interpreting their implications on food consumption and production for the decisionmakers. The analyst's task of presenting a comprehensive model of the food and agriculture sector is complicated by the fact that two of the major policy actors, consumers and farmers: have conflicting objectives; are on opposite ends of the food market spectrum; are spatially separated; and both are constrained by the biological processes of agriculture.

While the study of market behavior of consumers and producers gives the policy analyst a key vantage point for evaluating policy options, he should also recognize some important limitations of the market. Although markets have been consistently demonstrated to be efficient means of promoting increased social welfare, they are often inappropriate instruments for redistributing wealth. Markets also fail to optimally allocate resources in instances where: (1) there is monopoly behavior by sellers or monopsony

behavior by buyers; (2) there are technical externalities in production or consumption; (3) certain common property, or public goods, cannot be reasonably allocated under an individual, private-property ownership scheme; and (4) prices are set at non-equilibrium levels by the government. Consumer and producer subsidy schemes, while producing benefits to certain sub-populations of policy actors, also often distort the market to produce other negative effects that were unintentional.

Major Food, Agriculture, and Nutrition Policy Issues

There is a long history of problem identification in food and agricultural policy. Although the degree of emphasis may vary according to the level of development, most of these policy issues can be classified into four broad areas.

1. Employment of Agricultural Resources

Most countries seek to fully employ all of their farm workers and rural lands to provide a stable, adequate supply of food and balanced economic growth in the urban and rural sectors.

Unemployed or underemployed agricultural resources are often symptomatic of many other social problems that transcend the agricultural sector. Inadequate or contradictory financial incentives to farmers may be due to structural problems in agricultural markets, trade distortions, or inadequate social infrastructure.

2. Stabilization of Commodity Markets

Agricultural production may be unstable because of weather, commodity price changes, international trade disequiliberia, and unreliable supplies of agricultural inputs. The instability of agricultural supply and the fact that the quantity of food

demanded is relatively unresponsive to price changes together cause food prices to be highly variable. Consequently, farmers seek policies to stabilize their incomes, usually by setting farm price floors. Urban consumers' demands for food price ceilings represent a powerful counterpoint to farm interests.

The most common methods of attacking market instability have involved producer and consumer subsidies, price controls, and trade sanctions. Each approach has imposed additional burdens on the market while producing limited benefits.

The introduction of new agricultural technologies have often increased food and fiber production, but at the cost of adding futher price variability through increased supply.

3. Trade and Specialization

One of the most crucial economic policy issues facing developing countries is the question of import substitution. Many countries have long term balance of payments deficits. There is great financial pressure to strengthen the agricultural sector if a substantial part of the deficit is due to food imports. If a country attempts to reduce food importation, it risks absolute food shortages or reduced foreign exchange earnings by reducing the cultivation of export crops.

The shift toward agricultural self-sufficiency may benefit the country by reducing the foreign exchange costs of food imports, but it will likely reduce the cultivation of some export crops that produce foreign exchange earnings. If a domestic crop has a comparative disadvantage in the workd market, its substitutiion for imported food will reduce foreign exchange

costs, but raise domestic prices. If the shift results in a net cost, decisionmakers will have to compare that cost with the presumed, but unmeasured, benefits of reduced reliance on foreign food suppliers.

Specialization in a narrow range of agricultural products according to a strict interpretation of the Law of Comparative Advantage tends to employ land and labor resources where their returns are highest, but it exposes the country's agricultural export sector to greater instability in the international market.

The importation of food under the provisions of food aid agreements, such as Public Law 480, increases the domestic food supply, but reduces domestic production incentives. The policy process will have to assess the conflict between short-run benefits to consumers and long-term disincentives to farmers.

4. Improved Nutritional Status

Evidence from countries throughout the agricultural development continum indicate that there are substantial lags between increased agricultural output and sustained improvement in the nutritional status of the poor. The combination of low income, low nutritional quality of available foods, and adverse food price ratios often result in delayed nutritional improvement. The impacts of agricultural policies are commonly measured only in market terms, ie. price and quantity changes. The nutritional consequences of these policies can often be so adverse as to raise questions about the merits of the other market benefits.

By transforming market changes in food consumption into nutritional equalivalents, the policy analyst can demonstrate the effectiveness of a policy option in improving nutritional status,

given current food prices and supplies. In instances where the market effects of an agricultural developement policy has an adverse or limited nutritional impact, the policy analysis should produce new options for meeting nutrition goals. Nutrition behavior is strongly influenced by market condtions, but education and training can enable consumers to achieve improved nutritional status under adverse economic conditions.

CHAPTER 2

DEMAND

Food consumption always occupies a central place in a nation's formulation of social and economic policy. The wealthiest households within a country typically spend less than 10 percent of their disposable income on food while the poorest households may spend more than 60 percent of their disposable income for food. These disparities highlight the critical importance of food expenditures in most household budgets. In order to develop agricultural policies that effectively address consumers' nutritional needs and society's food consumption norms, policy analysts need positive information from market and household surveys and a working knowledge of econometric analyses of food demand. The prerequisite of such analyses is a clear understanding of consumer demand theory.

Consumer Behavior

Any consumer must resolve the conflict between many or unlimited needs and a limited set of means (purchasing power) for satisfying those needs. The resolution of the conflict involves the consumer's attempt to maximize satisfaction by purchasing various goods and services according to their prices and their individual contributions to satisfaction, subject to the amount of income or wealth available for purchases.

Utility Maximization

The consumer's degree of need for a good can be measured by the amount of satisfaction he derives from consuming the good.

Although a direct measure of satisfaction has not yet been devised, the relationships in Figure 2.1 give some valuable insights into the problem. In Figure 2.1a, the horizontal axis measures the units of consumption of a good (Q) and the vertical axis measures the total utility (TU), or satisfaction, corresponding to varying levels of Q. As consumption of Q increases, TU increases, but at a decreasing rate. Within the range of Q shown in Figure 2.1a, TU reaches a maximum at $\bar{Q}$, then declines.

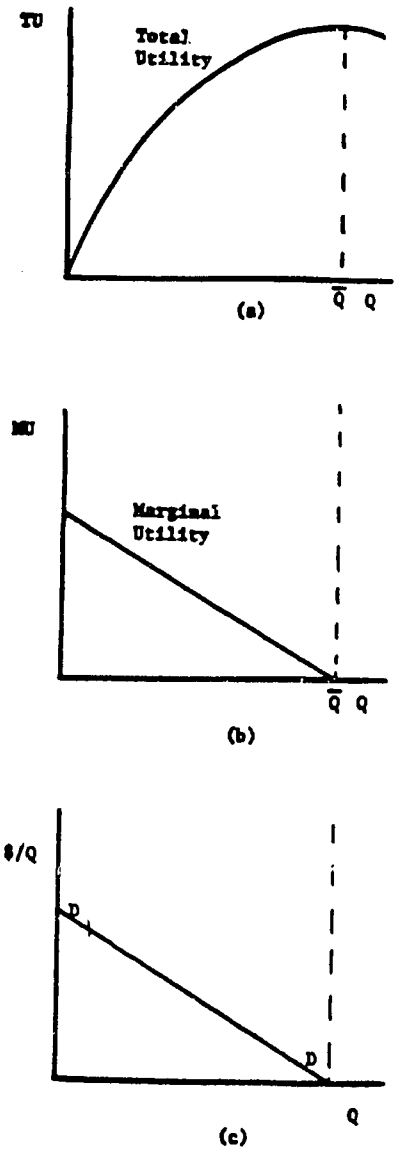


Figure 2.1

In Figure 2.1b, the horizontal axis is unchanged, but the vertical axis measures marginal utility (MU), or the change in total utility due to a change in the consumption of Q. The downward slope of MU indicates that the successive increases in TU become smaller as Q is increased and become zero at $\bar{Q}$ where TU is maximized.

Figures 2.1a and 2.1b demonstrate the Law of Diminishing Utility, which states that as consumption of a good increases, total utility will ultimately increase at a decreasing rate. Although the law helps explain how satisfaction varies with consumption, it does not show the optimum level of consumption if

good Q is not free. To answer the question of the optimum level of consumer satisfaction, it is necessary to understand the concept of demand.

Demand

In Figure 2.1c, Figure 2.1b has been reproduced, except that the vertical scale has been converted to dollars by assuming that each MU unit is worth one dollar. This assumption may seem heroic since satisfaction cannot be measured directly, but the analogy to observed consumer behavior is appropriate. The vertical axis of Figure 2.1c can now be interpreted as the price ($/Q) the consumer is willing to pay for one more unit of Q. The downward sloping shape of the curve in Figure 2.1c follows the Law of Demand, which states that an individual will consume more of a good if the price is lowered. The curve is identified as DD to note that is is a demand schedule.

The consumer's satisfaction due to consumption of good Q is jointly determined by the marginal utility of Q, the marginal utility of Q with respect to the consumption of other closely related goods, and the amount of income or wealth available for purchasing Q and the other closely related goods. The level of income or purchasing power serves as a constraint on the quantity of each good that can be purchased, and therefore added to the consumer's level of satisfaction (TU).

The market demand curve for a good is found by summing all individual demand curves horizontally. The market demand curve shows the set of prices at which consumers are willing to buy corresponding quantities of the good in a certain place during a

certain time. The quantity of a good demanded in the market (Q_d) is a function of price per unit (P), prices of closely related goods (P_{crg}), disposable income (Y), and population (Pop), or

$$Q_d = f(\underset{(-)}{P}, \underset{(-,+)}{P_{crg}}, \underset{(+)}{Y}, \underset{(+)}{Pop}) \qquad [2.1]$$

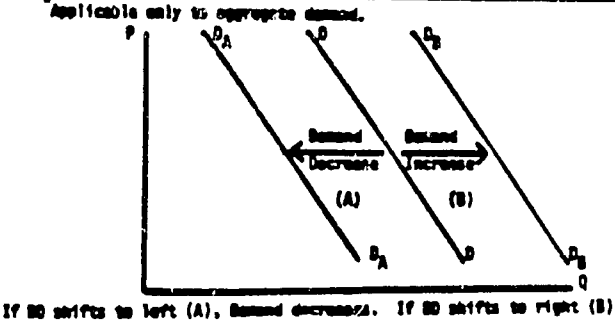
Price is inversely related to Q_d according to the Law of Demand. Income and population are normally directly related to Q_d. The relationship between Q_d and the prices of closely related goods may be either inverse or direct. If the price of a closely related good is inversely related to Q_d, the related good is tentatively labeled as a substitute for Q. If Q_d varies directly with P_{crg}, then the related good is tentatively labeled as a compliment for Q.

Figure 2.2 summarizes the distinctions between "changes in demand" and "changes in the quantity demanded". The phrase, "change in demand" is commonly meant to be a change in the quantity of a good purchased by consumers due to changes in demand shifters. The demand shifters in equation 2.1 are prices of closely related goods, disposable consumer income, and, at the aggregate level, population. When the market

EFFECTS OF CHANGES IN PRICE AND DEMAND SHIFTERS ON DEMAND AND QUANTITY DEMANDED

Kind and Direction of Change →	INCREASE		DECREASE	
	ΔQ_D	ΔD	ΔQ_D	ΔD
Price	decrease	no change	increase	no change
Consumer Disposable Income	increase	increase (B)	decrease	decrease (A)
Price and Substitute Good	increase	increase (B)	decrease	decrease (A)
Price of Complimentary Good	decrease	decrease (A)	increase	increase (B)
Tastes, Preferences	increase	increase (B)	decrease	decrease (A)
Population*	increase	increase (B)	decrease	decrease (A)

*Applicable only to aggregate demand.



If DD shifts to left (A), Demand decreases. If DD shifts to right (B), Demand increases.

Figure 2.2

price changes, demand, or the schedule of quantities of the good that will be purchased at a corresponding series of prices, does not change—there is a change in the quantity demanded, which is represented by movement along the demand curve. Tastes and preferences are treated as demand shifters in Figure 2.2, although economists increasingly arguing that tastes and preferences vary by ethnic or cultural traits, but are ultimately determined simultaneously with utility functions and are therefore not truly independent demand shifters. In Figure 2.2, tastes and preferences are assumed to reflect habits that increase the satisfaction or utility associated with the consumption of good Q.

Price Elasticity of Demand

Demand relationships are often described in terms of elasticities. For the simple demand function in equation 2.1, the own-price elasticity of demand is defined as:

$$E_p = \frac{\%\Delta Q_d}{\%\Delta P} \qquad [2.2]$$

and

$$E_p = \frac{\partial Q_d}{\partial P} \frac{P}{Q_d} \qquad [2.3]$$

In equation 2.3, $\partial Q_d/\partial P$ is the slope of the demand curve and the parameter for price in equation 2.1. Since the slope of the demand curve is negative, the price elasticity of demand must be a negative value. For values greater than -1, but less than zero, the price elasticity of demand is commonly described as price <u>inelastic</u>. This means that a one percent <u>increase</u> in price causes <u>less</u> than a one percent <u>decrease</u> in the quantity demanded. price elasticity of demand is exactly -1, demand for the good is has <u>unitary</u> elasticity with respect to price—a one percent

increase in price causes a one percent decrease in quantity demanded. Demand is elastic with respect to price if E_p is less than −1, meaning that a one percent increase in price causes more than a one percent decrease in the quantity demanded.

EXAMPLE 2.1

Suppose a simple demand equation is estimated by statistical methods as:

$$Q_d = 100 - P \qquad [2.4]$$

By using equation 2.2, the price elasticity of demand for prices of 20, 50, and 80 can be calculated as follows:

P	Q_d	$\frac{dQ_d}{dP}$	$\frac{P}{Q_d}$	E_p
20	80	−1	0.25	−0.25
50	50	−1	1	−1
80	20	−1	4	−4

WHAT HAPPENS TO THE ELASTICITIES WHEN THE PRICE COEFFICIENT IS CHANGED TO −2 (SLOPE OF THE DEMAND CURVE MADE TWICE AS STEEP)?

WHAT HAPPENS TO THE ELASTICITIES WHEN THE INTERCEPT IS DOUBLED (200 INSTEAD OF 100), AND THE PRICE COEFFICIENT REMAINS −1 ?

A common example of a demand function with unitary elasticity throughout is the rectangular hypoberla,

$$Q_d = \frac{a}{P}, \qquad [2.5]$$

where a is a positive constant. The derivative of this function not only expresses the rate of change in Q_d with respect to a unit change in P, but is also the price elasticity of demand.

The derivative can be found by two different rules. First,

the function can be restated as a power function:

$$Q_d = aP^{-1} \qquad [2.6]$$

where $\frac{dQ_d}{dP} = -aP^{-2}$, and $E_p = \frac{dQ}{dP}\frac{P}{Q} = \frac{-aP-2P}{aP^{-1}} = -1$

Equation 2.6 can be restated in logarithms as:

$$\ln Q_d = \ln a - \ln P \qquad [2.7]$$

and $\frac{d \ln Q_d}{d \ln P} = -1$, which is the instaneous rate of proportional change in the function, or price elasticity of demand. From these results, it should be apparent that the price elasticity of demand of any double-logarithmic function in the general form, $\ln Q_d = \ln a + b \ln P$, is b (which must be negative), the slope coefficient for the logarithm of price. The ease of calculating the price elasticity has made the double-log function a popular specification for demand equations.

If a demand function is specified as linear in all variables, the price elasticity of demand varies at each point on the demand curve. This can be confirmed by evaluating the elasticities for equation 2.4. It should also be noted that the absolute value of the elasticity varies directly with price.

Double-log demand functions have constant price elasticities for all points on the demand curve. This fact should be considered before deciding how to specify a demand function.

EXAMPLE 2.2

Suppose the following price-quantity data are collected on a particular market. Ten data points are observed and prepared for estimation of the market demand function using regression methods. The main objective is to estimate the price elasticity of demand. The data are as follows:

obs.	Q	P
1	5	8.5
2	12	8.4
3	22	6.2
4	37	4.6
5	43	5.2
6	51	3.3
7	62	2.3
8	77	2.8
9	82	1.7
10	95	1.2

A linear demand function is specified as:

$$Q_d = a + bP \qquad (b \text{ assumed} < 0)$$

Ordinary least squares (OLS) regression procedures were used to estimate the equation as:

$$Q_d = 97.8 - \underset{(1.14)}{11.1}P$$

$$R^2 = .92$$

Regression std. error of est. = 9.0

The standard error of estimate of the price parameter is in parentheses. The "t" value for the price variable is 9.8 and the t value for 8 degrees of freedom at the 1% confidence level is 2.89, so there is less than a 1% chance that the price coefficient is zero.

A double-log demand function was specified for the data as:

$$\ln Q_d = a + b \ln P \qquad (b \text{ assumed} < 0)$$

The OLS estimate of this function using the same data is:

$$\ln Q_d = 5.23 - \underset{(.24)}{1.26} \ln P$$

$$R^2 = .78$$

Regression std. error of est. = .47

PLOT OF RAW DATA AND TWO DEMAND EQUATIONS

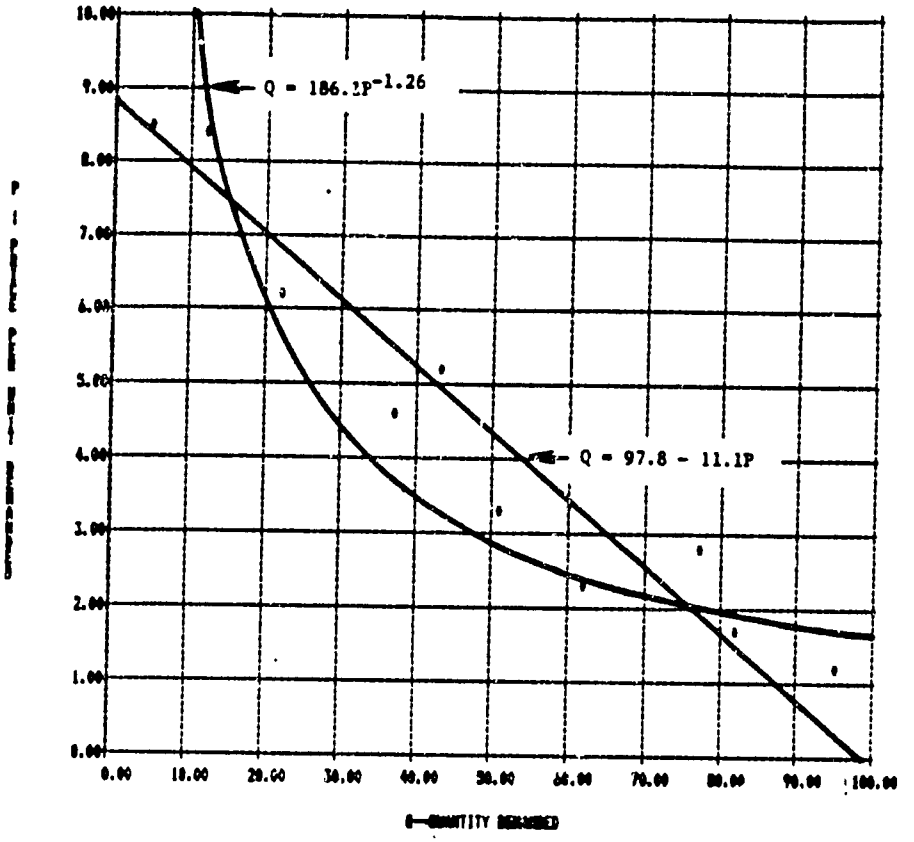


Figure 2.3

The "t" value is 5.3, so there is also less than a 1% chance that the price coefficient of this equation is zero.

The statistical results show that the linear equation has better "goodness of fit", but it is not necessarily chosen by the researcher. Figure 2.3 presents the two equations over a plot ot the raw data. Notice that the double-log function has been converted into a power function by taking the anti-log of the intercept, or raising "e" to the 5.22(63) power.

It is commonly assumed that observed price-quantity data points signify the intersection of a set of supply and demand curves that are in equilibrium at predetermined values of various exogeneous, supply and demand shifters.

Following this assumption, what are the price elasticities of demand for each equation at observed prices 1.7, 5.2, and 8.4?

	Price Elasticity of Demand		
Eq.	P=1.7	P=5.2	P=8.4
Linear	_____	_____	_____
Log-log	_____	_____	_____

How do you interpret the elasticities? Which equation do you prefer? Why?

The Demand System

The discussion above has been limited to a single demand equation. Because of consumption interdependence between goods and the simultaneous nature of many consumption activities, a single demand equation is often inadequate for explaining the consumption of a good. Changes in prices and income have implications about the mix of goods consumed in the household that is ultimately reflected in economy-wide consumption patterns. A person consumes i=1,2,...,m goods and his m x m demand system can be aggregated to represent large groups of consumers.

The consumer's chief objective is to maximize total utility from the consumption of m goods, subject to the amount of income he can spend on any combination of the goods. The problem can be stated as:

$$\max U(Q_1,\ldots,Q_m) \text{ subject to } \sum_{i=1}^{m} P_i Q_i = I \qquad [2.8]$$

where $U(Q_1,\ldots,Q_m)$ is the utility function for m goods, P_i is the unit price of the i-th good, Q_i is the quantity of the i-th good consumed, and I is the total income or wealth available to spend on all of the goods. The utility function is assumed to have a

shape similar to the function in Figure 2.1a, with respect to each good.

By defining the constrained maximization problem as the Lagrangian:

$$L(Q,\lambda) = U(Q) + \lambda(I - PQ) \quad , \qquad [2.9]$$

the necessary and sufficient (Kuhn-Tucker) conditions for a global maximum are:

$$\frac{\partial U}{\partial Q_i}(Q_i,\ldots,Q_m) - \lambda P_i = 0$$

$$(i = 1,\ldots,m) \qquad [2.10]$$

and

$$I - \sum_{i=1}^{m} P_i Q_i = 0$$

Solving this system yields the optimum levels of Q that maximize utility subject to the income constraint. The solution also allows the derivation of m demand functions:

$$Q_i = q_i(P_i,\ldots_m, I) \qquad [2.11]$$

$$(i=1,\ldots,m)$$

The price elasticity of the i-th good with respect to the j-th price is:

$$E_{ij} = \frac{\partial Q_i}{\partial P_j}\frac{P_j}{Q_i} = \frac{\partial \ln Q_i}{\partial \ln p_j} \qquad [2.12]$$

$$(i,j=1,\ldots,m)$$

Where $i=j$, E_{ij} denotes the own-price elasticity. For $i \neq j$, E_{ij} denotes the cross-price elasticity of demand.

The income elasticity of the i-th good is:

$$\eta_i = \frac{\partial Q_i}{\partial I}\frac{I}{Q_i} = \frac{\partial \ln Q_i}{\partial \ln I} \qquad [2.13]$$

In order for the demand equations to meet theoretical conditions for utility maximization, the system of m equations must satisfy several restrictions. The budget constraint has already been imposed. The proportion of income spent on a good is called the budget share, s_i,

$$s_i = \frac{P_i Q_i}{I} \qquad [2.14]$$

$$(i=1,\ldots,m) \quad ,$$

and the budget shares must sum to 1 in order to fully utilize income.

If all prices and income are doubled, the quantity of a good demanded will not change. This means that each demand equation is homogeneous to degree zero. Following Euler's theorem on homogeneous functions, the homogeneity restriction on the i-th demand equation is:

$$\sum_{(i=1)}^{m} E_{ij} + \eta_i = 0 \qquad [2.15]$$

$$(j=i,\ldots,m)$$

The third set of restrictions are the Slutsky conditions, which require, in elasticity form, the following negativity conditions:

$$E_{ii} + s_i \eta_i \leq 0 \qquad [2.16]$$

$$(i=1,\ldots,m) \quad ,$$

and the following symmetry conditions:

$$\frac{E_{ij}}{s_j} + \eta_i = \frac{E_{ji}}{s_i} + \eta_j \qquad [2.17]$$

$$(i,j=1,\ldots,m)$$

Equation 2.16 is one of the most important conditions that a demand system must satisfy. The equation is used to classify goods into one of three categories based on the slope of the demand curve and the first derivative of Q_d with respect to income. If the price slope is negative, the good is a normal good. If the price slope is positive, the good is a Giffen good. If the income slope is positive, the good is a superior good. Finally, if the income slope is negative, the good is an inferior good.

The combined effects of income and price changes result in three classifications of goods. A normal, superior good shows decreased consumption as price increases, but increased consumption as income increases. A normal, inferior good shows decreased consumption as both price and income increase. Finally, a Giffen good shows increased consumption as price increases, but decreased consumption as income increases. It should be evident from the specification of the utility function that a fourth category, where consumption increases when both price and income increase, is inconsistent with basic theory.

EXAMPLE 2.3

The category that describes the price and income consumption behavior of a good will vary with the income level of the consumer. International comparisons of consumption behavior also demonstrate that a good may not be in the same category in every country.

LIST SOME FOODS FOR EACH OF THE THREE CATEGORIES. HOW MIGHT THEIR CLASSIFICATIONS VARY WITHIN A COUNTRY AND BETWEEN COUNTRIES?

The fourth restriction is the Engle aggregation or "adding up" condition. This condition follows from the budget constraint

in elasticity form as:

$$\sum_{(i=1)}^{m} s_i \eta_i = 1 \qquad [2.18]$$

The final restriction is necessary to satisfy the Cournot aggregation conditions. This restriction is sometimes called the "column" restriction. In elasticity form, each price column of the of the demand equation system must meet the following conditions:

$$E_{ii} s_i + \sum_{(j=1)}^{m=1} E_{ji} s_j = -s_i \qquad [2.20]$$

$$(i=1,\ldots,m\ , \quad \text{and } i \neq j \text{ for each } E_{ji})$$

<u>The Demand Elasticity Matrix</u>

The primary product of any analysis of a demand system should be the production of a demand elasticity matrix. For an m-goods system, there should be m demand equations, with the quantity demanded expressed as a function of all m prices and the total expenditures for all m goods. After applying the restrictions discussed above, statistical estimation should produce price and income coefficients that can be used to construct an elasticity matrix that has m rows (1 row per demand equation/good) and m+1 columns (1 column per good for own-price and cross-price effects, and an addition column for the income effect). The price components of the system can be specified as a matrix D with dimensions m x m. Each element of the matrix, D_{ij}, is analogous to E_{ij} above and defines the elasticity of product Q_i with respect to price P_j. Where i=j, D_{ij} is the own-price elasticity of demand and has a negative sign. For all off-diagonal elements (i≠j), D_{ij}

is the cross-price elasticity of demand and the signs may be negative or positive.

Changes in quantities demanded ΔQ, can be predicted with respect to changes in product prices by measuring changes as percentages and post-multiplying the system demand elasticity matrix, D, by a vector of price changes (percent changes), ΔP, as follows:

$$\underset{(m \times 1)}{\begin{bmatrix} \Delta Q_1 \\ \vdots \\ \Delta Q_m \end{bmatrix}} = \underset{(m \times m)}{\begin{bmatrix} D_{11}, \ldots, D_{1m} \\ \vdots \qquad \vdots \\ D_{m1}, \ldots, D_{mm} \end{bmatrix}} \underset{(m \times 1)}{\begin{bmatrix} \Delta P_1 \\ \vdots \\ \Delta P_m \end{bmatrix}} \qquad [2.21]$$

where ΔQ is a $m \times 1$ column vector of changes in quantities demanded; D is an $m \times m$ square matrix of price elasticities of demand; and Δ is an $m \times 1$ column vector of price changes.

EXAMPLE 3.4

Suppose a hypothetical demand system is comprised of 3 goods (m=3). Assuming predetermined values for D and a 3 percent increase in the price of each goodf, ΔQ is determined (in percent changes) as follows:

$$\begin{array}{c} \Delta Q \\ ___ \\ ___ \\ ___ \end{array} \begin{bmatrix} -3.0 \\ -2.7 \\ -3.3 \end{bmatrix} \quad \begin{array}{c} S \\ \begin{bmatrix} -0.8 & 0.2 & -0.4 \\ -0.1 & -1.1 & 0.3 \\ 0.2 & -0.4 & -0.9 \end{bmatrix} \end{array} \quad \begin{array}{c} \Delta P \\ \begin{bmatrix} 3.0 \\ 3.0 \\ 3.0 \end{bmatrix} \end{array}$$

Notice how the structure of the D matrix causes a system-wide 3 percent increase in prices to have different impacts on consumer response.

Suppose good 2 (i=2) has a 3 percent increase in price, but the other two goods have no price changes. What would be the predicted percent changes in the quantity of each good demanded? Record the new ΔQ values in the appropriate blanks and compare the differences in the two ΔQ's.

The demand elasticity matrix, D, gives the policy analyust a powerful means of predicting or simulating consumers' responses to assumed or predicted price changes. Before D can be estimated, a wide assortment of consumption data should be collected and analyzed.

Food Consumption Data Needs

Food policy analysis requires several types of data on food consumption behavior. Information is needed on aggregate, economy-wide consumption levels and corresponding prices. Food consumption data are also needed from household-level data collection methods. Food consumption patterns should be monitored over time to detect trends in habit formation. Finally, any food consumption monitoring system should make a major effort to collect data that can be segmented by geographic area and by income level.

Many countries make periodic estimates of food consumption at the national level by means of supply-demand balance (SDB) studies of annual differences imports, exports, farm production, and food stocks. These estimates reflect the assumed net results of food consumption among the economy's many different socio-economic groups. This method produces estimates of quantities consumed which can be divided by population to arrive at an estimated level of consumption per capita. Prices paid by consumers cannot be reasonably measured by this method because the procedures for tracking prices are usually much more difficult and expensive than quantity estimation.

Estimates of food consumption by the SDB method should be complemented by other data collection systems that monitor food

consumption directly at the household level. Household survey methods are costly, but they provide information that cannot be reasonably estimated by other methods. Food prices and expenditures estimated from household surveys are more likely to measure retail prices than other estimates based on data collected at points in the food marketing chain before the retail level. Food consumption estimates from household surveys are also useful for making comparisons with SDB esitmates to evaluate the consistency and validity of the two methods. Household surveys should also provide estimates of food consumption according to demographic characteristics.

Household food consumption surveys should be based on appropriate random sampling procedures. The type and quality of data collected by surveys is related directly to the amount of resources committed to the surveys.

One of the most costly, but useful surveys involves a panel of households that are reinterviewed several times over a three to five year period. Survey panels have high start-up costs, but the respondents become much more proficient than in the case of one-time interviews.

If a household is asked to state its food consumption for a certain time period during one interview, the responses will have high error rates unless the interviewers: receive extraordinary training; use a sophisticated questionnaire; and spend well over one hour on the interview. An alternative to the one-time interview is the food consumption/expenditure diary. The interviewer visits the household at least twice. On the initial

visit, the interviewer establishes rapport with the household and explains the information to be collected. During the next few days or weeks, a designated member of the household records food consumption and food expenditure information at frequent intervals, perhaps once a day. The interviewer may revisit the household before the diary is completed to make sure the records are being kept correctly. At the end of the diary period, the interviewer visits the household a final time to collect the diary and make brief field checks for data consistency, accuracy, and completeness.

Most household food consumption surveys only collect food expenditure data because of the great difficulty in measuring quantities of foods consumed. Food expenditures do not give separate estimates of price and quantity, which complicates the econometric procedures used in estimating elasticities. Fortunately, an econometric method aptly named the linear expenditure system can estimate a theoretically valid set of elasticities without having separate price and quanty data.

Demand Elasticity Estimation Procedures

The past two decades have witnessed a dramatic increase in econometric methods of estimating demand elasticities. Much of the progress has been due to the increased availability of main-frame computing systems. Many other advances have occured simply through standardization of procedures. Demand systems are now estimated with increasing frequency in the United States, Australia, Canada, and Western Europe. In the developing countries, demand estimation is primarily by single-equation methods because of inadequate data, a shortage of trained

researchers, and limited computing resources.

Specification of Statistical Estimation Model

Demand models are classified as either single equation models or systems of equations models. The linear demand model specifies the quantity of a good demanded (Q_d) as a linear function of the good's price, the prices of closely related goods, and income. In this model, income is generally specified as total expenditure or total disposable income. The specification of the semilogarithmic demand function the same functional form and raw variables as the linear demand model, however all "right-hand side" variables (prices and income) are transformed into logarithms. The most commonly used single equation model is the log linear, double log, log-log or constant elasticity form. It is a simple modification of the linear demand model by converting all variables to logarithms. It is a popular functional form because the price and income regression coefficients are also constant elasticities, as was demonstrated with equations 2.5-2.7. Single equation models often produce biased elasticity estimates, particularly for the income and cross-price elasticities.

Systems of equations models allow more rigorous imposition of theoretical restrictions than single equation models. There are three general groups of systems of equations specifications. The specified utility function group includes the linear expenditure model, which is one of the most commonly used systems of equations models. The specified indirect utility function group includes the indirect addilog system and is generally implemented by inserting demand functions into the utility function. The other group

consists of the constant elasticity system, which in its simplest form specifies each demand equation in the system as a double logarithmic function.

The log linear systems of equations specification is popular beause of its ease of implementation and interpretation. For a system of m goods, the i-th demand equation can be specified in a log linear regression equation as follows:

$$\ln Q_i = a + \sum_{(i=1)}^{m} b_i \ln P_i + b_{iI} \ln I + e_i \qquad [2.22]$$

where $\ln Q_i$ is the natural logarithm of the quantity demanded of the i-th good; a is the intercept of the equation; b_i is the regression coefficient and elasticity of the price of the i-th good; $\ln P_i$ is the natural logarithm of the price of the i-th good; b_{iI} is the regression coefficient and the elasticity of Q_i with respect to total expenditures on m goods; lnI is the natural logarithm of total expenditures; and e_i is the statistical error associated with the estimation of the i-th demand equation.

Restrictions on the Demand System

The theoretical restrictions summarized in equations 2.14-2.20 can be imposed on the regression coefficients of equation 2.22. The m-equation system can then be estimated for m own-price elasticities, m^2-m cross-price elasticities, and m income or expenditure elasticities. Symmetry conditions will insure that the own-price elasticities are negative.

System Estimation Procedure

The m-equation system can be conveniently estimated with a generalized least-squares estimation procedure commonly noted as the "seemingly unrelated equations" or "seemingly unrelated

regressions" (SUR) technique. SUR estimates all equations in the system simultaneously, but does not have explanatory endogeneous variables. Each Q_i is endogeneous, but appears only in the i-th equation.

The SUR procedure can be summarized in three steps. First, OLS is applied to each equation. Next, an m x m covariance matrix is created from the residuals of each equation in the first step. The degree of correlation of these residuals indicates the extent that equations in the system are not independent. The third step is the generalized least-squares estimation of all parameters in the system using the covariance matrix of step 2.

The Sri Lanka Demand System

Chieruzzi, Morgan, Yetley and Tun have assessed the application of SUR to a 12-equation demand system. Each equation was specified in double logarithmic form. The data were collected in 1969-70. Price and quantity data were collected on household consumption of more than 100 food items during a 7 day period.

Table 2.1 presents the matrix of price and income elasticies created by weighting 10 sub-population elasticity matricies estimated for five income groups in urban and rural areas. The first 12 columns (rows) list the own-price and cross-price elasticities of demand for rice (RIC), cereals (CER), food consumed away from home (FAH), spices (SPI), vegetables (VEG), fish (FIS), animal products (ANI), fruits (FRU), sugar (SUG), edible oils (OIL), alcohol-tobacco-betel nuts (ALC), and non-alcoholic beverages. The thirteenth column (I) lists the income elasticities of demand for each of the 12 food groups.

Table 2.1 Sri Lanka Elasticity Matrix for 12 Foods

	RIC	CER	FAH	SPI	VEG	FIS	ANI	FRU	SUG	OIL	ALC	NAL	I
RIC	-.65	-.04	-.16	-.01	-.00	.01	-.08	-.04	.02	-.05	-.14	.02	1.16
CER	.07	-.58	-.03	-.03	.03	-.12	-.01	-.00	.01	.07	-.05	-.02	.82
FAH	-.42	-.12	-.19	-.04	-.05	-.05	-.03	-.06	-.01	-.00	.08	-.01	.90
SPI	.02	-.08	-.03	-.70	-.05	-.06	-.03	.03	.03	-.01	-.05	.04	.90
VEG	.05	-.01	-.03	-.05	-.73	.17	-.09	.04	-.02	-.09	-.07	-.02	.87
FIS	.06	-.19	-.03	-.07	.14	-1.01	.14	-.03	.01	-.00	-.08	.02	1.08
ANI	-.07	-.13	-.04	-.05	-.10	.14	-.80	.00	.00	.02	-.01	-.02	1.13
FRU	-.06	-.05	-.06	.03	.03	-.01	.04	-.84	-.06	.06	.03	-.00	.89
SUG	.12	-.04	.00	.04	-.00	.03	.05	-.04	-.96	-.01	.01	.00	.82
OIL	-.42	.17	-.01	-.04	-.36	-.01	.10	.20	-.06	-.54	.06	-.11	1.06
ALC	-.22	-.12	.03	-.07	-.10	-.07	-.03	-.01	-.02	.01	-.61	-.01	1.23
NAL	.19	-.13	-.03	.16	-.08	.08	-.09	-.02	-.01	-.13	-.04	-.88	.98

Validity Issues

There are several problems that complicate the estimation procedures when survey data are used to estimate demand equations. Nonconsumption of each food group causes zero values to be used in a function specified as double logarithmic, which is mathematically infeasible. Quantity consumption data are important sources of information for calibrating national SDB consumption estimates and estimating individual nutritional status. Food consumption should monitored over time and over wide ranges of household income in order to have a better understanding

of changing food consumption habits and the effects of these changes on low income households.

The Zero Consumption Problem

Many household observations were removed from the Sri Lanka data set because at least one food group was not consumed by the household during the survey period. These observations would have introduced zero values into a model that requires all variables to have positive, non-zero values in order to be transformed into logarithms.

If the observations were retained in the data set, an alternative function form would be necessary. Researchers sometimes include these observations at very low consumption values (.1) and estimate the price that would have been paid for that amount as some multiple of the mean price or highest price paid by other consumers. This technique raises as many validity questions as the practice of removing the nonconsumers.

Measures of Consumption Quantities

One of the greatest advantages of household food consumption surveys is the opportunity to measure actual food intake. This information is important for nutritional and medical programs targeted for undernourished subpopulations.

The quantity measures of household food consumption also help nation food policy analysts evaluate the accuracy of other macro food consumption estimation procedures. The household estimates are also useful in assessing historical records on food consumption.

Consumption Over Time, Income, Regions

It is important to update household surveys at least once every decade in order to assess subtle changes in food consumptic habits that may one day present a serious food policy problem. A new surveys are completed, newly estimated demand systems can be estimated and compared with previous estimates. Changes in price and income elasticities over time and over income classes have important policy implications for planning new agricultural development projects.

The surveys should also attempt to improve the knowledge of food consumption in geographic areas targeted for development assistance, but underrepresented in aggregate food consumption statistics. Regional variation in food consumption usually has an income component, but ethnic and cultural influences can be power forces for modifying the elasticity structure.

CHAPTER 3

SUPPLY

Food policy analysis ultimately requires a detailed set of information about the responsiveness of farmers to changes in product and input prices. The policy analyst must be concerned with maintaining current and historical data that can be used to develop models of farm production behavior. Parameters estimated in supply response models provide policy analysts the means to depict interaction between the farm sector and household food consumption.

Producer Behavior

Farmers attempt to maximize profits by producing a commodity with technical efficiency at a level that is appropriate for the selling price and the cost of production. In order to achieve technical efficiency, the producer must know the nature of the input-output relationship for the product.

The Production Function

Figure 3.1 shows a production function that exhibits the three possible input-output relationships. In Figure 3.1a, the horizontal axis measures units of an input (X), such as labor, fertilizer, or irrigation water, and the vertical axis measures units of output as total physical product (TPP), such as rice, wheat, or cotton. As inputs are increased from the zero level, output increases at an increasing rate until point A is reached on the TPP curve. As additional inputs are used, output continues to increase, but at a decreased rate, until output is at a maximum at point C. As inputs are added beyond X_c, TPP declines. This

input-output relationship commonly occurs in biological processes and is ideally suited to demonstrate the economics of production.

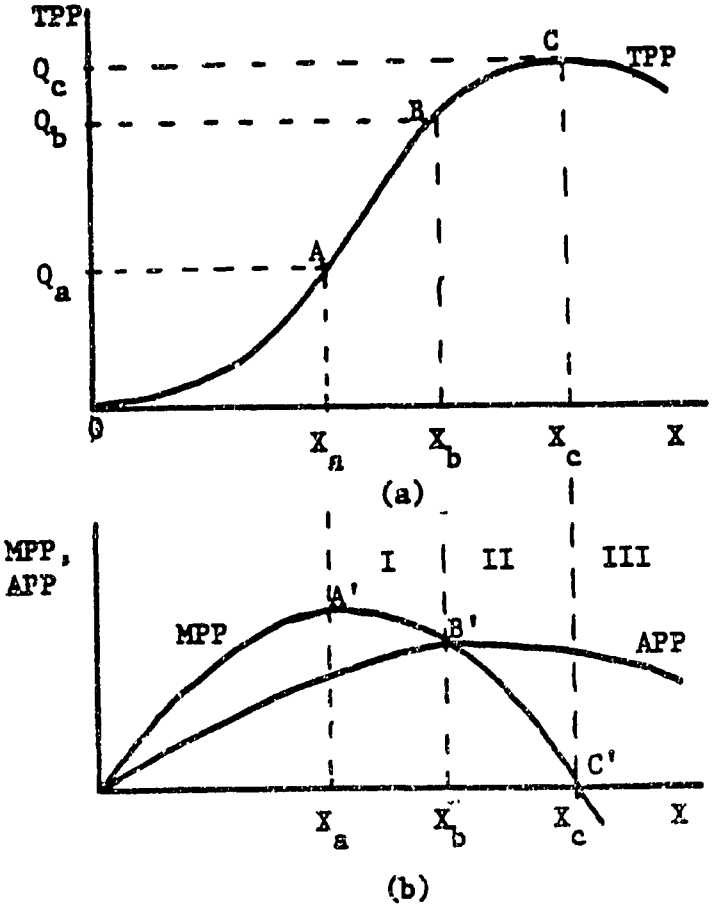


Figure 3.1

In Figure 3.1b, the horizontal axis is unchanged, but the vertical axis measures two attributes of the function in Figure 3.1a. The slope of the TPP curve, or change in output due to a change in input, is measured by the marginal physical product (MPP) curve. MPP is a maximum at point A', where the inflection point occurs on TPP, but falls to zero at point C', where TPP is a maximum. The range of X from X_a to X_c demonstrates the Law of Diminishing Returns, which states that as inputs are added to a production process, output will ultimately <u>increase</u> at a <u>decreasing</u> rate. The law describes physical limits to production, which occurs at point C in Figure 3.1a. By understanding this input-output relationship, the producer knows that any input level greater than X_c would be wasteful.

Units of output per unit of input (APP) is a maximum at point B' in Figure 3.1b. This point indicates maximum technical efficiency in the production of Q. Point B also indicates the <u>minimum</u> level of output where the producer <u>may</u> be able to earn enough from sales of Q to equal the cost of X.

If X is not free, then profit will not be maximized at point C, as will be demonstrated below. Therefore, if any profit is to be made from this production process, it will come from production levels somewhere between Q_b and Q_c in what is called Stage II of Production. Stage I (all points below B) is irrational because technical efficiency has not yet been achieved. Stage III (point C and all points to the right of C) is irrational because either too many inputs are used, or (in the case of point C) the last incremental increase in X produces nothing and therefore cannot pay for itself.

<u>Costs of Production</u>

The producer faces two types of costs in the production of Q. The cost of the variable input X is a <u>variable cost</u>. Taxes, depreciation on equipment and buildings, land and equipment rents, and capital charges do not vary with the level of production and are classified as <u>fixed costs</u>. Figure 3.2a shows the costs of production where total fixed costs (TFC) are constant for all levels of output and total variable costs (TVC) varies directly with the price of X and directly with Q, but at opposite

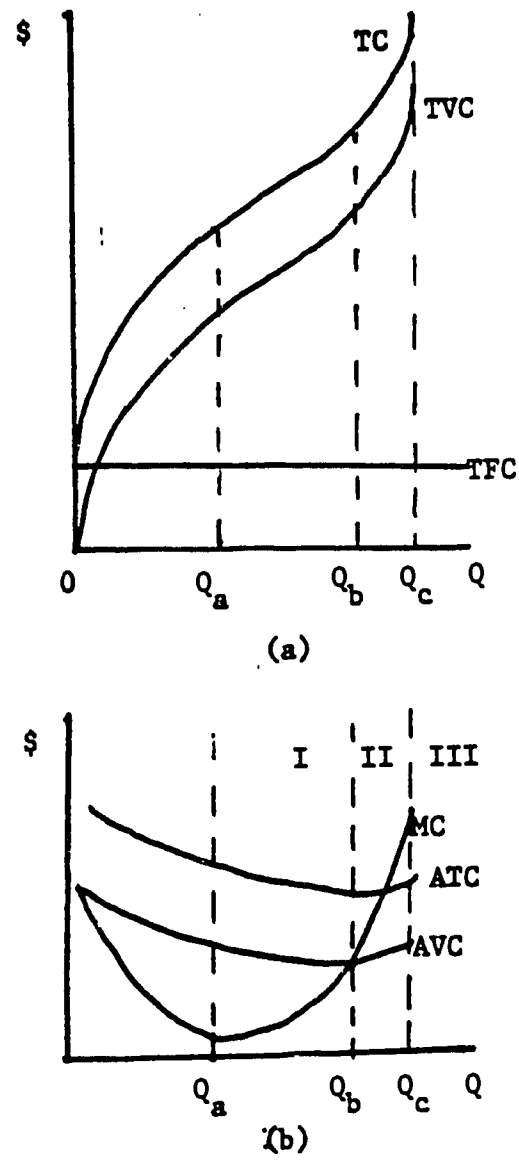


Figure 3.2

rates of change from the production function. Total cost of production (TC) is the sum of TFC and TVC.

The unit cost curves in Figure 3.2b reflect the symmetry of Figure 3.1b. At output level Q_a, the change in total production costs per unit change in output, or marginal cost (MC) is at a minimum. At Q_b, the beginning of Stage II of Production, the average variable cost (AVC) is a minimum and equal to MC. Average total cost of production (ATC) is a minimum at a point between Q_b and Q_c.

Profit Maximization

In Figure 3.3a, profit, the excess of total revenue (TR) above total production costs (TC) is greatest at output level Q'. Since TR is the product of selling price and quantity sold, the TR curve represents a constant price for all levels of output.

In Figure 3.3b, the unit cost curves show that profit would be zero at price P_3 and output Q_3. At price P_4, the producer will produce Q_4 and his profit per unit of output will be the difference between P_4 and average total cost (ATC) at Q_4. At price P_2, the producer would produce Q_2, but only for a short period of time because that price

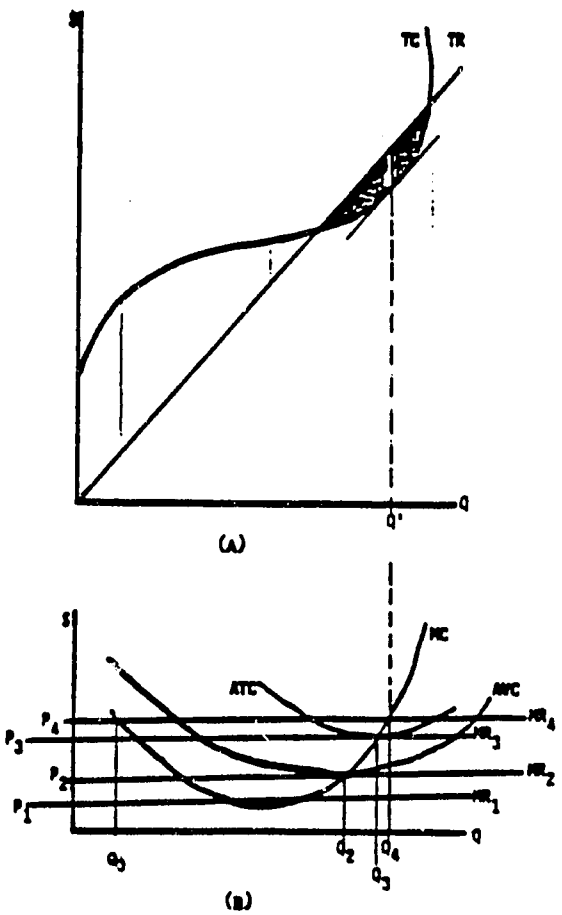


Figure 3.3

will only pay for the variable cost of production (the cost of input X). At price P_1, no production will occur because the product price will not even pay for variable costs.

At Q' in Figure 3.3a, the slope of TC (MC) is equal to the slope of TR (MR). The corresponding level of output in Figure 3.3b, Q_4, marks the level of output where the selling price, P_4, which is also marginal revenue (MR_4), is equal to MC. It should now be apparent that over the range of production where TR exceeds TC, profit will be maximized at the level of output where marginal cost equals marginal revenue. It should be noted that MC also equals MR at output level Q_0, but profit is <u>minimized</u> (loss is maximized) because production is in Stage I.

<u>Supply</u>

Figure 3.4a is a simplified version of Figure 3.3b. Note that as price varies from P_2 to P_4, output varies from Q_2 to Q_4, respectively. When price is in the P_2-P_3 range, the producer will be able to pay for variable production costs, but not all of fixed production costs will be covered. Over a short period of time, the producer will tolerate such low prices, but he will ultimately have to receive a price of at least P_3 in order to cover both fixed and variable

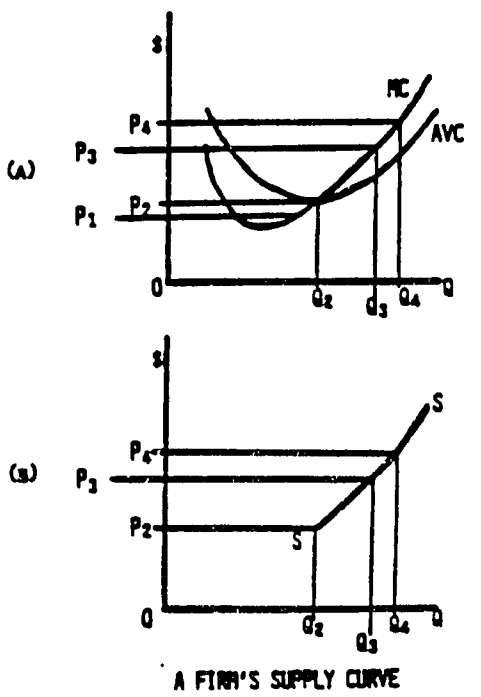


Figure 3.4

costs of production.

Figure 3.4b includes only that part of the marginal cost curve that is equal to, or greater than average variable cost. This portion of MC is the producer's <u>supply curve</u>. It is a schedule of quantities of the product that will be offered for sale at a corresponding set of prices. The Law of Supply states that the quantity offered for sale will increase as the price increases. At each point on the supply curve, the producer operates at the level of production where MC=MR, which maximizes total revenue minus total variable costs.

In a simplified view of the producer's market, the quantity of a good supplied (Q_s) is a function of unit price (P), the level of technology (T), and the price of variable inputs (W), or

$$Q_s = f(\underset{(+)}{P}, \underset{(+)}{T}, \underset{(-)}{W}) \qquad [3.1]$$

Price is directly related to Q_s, according to the Law of Supply. As technology increases, MPP increases and MC decreases, causing Q_s to increase. As input prices increase, MC increases, causing the new MC=MR point to occur at a lower level of output. In the case of agriculture, the quantity of food and fiber supplied is also directly related to weather favorability (W). As weather conditions become more favorable for the biological process, production increases (or output per unit of variable input increases). Optimum weather conditions will vary according to the biological requirements of the respective production process.

The sum of each farmer's quantity supplied at a particular price is the <u>aggregate</u> quantity supplied at that price for all farmers competing in the market for the commodity in question. In

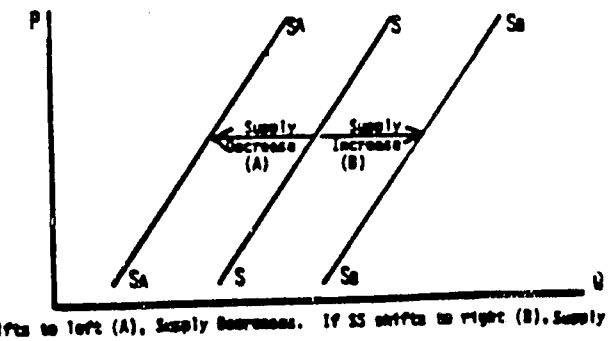
terms of Figure 3.4b, the aggregate supply curve representing all farmers producing a particular commodity is the horizontal summation of each farmer's supply curve. The aggregate supply curve will therefore have approximately the same range of values for the vertical axis as Figure 3.4a. The horizontal axis of the aggregate supply curve will range from zero to the amount of the commodity that all farmers will supply at the highest market price.

The phrase, "change in supply" is commonly meant to be a change in the amount of the commodity offered for sale due to changes in supply shifters. The supply shifters in equation 3.1 are technology, input prices, and, in the case of agriculture, weather. If trade is considered, imports of the commodity are an additional supply shifter. When the market price changes, supply, or the schedule of quantities of the product that will be offered for sale at a corresponding series of prices, does not change—there is a change in the quantity supplied, which is represented by a movement along the supply curve. Figure 3.5 summarizes the distinctions between "changes in supply" and "changes in the quantity supplied".

EFFECTS OF CHANGES IN PRICE AND SUPPLY SHIFTERS ON SUPPLY AND QUANTITY SUPPLIED

Kind and Direction of Change →	INCREASE		DECREASE	
	ΔQS	Δ S	ΔQS	Δ S
Price*	increase	no change	decrease	no change
Variable Input Price*	decrease	decrease (A)	increase	increase (B)
Technology*	increase	increase (B)	decrease	decrease (A)
Weather (favorability)#	increase	increase (B)	decrease	decrease (A)
Imports@	increase	increase (B)	decrease	decrease (A)

* applicable to all firms
\# particularly applicable to agriculture
@ applicable if trade is considered.



If SS shifts to left (A), Supply Decreases. If SS shifts to right (B), Supply Incr

Figure 3.5

Price Elasticity of Supply

Supply relationships are often described in terms of elasticities. For the simple supply function specified in equation 3.1, the own-price elasticity of supply is defined as:

$$E_p = \frac{\%\Delta Q}{\%\Delta P} \qquad [3.2]$$

and

$$E_p = \frac{\partial Q}{\partial P} \frac{P}{Q} \qquad [3.3]$$

EXAMPLE 3.1

Consider the following simple supply equations:

$$Q_s = 1.5 + 5P \qquad [3.4]$$

and

$$Q_s = 6P^{.9} \qquad [3.5]$$

Considering the disucssion on elasticity calculations in the demand section, what is the price elasticity of supply of each of these equations for price levels of 1, 3, and 5?

	Price Elasticity of Supply		
Eq.	P=1	P=3	P=5
3.4	___	___	___
3.5	___	___	___

The Supply System

Thus far, the concept of supply has been presented in terms of only one commodity produced with one variable input. In actuality, farmers often produce more than one commodity and each commodity is produced with more than one variable input. Changes in the national availability of food from domestic sources derive from farm-level production responses to changing input and product

prices. The farmer produces $i=1,2,\ldots,m$ products with $j=1,2,\ldots,n$ inputs, and his $m \times n$ supply system can be aggregated and generalized at the national level.

The farmer's demand for the j-th input for the production of the i-th commodity is a function of all input prices and all product prices as follows:

$$X_{ij} = x_{ij}(W_j,\ldots,W_n,P_i,\ldots,P_m) \qquad [3.6]$$
$$(i=1,\ldots m \; ; \; j=1,\ldots,n)$$

where X_{ij} is the amount of the j-th input utilized by the farm in the production of the i-th commodity; W_j is the unit price of the j-th input; and P_i is the unit price of the i-th commodity. Each input is assumed to be normal ie., the quantity of the input demanded varies inversely with its price and directly with the price of the commodity produced.

The production function for the i-th commodity is defined as:

$$Q_i = q_i(X_{ij},\ldots,X_{in}) \qquad [3.7]$$

where Q_i is the level of physical output of the i-th commodity and X_{ij} is the amount of the j-th input used in the production of the i-th commodity. The function q_i is assumed to be twice-differentiable and obeys the Law of Diminishing Returns.

The profit function for $i=1,2,\ldots,m$ commodities produced with $j=1,2,\ldots,n$ inputs is specified as:

$$\Pi = \sum_{i=1}^{m} P_i q_i - \sum_{i=1}^{m} \sum_{j=1}^{n} W_j X_{ij} \qquad [3.8]$$

where Π is profit, or total revenue (sum of $P_i \times q_i$ over m

commodities) minus total cost for n inputs allocated to m production functions (sum of $W_j \times X_j$ over n inputs and m production functions).

The first-order conditions for profit maximization of the i-th commodity can be expressed as:

$$P_i \frac{\partial q_i}{\partial x_j} (x_j, \ldots, x_n) = W_j \qquad [3.9]$$

Equations 3.7-3.9 define equilibrium inputs, outputs, and profit for the m-commodity, n-input system. The production function (equation 3.7) also yields the output supply function. For the i-th commodity the supply function is defined as:

$$Q_i = s_i (P_i, \ldots, P_m, W_j, \ldots, W_n) \qquad [3.10]$$

where s_i is the supply function for the i-th commodity, in contrast to equation 1 where input demand (X_{ij}) is also a function (x_{ij}) of all input and product prices.

Differentiating profit maximizing conditions with respect to input and product prices yield symmetry and homogeneity comparative static conditions. For input demand functions, the symmetry conditions are:

$$\frac{\partial X_j}{\partial W_k} = \frac{\partial X_k}{\partial W_j} \quad , \quad \text{all } j,k \text{ inputs} \qquad [3.11]$$

For j=k inputs, the sign of the partial derivative will be negative, signifying a negatively sloped input demand curve. For j≠k inputs, partial derivatives with positive signs define inputs j and k as substitutes. If the partial derivatives are negative, inputs j and k are complements.

For output supply functions, the symmetry conditions are:

$$\frac{\partial Q_i}{\partial P_l} = \frac{\partial Q_l}{\partial P_i} \quad \text{for all } i,l \text{ outputs} \qquad [3.12]$$

For i=l outputs, the sign of the partial derivative will be positive, signifying a positively sloped output supply curve. For i≠l outputs, partial derivatives with positive signs define products i and l as complements in supply. If the partial derivatives are negative, products i and l are substitutes.

The conditions that are necessary and sufficient for profit maximization also reveal that all input demand and output supply functions are homogeneous to degree zero in all wages and prices, following Euler's theorem. Homogeneity conditions for input demand and output supply functions, respectively, are:

$$\sum_{k=1}^{n} W_k \frac{\partial X_j}{\partial W_k} + \sum_{l=1}^{m} P_l \frac{\partial X_j}{\partial P_l} = 0 \qquad [3.13]$$

(for k=1,2,...,n inputs)

and

$$\sum_{k=1}^{n} W_k \frac{\partial Q_j}{\partial W_k} + \sum_{l=1}^{m} P_l \frac{\partial Q_j}{\partial P_l} = 0 \qquad [3.14]$$

(for l=1,2,...,m products)

If each term in equation 3.13 is divided by X_j and each term in equation 3.14 is divided by Q_l, the homogeneity conditions for all input demand functions and output supply functions can be stated in elasticity form respectively as:

$$\sum_{k=1}^{n} Ex_j w_k + \sum_{l=1}^{m} Ex_j p_l = 0 \qquad [3.15]$$

(for k=1,2,...,n inputs)

and

$$\sum_{k=1}^{n} Eq_l w_k + \sum_{l=1}^{m} Eq_l p_l = 0 \qquad [3.16]$$

(for l=1,2,...,m products)

where Exw is the input price elasticity of demand for an input; Exp is the product price elasticity of demand for an input; Eqw is the input price elasticity of output supply; and Eqp is the product price elasticity of supply.

<u>The Supply Elasticity Matrix</u>

Analysis of the supply system is more complex than demand analysis because of the inclusion of input prices as crucial supply shifters. A simplified supply system that is compatible with the demand system presented in chapter 2 can be specified as a matrix S with dimensions m x m. Each element of the matrix, S_{il}, is analogous to Eqp above and defines the elasticity of product Q_i with respect to product price P_l. Where i=l, S_{il} is the own-price elasticity of supply, and has a positive sign. For all off-diagonal elements (i≠l), S_{il} is the cross-price elasticity of supply, and the signs may be negative or positive.

Changes in quantities supplied, ΔQ, can be predicted with respect to changes in product prices by measuring changes as percentages and post-multiplying the system supply elasticity matrix, S, by a vector of product price changes (percent changes), ΔP, as follows:

$$\underset{(m \times 1)}{\begin{bmatrix} \Delta Q_i \\ \cdot \\ \cdot \\ \cdot \\ \Delta Q_m \end{bmatrix}} = \underset{(m \times m)}{\begin{bmatrix} S_{i1}, \ldots, S_{im} \\ \cdot \qquad \cdot \\ \cdot \qquad \cdot \\ \cdot \qquad \cdot \\ S_{m1}, \ldots, S_{mm} \end{bmatrix}} \underset{(m \times 1)}{\begin{bmatrix} \Delta P_i \\ \cdot \\ \cdot \\ \cdot \\ \Delta P_m \end{bmatrix}}, \qquad [3.17]$$

where ΔQ is an $m \times 1$ column vector of changes in quantities supplied; S is an $m \times m$ square matrix of price elasticies of supply; and ΔP is an $m \times 1$ column vector of changes in product prices.

EXAMPLE 3.2

Suppose a hypothetical supply system is comprised of 3 products ($m=3$). Assuming predetermined values for S and a 5 percent increase in each product price, ΔQ is determined (in percent changes) as follows:

$$\begin{array}{c} \Delta Q \\ ___ \\ ___ \\ ___ \end{array} \begin{bmatrix} 1.0 \\ 4.5 \\ 6.0 \end{bmatrix} = \begin{array}{c} S \\ \begin{bmatrix} 0.5 & -1.1 & 0.8 \\ 0.2 & 1.5 & -0.8 \\ -0.1 & 0.4 & 0.9 \end{bmatrix} \end{array} \begin{array}{c} \Delta P \\ \begin{bmatrix} 5.0 \\ 5.0 \\ 5.0 \end{bmatrix} \end{array}$$

Notice how the structure of the S matrix causes a system-wide 5 percent increase in product prices to have much different impacts on the supply response of each product.

Suppose product 1 ($i=1$) has a 5 percent increase in price, but the other two products have no price changes. What would be the predicted percent change in the quantity of each product supplied? Record the new ΔQ values in the appropriate blanks and compare them with the estimates where all prices increase 5 percent.

The supply elasticity matrix, S, gives the policy analyst a powerful means of predicting or simulating farmers' responses to assumed or predicted product price changes. Before S can be estimated, a wide assortment of production data should be collected and analyzed.

Agricultural Production Data Needs

The policy analyst needs several kinds of supply response data. As a minimum, historical data are needed on physical

production of each commodity by region. In addition, production data should include specifications of farm size, enterprise mix, cultural practices, farm product prices, production costs, and farm input prices. These data are necessary to establish a realistic description of the conditions farmers face as they decide whether to produce solely for household use or produce additional amounts for sale in local markets.

Supply response data collection methods should consider the importance of variation in time, location, market level, and the observational unit. First, the data should reflect variation in supply response over time. As the number of annual production estimates increases, the data set becomes more valuable because it includes important trends that cannot be perceived in a single annual estimate. Changes in technology, market structure, and enterprise mix occur over time periods that are generally longer than one year. Although the data collection system may be designed to include these factors, their direct measurement is difficult. Hence, time-series data provide one of the best opportunities to measure their effects on supply.

Production estimates should include disaggregated estimates according to geographical variation in soil and climatic conditions. Climatic variation is the major cause of variation in livestock breeds and species and plant varieties and species. Climate also imposes constraints on cultural practices appropriate for each enterprise. In most instances, regional and local political subdivisions are a practical means of classifying geographic areas according to climatic homogeniety.

Time and location interact to affect supply response at every level in the market chain from farm field production to the retail food market. Data should be collected to reflect crop planting and livestock breeding activity, as well as actual crop and livestock production sold by the farmer. On-farm crop and livestock production losses are often a significant proportion of total farm production. At each successive level in the processing and distribution of farm supply, storage, spoilage, and processing losses reduce the amount of farm production ultimately available to the consumer. Estimates of the amount of commodities clearing the market at various levels between the farm and the consumer allow supply and demand models to be balanced to reflect market processing losses, levels of imports and exports, and changes in commodity stocks.

Finally, the choice of observation unit has a crucial influence on the usefulness of supply response data. Sampling frames should include observations at the farm level and at significant collection and distribution points in the marketing chain beyond the farmgate. Farm level samples drawn from production interviews of farmers and estimates using remote sensing techniques can offer survey cost savings, compared to estimates solely from farm interviews, while producing validity checks of alternative estimation procedures. Periodic farm management interviews should be conducted with representative farmers to determine current yields, production costs, technologies, enterprise mixes, input usage, and on-farm production losses. Budgets constructed from these interviews may be used to develop agricultural production functions.

Beyond the farmgate, data should be collected at major collection and distribution points in the marketing chain in order to systematically measure storage, processing, and spoilage losses. Marketing records of central grain elevators, livestock markets, processing facilities, and wholesale distributors should be surveyed frequently.

At whatever market level an observational unit is sampled, the relative merits of one-time sampling versus panel sampling should be considered. At the farm level, one-time sampling frames have the advantage of speed and ease of administration. Panels of farmers who are reinterviewed over several seasons have the advantage of more accurate responses and greater comparability of data over time. Beyond the farmgate, other market samples may be permanent panels because of small populations.

Supply Elasticity Estimation Procedures

The supply elasticity matrix, S, (equation 3.17) has received far less empirical attention than its corresponding demand elasticity matrix. In spite of data limitations, aggregation problems, and market spatial complications, considerable effort should be made to estimate S. Improved positive knowledge of S will finally allow policy analyses to be conducted in a general equilibrium framework based on a system-wide approach to production and consumption [Theil, 1980]. Improved understanding of supply elasticities will permit more accurate estimates of farm-level supply response, and more realistic analyses of the market linkages between farm production and non-farm household food consumption.

Specification of Statistical Estimation Model

The Constant Elasticity of Substitution (CES) production function is a special function that is compatible with the Law of Diminishing Returns. If the production function is assumed to be CES, the supply function can be specified as a log-linear function, which satisfies certain restrictions in a manner similar to the demand system. For a system of m products, the i-th supply equation can be specified as a linear regression model as follows:

$$\ln Q_i = a + \sum_{i=1}^{m} b_i \ln P_i + b_{ir} \ln R + e_i \qquad [3.18]$$

where $\ln Q_i$ is the natural logarithm of the quantity supplied of the i-th product; a is the intercept of the equation; b_i is the regression coefficient and elasticity of the i-th product price; $\ln P_i$ is the natural logarithm of the i-th product price; b_{ir} is the regression coefficient and elasticity of Q_i with respect to total revenue earned from m products; lnR is the natural logarithm of total revenue earned from m products; and e_i is the statistical error associated with the estimation of the i-th supply equation. Equation 3.18 can also be written in multiplicative form (ignoring the error term) as:

$$Q_i = e^a \left(\prod_{i=1}^{m} P_i^{b_i}\right) R^{b_{ir}} \qquad [3.19]$$

where e is the natural logarithm base.

Restrictions on the Supply System

Following the same methods used to estimate a demand system, an m-equation system can be estimated for m own-price elasticities, m^2-m cross-price elasticities, and m revenue

elasticities. Restrictions on elasticities to satisfy homogeneity, symmetry, 'Engle aggregation', and Cournot aggregation conditions also apply to supply systems with one important difference: symmetry conditions for the supply system require each own-price elasticity to be positive.

System Estimation Procedure

Once each equation has been specified in such a manner that its elasticities satisfy the theoretical restrictions, statistical estimation can commence. If the log-linear specification of equation 3.18 is adopted, the regression coefficients for prices and revenue are also constant elasticities and can be restricted with econometric programs run on main-frame computing systems. The Seemingly Unrelated Regression procedure discussed in Chapter 2 is also quite convenient and appropriate for estimation of supply systems.

Other Estimation Methods

Single-equation estimation methods are inadequate methods of estimation supply elasticities because the restrictions are difficult to satisfy and the simultaneous aspects of the supply system are not incorporated in the estimates.

Shumway and Chaing [1977] have estimated a system of supply elasticities by using linear programming and ordinary least squares regression. First, they ran a regional linear programming model for each of 15 years of actual farm prices for m products. Each product and its resource requirements were subjected to flexibility constraints to approximate each year in the time-series. The results produced 15 sets of price-quantity data for m products supplied. Finally, each Q_i was regressed on m prices,

with 15 observations for each equation. Shumway and Chaing did not address the restriction issue although all of the necessary data were avalable.

Validity Issues

Almost no supply elasticities have been estimated on a systems basis a discussed above. Most supply equations have been estimated wi gle-equation methods using either market level price-quanti data or derivations from production functions. A major reason for the slow adoption of system-wide supply analysis has been due to the preoccupation of policy analysis with individual commodities on a regional basis. Several data and theoretical problems have also impeded the systems approach.

Farm Supply Aggregation

A supply system specified for the national farm economy raises serious questions about how each farmer's supply response behavior is being represented. Most farmers specialize in only a few of the many enterprises that exist throughout the economy. Agri-climatic variation often prohibits a farmer from engaging in some enterprises that enjoy a comparative advantage in other regions of the country. This suggests that the national S matrix should be expected to have some zero cross-price elasticities because the two products do not realistically compete for the same land and labor resources.

The aggregation question also involves the method of data collection. The most convenient price-quantity data will likely be a national time-series generated from a wide variety of samples and estimates. Nation-wide farmer panel surveys of production

are usually not available. If panel data were available, the national price-quantity estimates would again have to deal with the zero production problem in the aggregation procedure.

The Time Problem

The supply system presented above implicitly assumed that price and quantity changes occur in the same time period, but agricultural production methods challenge that assumption. Most agricultural production decisions for the present growing season (or generation of livestock) are heavily dependent on the price situation in the previous growing season (or generation of livestock).

If the supply system is simply specified to assume that production in the present time period is a function of prices in the previous time period, the model may be more dynamically consistent, yet futher complicated by the fact that not all products would have the same production time period. Some crops can only be produced once per year. In some cases, two or more crops can be produced on the same land during a year. A tree crop can require several decades.

The Market Entry Problem

Specification of the supply system is also complicated by the various levels of market entry of food products. If all food products were produced on farms of similar size or scale, the market entry problem would be less serious. Because some food products are produced on plantations or in factory settings and may be completely processed and packed before leaving the firm. These products have marketing components in the farmgate price that are not included in raw, unprocessed farm product prices.

CHAPTER 4

THE MARKET SYSTEM

The actions of producers and consumers are influenced by market forces that operate to reduce conflicts between buyers and sells. Farmers often sell directly to consumers in economies where markets do not have significant transportation, storage, and processing industries. As the marketing system matures and begins to offer more processing and transportation services, the farmer and the consumer begin to have less contact.

In a highly developed economy, farmers are usually a smally proportion of the labor force and their products undergo several time, form, and place transformations off the farm before being purchased by consumers.

If the policy formulation process is to be successful in dealing with major agricultural issues, the analysts need a clear understanding of how the market sends economic signals that serve as valuable indicators of policy priorities.

The market determines the level of prices, and over the long-run, allocates the economy's capital, labor, and natural resources. The market sends signals on opportunities to import and export goods and services.

Price Determination

Producers use n inputs to produce m products, which are purchased by consumers. If there is free mobility of products and inputs, the market determines product and input prices as buyers and sellers meet and attempt to satisfy their selfish interests.

Producers respond to rising prices by increasing output. Consumers respond to rising prices by reducing consumption. The aggregate demand and supply schedules ultimate cross each other like a pair of scissors and set a so-called equilibrium price and a corresponding quantity that are somewhere between the extreme goals of producers and consumers. In Figure 4.1, the equilibrium price ($\bar{P}$) and the equilibrium quantity ($\bar{Q}$) are determined simultaneously by the values of exogeneous supply and demand shifters. The same process that occurs in Figure 4.1 for one good, occurs simultaneously for all goods and the inputs used to produce them.

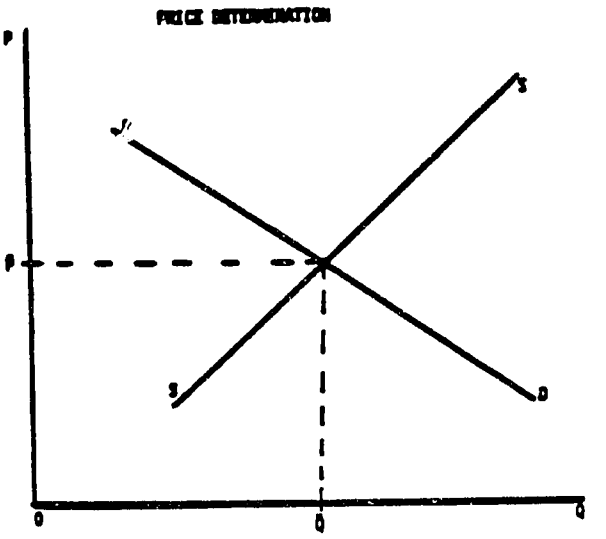


Figure 4.1

At the farm level, the farmer receives price signals from the results of other farmers entering the market to sell their products. The price that the farmer is offered is determined by the "industry" supply-demand situation. The industry consists of all farmers producing a particular product and their buyers. Once this large group has agreed on a price that is lower than the farmers' most optimistic level, but higher than the buyers' most optimistic level, the lone farmer has little alternative except to take the price set by the "industry".

The farmer considers the industry price to be fixed in the

short-run, or insensitive to his own production efforts. He therefore faces a flat demand curve at price level $\bar{P}$. In Figure 4.2, the farmer makes production decisions based on the point where the demand curve (marginal revenue) intersects his supply curve (marginal cost of production) to maximize profit.

If the market price and quantity are thwarted by an intervention into market operations, such a government price commission, the market will not clear products properly if the controlled price is not the same as the price determined by market forces. Figure 4.3 shows that a surplus will develop if the controlled price exceeds the market price, while a shortage will develop if the controlled price is less than the market price. In both cases, producers and consumers react in opposite directions, but their compromise

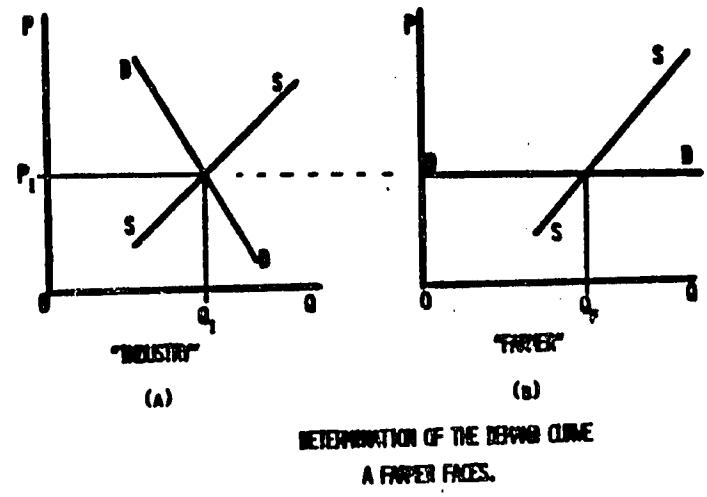


Figure 4.2

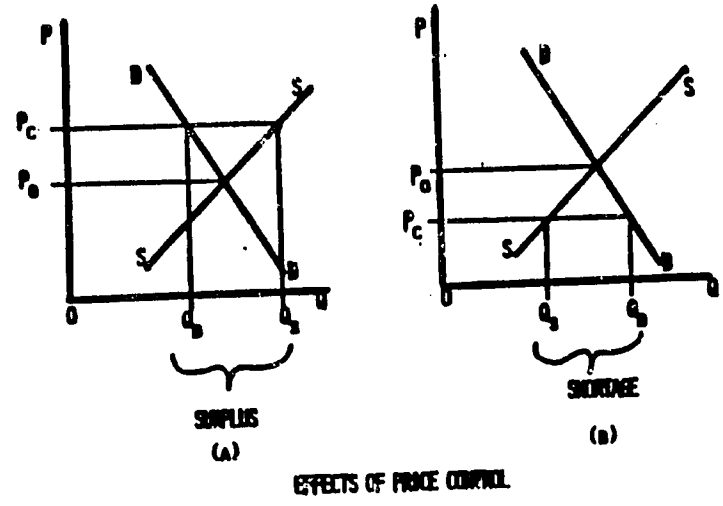


Figure 4.3

price is overruled.

One of the ways a farmer tries to protect himself from the risks of being a price taker is to shift his supply curve to the right (increase his supply) by adopting some new technology. Once the technology becomes productive, his supply increases. Ultimately, other farmers will adopt the new technology and cause the industry supply curve to shift to the right, which causes the market price to fall. Once the price falls, the farmer will begin the search for a new technology to repeat the process once again. Figure 4.4 describes this process as the "farmer's dilemma". It is ironic that the long-run benefits of agricultural technology accrue more to food consumers than to farmers because of the process described in Figure 4.4.

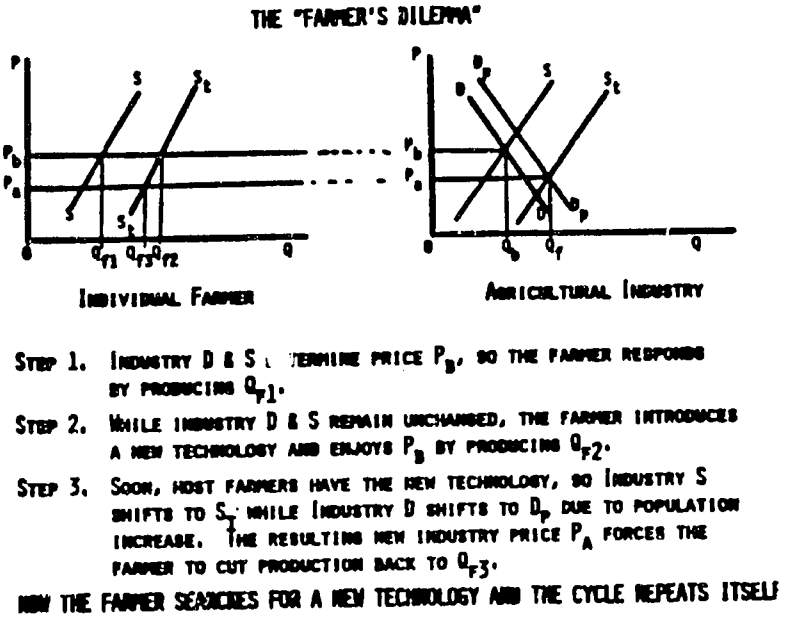


Figure 4.4

Product Transformation

In addition to determining prices and the amounts of goods that trade among buyers and sellers, markets also serve to transform goods and services as they pass through the marketing chain from producer to consumer. In the case of agriculture, the transformation includes: transportation to places more convenient

to consumers; processing and packaging to change the shape and appearence of the good; and storage to allow the product to be offered to consumers at a much later date than when it was harvested.

As the product leaves the farm production process, two important factors begin to work. First, the marketing process causes a decrease in the quantity originally produced because of processing waste, storage losses, spoilage, and grading. Inefficient processing equipment such as rice mills and oil extractors can easily lose one-half of the product received for processing.

Second, the unit price of the product begins to rise as the product is passed through additional marketing firms. The marketing margin is the percentage of the money spent by a consumer on a food product that is received by the farmer. For the United States, the marketing margin has remained at about 40 percent for many years.

Market Failure

The central theorems of welfare economics demonstrate that economic welfare is maximized when markets determine prices and quantities to be traded as in Figure 4.1. In several notable instances, however, markets fail to allocate resources efficiently. First, imperfect markets such as concentrated ownership of selling (monopoly) activities or buying (monopsony) cause market failure. The policy analyst should be aware of the degree of market inperfection in an economy and attempt to determine how the present situation occurred.

Markets also fail to operate efficiently when a resource is marketed that cannot be completely controlled or owned by one person. Water resources are an example of a public good that is ofter misallocated because property rights cannot be assigned in the conventional sense of private property.

CHAPTER 5

THE FOOD AND AGRICULTURAL POLICY SIMULATION MODEL

A computerized model has been developed to help agricultural policy analysts simulate many of the fundamental food and agricultural development policy issues. The model is national in scope and attempts to simulate many of the food production-consumption policy issues. Using the simulation model, policy analysts can routinely investigate the system-wide effects of simple or complex policy changes.

Theoretical Model

The general model can be specified in 13 equations. Each equation is in matrix form and represents the respective attributes of m major food groups in the market.

1. Percent Changes in Retail Prices

Although there are various ways to begin or enter the simulation of a market, this model assumes that an initial exogeneous change in the quantity of food in the retail market causes a shock that induces changes throughout the system. This exogeneous change in food marketed could be the result of changes in PL-480 or commercial shipments, changes in food production due to weather, or a new development project. The change in quantity marketed shifts the food supply curve. The impact on retail prices is specified as:

$$\%dP_r = D^{-1} * \%dQ_r \qquad [5.1]$$

where $\%dP_r$ is the percent change in the retail price of food; D^{-1} is the inverse of price elasticity of demand (sometimes referred to as price flexibility matrix); and $\%dQ_r$ is the percent change in

the quantity of food on the retail market. In matrix nomenclature, $\%dP_r$ and $\%dQ_r$ are m x 1 column matricies and D^{-1} is an m x m matrix. Income is assumed constant in the shortrun.

2. Percent Change in Farmgate Prices

The shock to retail food prices is transferred to the farmer in a two-stage process. First, the farmer's rational expectations about the impact of retail price changes on his farmgate price is not likely to be a one-to-one correspondence. For this model his perception of farmgate price changes is defined as:

$$\%dP_f = \%dP_r * R \qquad [5.2]$$

where $\%dP_f$ is the percent change in farmgate prices and R is the farmer's coefficient of rational expectations.

While expectations are a behavioral parameter, the marketing margin, or the proportion of a consumer's expenditure for a food item that is ultimately received by the farmer, reflects many of the structural characteristics of the marketing processes between the farmgate and the final consumer. The farmer's expected price change, based on the retail price change, must now be discounted as:

$$\%dP_{fm} = \%dP_f * M \qquad [5.3]$$

where $\%dP_{fm}$ is the expected farmgate price, adjusted for the marketing margin, and M is the marketing margin for each of N food groups.

3. Percent Change in Farm Production

The effective farmgate price change (equation 3) is translated into production response through a supply elasticity matrix:

$$\%dQ_p = S * \%dP_{fm} \qquad [5.4]$$

where $\%dQ_p$ is the percent change in farm production and S is an m x m matrix of supply elasticities. It is assumed that $\%dQ_p$ is in the present time period (t), but is a lagged response to a price change (%dPfm) that occurred in the previous time period (t-1).

4. Quantity of Farm Production

Equations 5.1-5.4 express price and quantity changes in percentage terms. Percent change in farm-level production is transformed into total production by:

$$Q_p = \underline{Q}_p * ((\%dQ_p/100) + 1) \qquad [5.5]$$

where Q_p is total production per time period and $\underline{Q}_p$ is average level of production assumed to exist over an intermediate time period.

5. Quantity of Farm Production Marketed

The amount of actual farm production, Q_p , is rarely the amount supplied by the farmer at the farm gate. A lesser amount is usually supplied because of on-farm harvest and storage loses and farm consumption by livestock or the household. The amount of farm production leaving the farmgate is defined as:

$$Q_{fs} = Q_p * H \qquad [5.6]$$

where Q_{fs} is the amount of farm production offered for sale at the farmgate and H is the proportion of farm production offered for sale, i.e., net of harvesting and farm storage losses and farm consumption.

6. Quantity of Retail Food Supply

Additional losses occur as the farm product moves from the farm gate through the marketing chain to the retail market. Milling, processing, storage, and spoilage losses can be a

significant proportion of the product supplied at the farmgate. The quantity of food supplied at the retail level is defined as:

$$Q_{rs} = Q_{fs} * D \qquad [5.7]$$

where Q_{rs} is the quantity of food supplied at the retail level and D is the proportion of farmgate food supply that remains for retail supply net of processing and distribution losses in the farm-retail marketing chain.

7. Market Balance

One of the most important problems in any market simulation model is the reconcilliation of the quantities supplied and demanded in the retail market. In this model, a balance equation is used to measure the deviation of actual retail supply in a particular time period, t, from the level of retail demand assumed to hold over an intermediate period of time. The equation is specified as:

$$Q_b = Q_{rs} - \underline{Q}_{rd} \qquad [5.8]$$

where Q_b is the balance, or difference between the quantities supplied and demanded in the retail market, and $\underline{Q}_{rd}$ is the quantity of food demanded in the retail market over an intermediate period of time. If the balance is positive, it implies that there is a food surplus in the market, which will tend to dampen food prices. If the balance is negative, it implies a market food shortage, a stimulus to raise food prices. No attempt is made to partition the food balance into stock changes and trade components, although successive simulations of food balances would be a useful point of departure for a subset of analyses dealing with stock changes and trade policy.

8. Self-Sufficiency Ratio

As a measure of a country's self-sufficiency, the ratio of market balance to intermediate term retail market demand is defined as:

$$R = Q_b' / \underline{Q}_{rd} \qquad [5.9]$$

where R is the self-sufficiency ratio. A positive ratio would imply the amount of excess domestic retail food supply as a proportion of domestic retail food demand. A negative ratio would imply the amount the shortfall in domestic retail food supply as a proportion of domestic retail food demand.

9. Percent Change in Retail Market Quantity

Because the model does not incorporate provisions for trade or changes in food stocks to absorb the balance, the quantity of food supplied to the retail market, Q_{rs} , is the amount that clears the market. The percent change in the quantity of food marketed is defined as:

$$\%dQ_{rm} = (Q_{rs} - \underline{Q}_{rd}) / \underline{Q}_{rd} * 100 \qquad [5.10]$$

where $\%dQ_{rm}$ is the percent change in the quantity of food marketed in the present time period, t , compared to the quantity of food consumed "on average".

10. Percent Change in the Market Quantity of Food Demanded

The simulation of changes in basic market parameters during the present time period ends by defining the following identity:

$$\%dQ_r \equiv \%dQ_{rm} \qquad [5.11]$$

where $\%dQ_r$ is the percent change in the quantity of food demanded in the market in time period t. If an additional time period is to be simulated, $\%dQ_r$ from the present period will enter equation 1 at the beginning of the next time period.

11. Nutritional Impact of Market Changes

The percentage change in the quantity of food marketed (equation 5.10) permits the estimation of changes in caloric and protein intake by:

$$dC = \%dQ_r * E * F * Cal \qquad [5.12]$$

and

$$dP = \%dQ_r * E * F * Pro \qquad [5.13]$$

where dC is the per capita daily change in calories; E is the proportion of the food that is edible/digestible; F is the units of food consumed daily per capita; Cal is the number of calories per unit of F; dP is the per capita daily change in protein; and Pro is the amount of protein per unit of F.

Summary of the Model

The model is formulated as a simple cobweb supply-demand system for m food groups. It is assumed that declining demand functions and rising supply functions exist for each food group. It is further assumed that the functions of consumers in the retail food markets and producers at the farm level represent *effective retail demand and effective farm field supply.*

The simulation cycle for time period t begins by assuming an exogeneous change in the quantity of food supplied at the retail level. While this change would be expected to intitally shift the retail supply along a relatively stationary retail demand curve, the model concentrates on the resulting price changes (Equation 1), which are then followed to the farmer to measure his response (Equations 5.2-5.5).

Farm field production is then transformed into farmgate supply (Equation 5.6), and finally into retail food supply

(Equation 5.7). For the purpose of analytical simplicity, and because empirical estimates of trade and stock change behavior are largely unavailable, the difference between retail food supply and some average level of consumption based on an intermediate time period is defined as the market balance (Equation 5.8). A self-sufficiency ratio (Equation 5.9) measures the extent to which retail market supply is sufficient for retail market demand.

The model reaches the end of the current time period by transforming the change in retail market quantity into a percentage basis (Equations 5.10-5.11). This percentage change now enters Equation 5.1 as the "exogeneous quantity change" in the next time period.

During each time period, the model generates data on price and quantity changes across all food groups in the system. The demand elasticity matrix, D, in Equation 5.1 allows the price simulation of cross-price effects of a quantity change in one food group on all other food groups. Yetley and Tun have empirical estimates of D for 12 food groups in Sri Lanka. The supply elasticity matrix, S, in Equation 5.4 similarly allows the simulation of cross-price enterprise substitution effects of changes in retail food prices on farm production. Far less empirical work has been done on farm supply elasticity systems but, as will be shown in the program section, the supply elasticity matrix can be easily changed to represent the analyst's choice of empirical and conditional subjective estimates.

The quantity changes in food consumption generated by the model are also quite useful in analyzing changes in nutritional status, in calorie and protein equilivalents, for each food group.

Simulations of such fundamental agricultural development policy issues as increased food production due to improved technology or increased food supply due to PL-480 shipments can be evaluated for nutritional efficacy.

Limitations of the Model

The model does not explicitly deal with the trade sector or domestic food stock changes. However, the "balance" quantity generated in Equation 5.8 offers valuable insights into the need for trade and stocking policies to moderate domestic price and quantity fluctuations.

Although the model has dynamic features, income changes have been deliberately excluded. The nature of the model dictates that it avoid introducing too many extenuating circumstances into the model. Income growth, and its concomitant impact on food consumption, are obviously central to any agricultural policy analysis, but their inclusion complicates the analytical focus of the model and drastically reduces the audience that can use the results effectively. Consequently, the demand elasticity matrix, D, is not income compensated.

The Simulation Model's Computer Program

The model was converted to computer interpretation using BASIC language. Source listings for the three programs are reported in documentation by Morgan. The programs are designed to be chain-merged into computer memory. Comment statements are used liberally throughout each program.

Program 1

The first program, M1II.BAS, initializes the beginning

variables, introduces the user to the simulation, and initializes the default values for D^{-1} (Equation 5.1), R (Equation 5.2), M (Equation 5.3), S (Equation 5.4), H (Equation 5.6), and D (Equation 5.7). Four of the program's major features are described below in more detail.

***** Read in Default Data

Default data are read into the active memory for the following variables:

Model Name	Program Name	Program Label
R	V1	"EPSILON, Expectation Values"
M	V2	"C, Marketing Margin (Farm Price/Retail Price"
H	V3	"Z1, On-Farm Net Harvested
M	V4	"Z2, Off-Farm Net Marketed (Proportion)"
D^{-1}	V5	"INVDij, Inverse Demand Elasticity Matrix"
S	V6	"Sij, Supply Elasticity Matrix"
D	V7	"Dij, Demand Elasticity Matrix"

Program variables V1-V7 are stored on a data file, M1II.DAT which was created with the word processing program, Wordstar. Program lines 650-990 open data file M1II, read in variables V1-V7, and close the file.

The demand elasticity matrix, D, and its inverse, D^{-1}, are based on empirical estimates by Yetley and Tun using household consumptin data collected in 1969-70. The demand elasticity matrix was estimated using Zellner's Seemingly Unrelated Regressions (SUR) procedure.

The remaining five variables in the data file M1II.DAT are subjective estimates. All expectation values, R, are assigned a value of 1 because no empirical estimates are available for Sri Lanka. All own-price supply elasticities are assigned a default

value of .5, while all cross-price elasticities are set at zero. Few supply elasticity systems have been estimated. Because such estimates are not avalilable for Sri Lanka, own-price elasticities are assumed to be inelastic, with no cross-price effects.

***** Review Default Values of Variables V1-V7

Program lines 1070-1550 describe a menu that asks the user which of the variables are to be printed for review. If a variable is selected, it is sent to the printer for a hard copy. Otherwise, the program skips to a value change section.

***** Change Default Values of Variables V1-V7

Lines 1560-1810 prompt the user for new values for any of the seven variables (Note the warning to the user in lines 1120-1150). As the user requests the location of a value to change, the screen replies with the present value for the cell and waits for the replacement value.

***** Chain Merge Program 2

Lines 1950-1960 define variables from Program 1 to be retained, delete all lines of Program 1, and enter Program 2 into the active memory.

Program 2

The second program, M2II.BAS is the heart of the simulation model. The major operations involve reading in additional default data and making any data changes requested, simulating Equations 5.1-5.13 of the general model, and chain merging Program 3.

***** Reading In and Changing More Default Data

Lines 1630-1780 open data file M2II.DAT, read in default

values for "average consumption" ($\underline{Q}_{rd}$), "average field production" ($\underline{Q}_p$), and the exogeneous change in quantity marketed that initially starts the simulation in Equation 5.1. The program defines these variables as W1-3, respectively. Lines 1790-2040 prompt the user for any values that are to be changed. All "quantiy change" values have zero default values, so the value for at least one food item must be given a non-zero value in order for the simulation model to produce fruitful results.

***** Simulation of Equations 5.1-5.13

Program lines 2110-3280 use variables V1-V6 from Program 1 and variables W1-3 from Program 2 to simulate Equations 5.1-5.13. Twelve commodities are presently included in the model, although the structure allows the number to be changed easily A). The simulation of the equations can be repeated for up to 12 cycles or time periods. At the end of each cycle, the results of the simulation of a particular variable can be printed out on hard copy (lines 1410-1540 and 3430-3630).

***** Chain Merge Program 3

Upon completion of the simulation, lines 3320-3330 define variables to be retained for Program 3, delete lines 1000-3630, and enter Program 3 into the active memory.

Program 3

Program 3, M3II.BAS, essentially prints a hard copy, at the discretion of the user, of the data generated in Program 2. Lines 5300-5460 produce a menu of printing options for the user. Lines 5470-5730 print the value of each variable, for each commodity, by cycle. Lines 5740-5940 print the data for only one variable, for each commodity, by cycle.

CHAPTER 6

APPLICATIONS OF THE POLICY SIMULATION MODEL

The model discussed in Chapter 5 has been developed to run on a microcomputer. The user is urged to become familiar with Chapter 5 before proceeding.

Starting the Computer

The programs that run the model were written in BASIC and therefore run on many computers. The general procedure for starting a computer is turn it on and "boot" a copy of the Mbasic language into the "A" drive, insert the policy simulation diskette into the "B" drive and type "LOAD "B:M1II"" <Carriage Return>. The diskette should be read and the introduction to the model will appear on the video screen.

Options

The programs have been written to pose questions relevant to the model that require only yes or no answers (Y or N) or choosing a number from a menu that represents the desired option.

The first option on the screen asks if you want to look at the default values for V1-V7. If you do, choose the appropriate number and the values will be printed. You are then asked if you want to make any changes. If you want to change values, the screen will prompt you by food name, row, and column to locate the cell you want to change. The present value of the cell will be printed on the screen. When you type in the new value and hit the return key, the old value is replaced by the new value.

After you finish data changes on V1-V7, the screen asks

which policy parameter you want to watch at the end of each cycle. If you decide to view a parameter, its values will be sent to the screen at the end of each cycle.

Default values for average production and consumption percent changes in quantities demanded are initialized then you are asked if you want to make any changes. All food categories have zero values for percent change in quantity demanded, so at least one food must be assigned a nonzero percent change. After these changes are made, you are asked how many cycle you wish to run the mode. Since the cobweb model can be unstable, you are cautioned to run only one cycle initially until you become more familiar with the model and the data.

The model then runs the requested number of cycles, stopping (if you requested) at the end of each cycle to send the results for a selected parameter to the scree. When all cycles are completed, you are asked which of the parameters you wish to have printed for all cycles. You may choose one, all, or stop the program. After the requested data are printed, the program ends.

Policy Option Simulations

After becoming familiar with the model, you will be able to simulate various policy options based on changes that you make in the default data. Changes in marketing margin assumptions can have a dramatic impact on the amount of farm production.

At the beginning of each simulation, be sure you have noted the assumptions (data changes) you have made. The main value of the simulation model is to compare the results of successive runs to measure the sensitivity of policy parameters.

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