

Table 7.1

Data to be Aggregated to Illustrate Index Number Formulas

Year	Commodity Z		Commodity Y		Gross Value (\$)
	Price p(\$/unit)	Quantity q(units)	Price p(\$/unit)	Quantity q(\$/unit)	
1965	.60	1,161	60	60	4,296.60
1975	1.20	725	80	85	7,670.00
1985	2.50	249	120	110	13,822.50

or					L(q)
	1965	(.60 X 1,161) + (60 X 60) = 4,296.60			100
	1975	(.60 X 725) + (60 X 85) = 5,535.00			129
	1985	(.60 X 249) + (60 X 110) = 6,749.40			157.

These values expressed as percent of the base year (1965) constitute the Laspeyres Index and indicate that the aggregate quantity of X and Z increased to 129 percent of the 1965 level in 1975 and to 157 percent of the 1965 level in 1985.

The Laspeyres price index L(p) is defined as

$$L(p) = \frac{P_{1Z}^q q_{0Z} + P_{1Y}^q q_{0Y}}{P_{0Z}^q q_{0Z} + P_{0Y}^q q_{0Y}} = \frac{\sum P_1 q_0}{\sum P_0 q_0}$$

or					L(p)
	1965	(.60 X 1,161) + (60 X 60) = 4,296.60			100
	1975	(1.20 X 1,161) + (80 X 60) = 6,193.20			144
	1985	(2.50 X 1,161) + (120 X 60) = 10,102.50			235.

The Laspeyres Index of price increased from 100 in the base year (1965) to 144 in 1975 and to 235 in 1985.

7.5.1.2 Paasche Index

In contrast to the Laspeyres Index which uses base year weights, the Paasche Index uses weights of the given or "current" year. The Paasche formula for a quantity index P(q) is

$$P(q) = \frac{p_{1Z}^q q_{1Z} + p_{1Y}^q q_{1Y}}{p_{1Z}^q q_{0Z} + p_{1Y}^q q_{0Y}} = \frac{\sum p_1^q q_1}{\sum p_1^q q_0}$$

or

	$P(q)$
1965 $\frac{(.60 \times 1,161) + (.60 \times 60)}{(.60 \times 1,161) + (.60 \times 60)} = \frac{4,296.60}{4,296.60}$	100
1975 $\frac{(1.20 \times 725) + (.80 \times 85)}{(1.20 \times 1,161) + (.80 \times 60)} = \frac{7,670.00}{6,193.20}$	124
1985 $\frac{(2.50 \times 249) + (120 \times 110)}{(2.50 \times 1,161) + (120 \times 60)} = \frac{13,822.50}{10,102.50}$	137.

The Paasche Index for price is

$$P(p) = \frac{p_{1Z}^q q_{1Z} + p_{1Y}^q q_{1Y}}{p_{0Z}^q q_{1Z} + p_{0Y}^q q_{1Y}} = \frac{\sum p_1^q q_1}{\sum p_0^q q_1}$$

or

	$P(p)$
1965 $\frac{(.60 \times 1,161) + (.60 \times 60)}{(.60 \times 1,161) + (.60 \times 60)} = \frac{4,296.60}{4,296.60}$	100
1975 $\frac{(1.20 \times 725) + (.80 \times 85)}{(.60 \times 725) + (.60 \times 85)} = \frac{7,670.00}{5,335.00}$	139
1985 $\frac{(2.50 \times 249) + (120 \times 110)}{(.60 \times 249) + (.60 \times 110)} = \frac{13,822.50}{6,749.40}$	205.

7.5.1.3 Fisher Ideal Index

It is apparent that the Laspeyres Index and Paasche Index do not give the same measures of the composite quantity or price indices. The advantage of the Laspeyres Index and a reason it is most widely used is its convenience. Only base period prices are needed to compute the quantity index and only base period quantities are needed to compute the price index. This saves expenses of gathering data. In this example, the Laspeyres Index gave the higher estimate of the composite price and quantity changes. The Paasche Index gave lower estimates of the composite price and quantity changes for 1965 to 1985. The two indices give the upper and lower bounds of changes in price and quantity but there is no resolution to the issue of which is more accurate.

Although the index number problem has no solution, the Fisher Ideal Index has been proposed as a compromise between the extreme results from the base period weighting under the Laspeyres Index and given period weighting under the Paasche Index. The Fisher Ideal is the geometric mean of the Laspeyres and Paasche Indices. The Fisher Ideal Index is $F(p) = \sqrt{L(p)P(p)}$ for price and $F(q) = \sqrt{L(q)P(q)}$ for quantity. The Fisher Ideal not only gives results between the Laspeyres Index and the Paasche Index, it also meets the so called factor reversibility test. That is, the Fisher Index for price multiplied by the Index for quantity gives the actual exact index for the value computed directly from the price and quantity data in Table 7.1.

Results are summarized for the example in Table 7.2. The Fisher Ideal Index is preferred conceptually but requires more data than the Laspeyres Index. The three index number formulas do not exhaust the possibilities - other index number formulas have been proposed and utilized (see Tomek and Robinson, 1981, pp.204-269; Yamane 1967, ch.11, for further discussion of formulations). The actual choice of formulas will depend on the data and computational resources available. A common approach is a combination of the Paasche and Laspeyres formulations by using base period weights but updating them periodically to better represent current price or quantity weights.

7.5.2 Index Number Uses

Examples of composite series useful in the analytical programme are indices of prices received and paid by producers and indices of factor or multifactor productivity.

7.5.2.1 Price Indices

An index of prices received by producers measures trends in a composite of commodities produced by farmers. The composite may be for commodity groups such as coarse grains, foodgrains, all crops, all live-stock and livestock products, or for crops and livestock combined. Trends in such series may be of interest directly or indirectly for inclusion in supply analysis discussed earlier.

An index of prices paid by producers measures trends in a composite of inputs. The composite may be for an input group such as purchased inputs, production inputs, purchases for consumption, farm produced inputs, or for all inputs. An input price index may be used to adjust commodity support prices or to deflate prices in supply analysis.

Table 7.2
Summary of Quantity, Price, and Value Indices
Computed from Laspeyres, Paasche, and Fisher Ideal Formulas

Year	Quantity	Price	Value	Actual Value
<hr/>				
Laspeyres				
	L(q)	L(p)	L(q)L(p)	
1965	100	100	100	100
1975	129	144	186	179
1985	157	235	369	322
<hr/>				
Paasche				
	P(q)	P(p)	P(q)P(p)	
1965	100	100	100	100
1975	124	139	172	179
1985	137	205	281	322
<hr/>				
Fisher Ideal				
	$\sqrt{L(q)P(p)}$	$\sqrt{L(p)P(p)}$	F(q)F(p)	
1965	100	100	100	100
1975	126	142	179	179
1985	147	219	322	322

The ratio of the index of prices received by producers to the index of prices paid by producers measures the terms of trade for agriculture. Changes in terms of trade can measure changes in farm economic well-being or incentives to produce. It is important to note, however, that the well-being of persons in agriculture depends on productivity, off-farm income, and other factors as well as on terms of trade.

7.5.2.2 Productivity

Productivity generally refers to ratios of input to output (US Department of Agriculture, 1980). If only one input and one output are involved, productivity can be measured by technical efficiency. With more than one input or output, economic efficiency is involved because aggregation is necessary using price-weight procedures described above.

Productivity does not necessarily measure economic efficiency (Tweeten 1979, ch.5). The divergence between the two concepts is greatest for partial productivity measures. Common partial productivity measures include gross farm output per unit of farm labour, persons supplied per farm worker, or crop yield per hectare. Improving economic efficiency entails substitution of profitable and productive conventional inputs such as farm labour and land. In the process, output per unit of labour increases as output expands or as less efficiency labour resources are released to other uses. Thus increased labour productivity as measured by gross output per unit of labour may be a sign of labour inefficiency - economically inefficient labour in a sector is replaced by improved capital inputs.

Measuring the economic efficiency of agriculture requires both static and dynamic measures. Static measures of efficiency were listed in earlier sections and include rates of return on resources, benefit-cost ratios, and net social loss or gain. A traditional farming economy characterized by a closed set of technologies for decades is likely to have made resource adjustments eliminating economic disequilibrium. That is, resources are allocated to their highest and best use. Lack of profitable alternatives that would reward producers for foregoing consumption to invest for the future retards economic progress. Dynamic efficiency is unlikely to be evident despite presence of static efficiency.

Multifactor productivity as measured by total input relative to total output over time is a useful measure of dynamic efficiency. As productive and profitable improved inputs are made available from agricultural research, extension, and education in a traditional economy, economic disequilibrium will become apparent in higher rates of return on new inputs such as high-yielding varieties. As producers adopt these new inputs, total inputs will be reduced or output expanded to increase multifactor productivity. Thus a dynamic agriculture may show static inefficiency but does not necessarily indicate static efficiency - static measures of efficiency may show disequilibrium over a period of multi-factor productivity growth.

Static measures of efficiency are useful to show opportunities for allocating resources and products in ways that reduce real costs or increase real output, and to show the social costs of not seizing such opportunities. An economy that creates static disequilibrium through improved inputs from agricultural research and extension and has producers who quickly allocate resources to reduce static disequilibrium will display much dynamic efficiency apparent in productivity gains and national income growth. Human resource investments can be decisive in increasing capabilities of producers to respond appropriately to disequilibrium. If producers respond and static disequilibrium is reduced, the result will be apparent in increased multifactor productivity and

national income. But in a truly dynamic economy, agricultural disequilibrium will constantly be generated from a continuing flow of improved capital inputs, technology, management, marketing, and product mixes. Disequilibrium is unlikely to be fully eliminated even if producers are responsive to continuing incentives for change in a growing economy.

Multifactor productivity ideally is measured by total output divided by total inputs including conventional farm labour, management, and capital (including land) as well as non-conventional inputs such as general and vocational education and agricultural research extension. In the case of durable resources the input is measured by the service flow cost - interest, depreciation, repairs, and maintenance.

Non-conventional inputs are not easily measured and a common procedure is to estimate productivity as real farm output per unit of conventional farm inputs. This series has the advantage of showing shifts in the aggregate farm supply curve over time and hence for predicting future supply-demand balance and real price trends. But it has the disadvantage of any partial productivity measure. That is, the way to increase efficiency of conventional resources is to use non-conventional resources to the point where their marginal productivity is zero. Because these non-conventional resources have an opportunity cost (resources used for research, education, and extension have value elsewhere), it is inefficient to drive their marginal product to zero. It follows that an analytical programme must consider the efficient use of both conventional and non-conventional resources^{5/}. Rates of return on conventional inputs or non-conventional inputs (see Ruttan 1982) above or below rates of return elsewhere (adjusted for risk) imply static inefficiency which eventually will be apparent in dynamic efficiency.

5/ Sometimes it is useful to measure sources of output gains over time. Using terminology from section 7.4 and given the elasticity of production E_{ik} of input k with respect to output i , the percentage increase in output i , O_i , is

$$O_i = \sum_k E_{ik} X_k$$

where X_k is the percentage increase in input k . The formula enables the analyst to estimate the contribution of each input k to output over time.

7.6 Economic Accounts for Agriculture

Agricultural analysis, formulation of economic policy and development planning generally require comprehensive and coherent information on all aspects of agricultural activity. Traditional agricultural statistics provide a wide range of data on crops, livestock, prices, etc. Such data are usually presented as separate and independent information, and it is necessary to have a coherent framework in which such data can be described and presented for analysis. The economic accounts for agriculture (FAO 1985a) provide such a framework for recording data relating to agricultural production and other activities in agriculture. Since agriculture is only a part of the total economy, these accounts are designed to fit the general scheme of accounts for the economy as a whole consisting of a system of national accounts, and they provide background information necessary to assess agricultural activities and developments against the performance of the other sectors.

The economic accounts consist of three basic accounts - production, income and outlay, and capital formation - and a number of supporting tables and worksheets. The main accounts match total agricultural production against the inputs used in production, capital formation against its finance; and income received by agricultural holdings against their expenditure. The supporting tables and worksheets provide detailed information from which the aggregates presented in main accounts are computed. As these accounts are compiled using alternative sources of information such as the agricultural census, farm management reports and household expenditure surveys, the economic accounts are also useful in checking the internal consistency of all the data relating to the sector.

The production account can provide a detailed picture of the structure of the industry - the composition of total agricultural output, the inputs used in producing these goods and their cost, the value added generated in the sector and its distribution among the population engaged in agriculture. When built up into time series with production accounts spanning a number of accounting periods, expressed in constant prices using index number methods discussed in Section 7.5, trends in pattern of production, sales, and shifts in emphasis from one type of farming to another become apparent. Such series also facilitate analysis of the inter-active effects of prices, production, sales and costs, ex post evaluation of on-going programmes, and observation of the effects of agricultural policies.

These accounts, as part of a system of national accounts, show the contribution of agricultural sector to the total gross domestic product of a country reflecting the importance of the sector to the total economy. The production account aggregates can be combined with figures for the number of persons engaged in agriculture to measure labour productivity in agriculture and such measures are necessary to make comparisons of inter-sectoral efficiency. It is possible to account for the dualistic nature of agriculture in many developing countries, and prepare separate economic accounts that are suitable for comparing income of traditional agricultural sector with income of the more advanced agricultural sector. Further, information contained in the worksheets and supplementary tables can be used in the computation of volume indices for inter-regional and inter-country comparisons of output and productivity.

The information on input use and output mix contained in these accounts can be used in the construction of input-output tables which provide a useful aid to answering questions about how the economy will respond to particular changes and what are the repercussions of changes in the final demand requirements on other industries.

Extensive analysis of the material presented in these accounts can be undertaken to throw light on many facets of the sector and assist in decision making processes connected with the planning and future development of agriculture, but only a few major aspects were highlighted in this section.

7.7 Project Analysis

Many agricultural policies entail investment, production, and income streams spread over many years. Analysts frequently are called upon to evaluate the net payoff from past projects or to determine the economic feasibility of prospective projects. Numerous such analyses have been made for human resource investments in general education (Hansen 1963) and vocation-technical training (Shallah and Tweeten 1970); in irrigation, roads, bridges, and transportation (Adler 1971); and in agricultural research and extension (Ruttan 1982). The theory and application of project analysis is detailed in a number of sources (see Little and Mirrlees 1969; Squire and Van der Tak 1975; Gittinger 1982).

7.7.1 Net Present Value, Benefit-Cost Ratio, and Internal Rate of Return

Conceptually, the requirement for project analysis is to determine the stream of costs of the project C_0, C_1, \dots, C_n and benefits B_0, B_1, \dots, B_n over the n -year life of the project (until C_{n+1} and $B_{n+1} = 0$). The streams of costs and benefits are discounted or compounded to a common point in time. If the discount rate (to be discussed later) on funds for the project is r , the net present value (NPV) of the project is

$$(7.7.1) \text{ NPV} = B_0 - C_0 + \frac{B_1 - C_1}{1 + r} + \frac{B_2 - C_2}{(1 + r)^2} + \dots + \frac{B_n - C_n}{(1 + r)^n}$$

where the subscript 0 refers to the first day of the project, subscript 1 refers to the end of the first year, and so forth. Of course, some of the B s and C s may be zero in the above formula. If the net present value is positive, the project is attractive to decision makers.

Other formulations are also used to measure economic payoff from projects. Sometimes a benefit-cost ratio is computed from the same data as in equation 7.7.1. The benefit-cost ratio is calculated as

$$(7.7.2) \text{ B/C} = \frac{B_0 + B_1/(1 + r) + B_2/(1 + r)^2 + \dots + B_n/(1 + r)^n}{C_0 + C_1/(1 + r) + C_2/(1 + r)^2 + \dots + C_n/(1 + r)^n}$$

Other things equal, projects with high B-C ratios are favoured over those with low ratios. If only one project can be undertaken, the project with the highest NPV may be selected. In other instances, a choice must be made among several projects, any one or more of which are potentially fundable. Two or more projects funded simultaneously may provide a higher net present value than one large project. If projects are not mutually exclusive, they may be ranked by B-C ratios. But the ranking of projects depends heavily on the discount rate chosen to compute NPV or the B-C ratio, a rate that decision makers may wish to vary for purpose of comparison but which tends to be inflexible and hidden in benefit-cost analysis.

If projects are not mutually exclusive, decision makers may desire to judge projects on the basis of the internal rate of return, choosing projects offering the highest internal rate of return. The internal rate of return is found by solving for the value of the discount rate r that makes the NPV equal to zero:

$$(7.7.3) \quad B_0 - C_0 + \frac{B_1 - C_1}{1+r} + \frac{B_2 - C_2}{(1+r)^2} + \dots + \frac{B_n - C_n}{(1+r)^n} = 0.$$

Given values for B_s and C_s , the internal rate of return r is calculated with ease using business calculators or programmes available for main-frame computers or microcomputers.

Even if economic benefit and cost streams are accurately measured, the resulting NPV, B-C ratio, or internal rate of return do not provide all the information often needed by those who make decisions. The analyst may also be called upon to provide measures of the riskiness of the project, whether it might be undertaken by the private sector rather than by the public sector, and the distribution of costs and benefits among groups arrayed by income level.

7.7.2 Choice of Discount Rate

The discount rate used to calculate a benefit-cost ratio or net present value may be the rate at which consumers discount future versus present consumption or may be the rate of return on funds invested in alternative projects. Consumers on the whole prefer present to future consumption. The poorer the consumers, the higher the premium placed on present consumption. In a well-functioning economy, the consumption rate of discount will equal the return on savings and investment which will equal the interest rate with appropriate adjustment for risk among investments. A typical discount rate or real rate of interest (market rate of interest less the inflation rate) is 10 percent in developing countries. A higher discount rate implies a greater premium on current consumption, greater incentive to save, and emphasis on investments that promise early payoffs. A common procedure in project analysis is to compute NPV and the B-C ratio using alternative discount rates so that the decision maker can compare results and determine sensitivity of results to alternative choices of discount rates.

7.7.3 Estimating Benefit and Cost Streams

The greatest challenge in project feasibility analysis is to determine the flow of benefits and costs. The principles of estimating costs and benefits are similar to those for classical welfare analysis discussed earlier. The area beneath the long-run social demand (long-run marginal revenue) curve is benefit B_1 and the area beneath the long-run supply (long-run marginal cost) curve is cost C_1 . The difference between benefits with and without the project estimated for each year of

the project traces the benefit stream. A similar procedure for costs (variable costs with and without the project each year) traces out the cost stream.

Principles of determining benefits and costs are illustrated further using the Policy Analysis Matrix (PAM) in Table 7.3. The table lists the accounting matrix for one year. Investments with a longer duration require comparable calculations for each year of the life of costs and benefits, a task made manageable by systematic trends in data. Calculations need to be in constant (inflation corrected) prices if real rather than nominal rates of return are at issue. Net costs (benefits) are from the differences calculated with and without the project.

The first row in Table 7.3 measures profits based on actual market prices, costs, and receipts, hence is applicable to a private firm. Changes in the first row can indicate the impact on private firms of changes in price supports, taxes, subsidies, research, or other public projects and policies.

Table 7.3

Accounting Matrix for Static Efficiency and Policy Analysis

	Receipts	Costs		Receipts
		Tradeable Inputs	Domestic Factors	Less Costs Profits
Private prices	A	B	C	D ¹
Efficiency on social prices	E	F	G	H ²
Effects of policy and market failures	I ³	J ⁴	K ⁵	L ⁶

Source: Hillman and Monke (1985, p.8); and Pearson (1985).

1. Private profit, $D = (A - B - C)$
2. Social profit, $H = (E - F - G)$
3. Output transfers, $I = (A - E)$
4. Input transfers, $J = (B - F)$
5. Factor transfers, $K = (C - G)$
6. Net policy transfers, $L = (D - H) = (I - J - K)$

Evaluation of payoffs in efficiency prices or social prices in the second row in Table 7.3 is appropriate to determine net benefits of a project or policy for society as a whole. Efficiency prices are appropriate if the objective of public policy is to increase real national income. Appropriate efficiency prices for commodities that are internationally traded are world border prices - expected cif import prices for importables and expected fob export prices for exportables. That is, efficiency prices reflect the opportunity cost of importing to meet domestic needs using foreign exchange or selling abroad to earn foreign exchange.

World prices for domestic factors of production (labour and capital) tend to be inappropriate or unavailable. Hence these factors are valued according to their social opportunity cost as measured by national income foregone by removing the factors from their next best alternative. These factor costs must be adjusted to correct for market failure such as environmental degradation and for distortions introduced by taxes, exchange rates, subsidies, interest rate ceilings, union wage scales, or other public or private interventions that reduce efficiency allocations.

Tradeable commodities and inputs are defined as those which are traded internationally. Non-tradeable commodities and inputs are neither imported nor exported because it does not pay to do so, so that prices are determined by the domestic market. Prices of non-tradeables are influenced by distortions in prices of tradeables. Hence prices of non-tradeables must be adjusted if market prices of tradeables are adjusted. The preferred adjustment is to compute the value of non-tradeables from the corrected value of tradeable inputs, capital, and labour used in the non-tradeable items. This requires complex input-output tables measuring inputs by source to produce non-tradeables. Such information may be unavailable or highly inaccurate in developing countries. An alternate procedure is to use domestic prices of non-tradeables adjusted for distortions such as subsidies or taxes causing deviations of prices from those of a well-functioning market. (It may also be noted that receipts in Table 7.3 may need to be divided into those for tradeable and non-tradeable commodities.) Durable capital costs are expressed as the flow of inputs necessary to maintain output. The flow includes depreciation, interest, maintenance, and operating costs. Land may be costed in the same manner or by its rental value.

The last row in Table 7.3, the difference between the first and second rows, measures the effects of policy and market failure. In the absence of market failure or policy distortions, all entries in the final row will be zero, and what is profitable for private firms will also raise national income.

In the case of a project with benefits (receipts) and costs spread over several years, the difference between benefits (costs) with and without the project for each year can be entered in equation 7.7.1 and the net present value calculated and compared with other projects. The data are from the first row of Table 7.3 for a private firm and from the second row for a public project.

If an internal rate of return is calculated, an iterative procedure is required because the cost of durable inputs must include interest charged at the internal rate of return. After solving for the internal rate of return, that return is then used to charge for durable capital. The procedure is repeated until the calculated internal rate of return is also the interest rate on durable capital - a procedure made manageable on a microcomputer or mainframe computer.

As indicated earlier, the second row in Table 7.3 determined from efficiency prices indicates the influence of a project on national income. An alternative is to measure costs, benefits, and net benefits at social prices to account for the value of a more equitable distribution of income. One approach is to adjust the efficiency measures by the marginal utility of income. To do so, those who will pay costs (taxpayers, investors, etc.) and who will receive benefits (consumers of a public project) may be divided into income quintiles or other grouping based on total income per family. The cost incurred and benefits received by each income group can be assigned a marginal utility of income based on weights (1) given by policy makers or (2) from a utility function derived from socio-psychological measures of well-being (see Harper and Tweeten 1977; Tweeten, Mylay, and Dellenbarger 1986). Multiplying efficiency benefits and costs for each income group by the marginal utility of income (for convenience, the middle income quintile can be normalized to a marginal utility of 1.0) and summing over all income groups forms the social benefit-cost ratio to be compared among projects.

Data may not be available or reliable to convert efficiency measures of row 2 into social well-being measures or even to show the distribution of costs and benefits among income groups. In such cases, decision makers will use ad hoc judgements to adjust efficiency measures of project appraisal for social and political factors that influence the choice of projects. In some instances, both equity and efficiency are enhanced by making investments solely based on efficiency and using direct transfers to raise incomes of the poor (see Harberger 1984).

Finally, social net benefits might be adjusted for riskiness of each of several projects in determining the net social benefits among several projects whose social feasibility is being estimated.

7.8 Simulation Analysis

Simulation attempts to reproduce on a small scale the actual essential elements of an operating market, socio-economic system, or other unit of inquiry. By allowing the analyst to observe and experiment with the working of the system in the "laboratory" of a computer model, simulation is a powerful tool of policy analysis. Because of computational requirements of simulation models, it is not coincidental that their popularity has been closely correlated with the use of computers.

Simulation may be simple or complex. Trade-offs are inevitable: large models provide greater realism but are costly to build and maintain; small models are less costly but may lack essential realism. There is merit in keeping simulation models as simple as possible consistent with meeting needs of policy analysts.

7.8.1 System Simulation Models

System simulation emphasizes accounting for all components in the system that bear significantly on the analysis and solutions to problems. System simulation models offer a broad and flexible means of dealing with the complexities of monitoring and evaluating food and agricultural policies, programmes, and projects. Their flexibility rests in their building-block organization, allowing for the development and incorporation of new components and the substitution of complex components for simpler ones as necessary to suit the particular analysis. They also allow for the use of a wide range of modelling techniques from different disciplines, depending on the needs at hand. Simulation is adaptive in that improved knowledge about data and structural relations can be progressively incorporated into the models.

A simulation model can incorporate one or more of several models discussed in this report including supply, demand, and balance sheet components; linear programming and other optimizing procedures; and behavioural equations. It can predict real world behaviour or show the impact of policy experiments including alternative tax rates, quotas, price controls, investments in land and water development projects, land reform, and population planning.

Because any model is only an approximation of reality, there will always be errors in its absolute predictions. Relative consequences, however, while still subject to error, tend to be more reliable in that data and structural inaccuracies usually affect the results of different

experiments in the same ways. For example, if simulation of Policy A results in \$100 million of additional farm income by 1990 while Policy B yields \$150 million, the fact that Policy B gave 50 percent more income relative to A may be a more accurate piece of information than the absolute numbers of \$100 million and \$150 million.

7.8.2 Selection of Model Type and Modelling Approach

Simulation models can have numerous forms including (Manetsch 1978):

- (1) a microscopic (individual or firm) versus macroscopic view (sector or national);
- (2) static versus dynamic behaviour, where dynamic models are generally characterized by feedback loops and time lags;
- (3) deterministic versus stochastic behaviour, where stochastic models explicitly include probability distributions to treat data series and parameters as random variables;
- (4) linear versus non-linear behaviour, where an example of a linear model is a doubling of fertilizer application causing a doubling of rice yield, and where a non-linear model allows for diminishing returns, thresholds, saturation points, and other types of constraints;
- (5) optimizing versus non-optimizing behaviour, where an optimizing model attempts to identify decisions which maximize profits, security, happiness, or efficiency or which minimize costs, poverty, malnourishment, or trade deficits; and
- (6) structural versus predictive, where predictive models emphasize ability to forecast future outcomes whereas structural approaches emphasize causal relationships among important variables of the system. These structural relationships are deduced using appropriate theory from disciplines such as economics, sociology, biology, and physics. The structure of the model, once specified, determines what data and statistical analyses will be needed to estimate parameter values and test the model's validity.

Emphasis in structural models is on the theoretical and logical validity of the causal relationships in order to understand why certain behaviour occurs in response to past and proposed policy conditions. For this reason, structural models are typically better at predicting and explaining qualitative behaviour and responses than at making forecasts of absolute numbers.

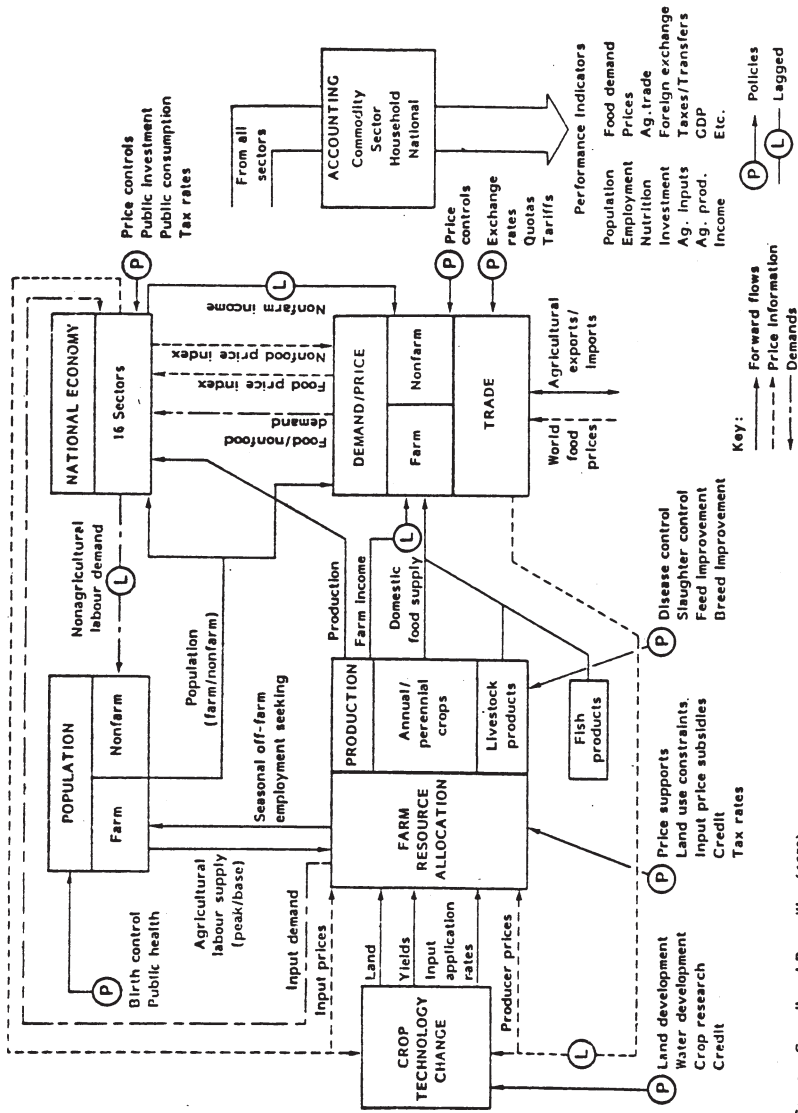
By contrast, behavioural predictive models are developed through an inductive process. Beginning with empirical data on the behaviour of variables of interest, relationships are chosen according to some criterion such as a least-squares fit. These statistical relationships will be a satisfactory predictor of what behaviour may occur under conditions similar to those used to estimate them in the first place. However, an understanding of how or why that behaviour occurs (i.e., causal relationships) is important in making decisions about the future under conditions which may never have existed before - a common situation in development planning. Because structural and predictive modelling have their own respective strengths and weaknesses, it is not surprising that practical models for policy analysis are hybrids typically falling somewhere between the two extremes.

Some general statements can be made about the requirements of developing and operating various types of models (Manetsch 1978):

- (1) Dynamic models are usually more costly to develop than static models. However, they usually provide decision makers with significantly more useful information.
- (2) Stochastic models usually are not much more expensive to build than deterministic models, but they are much more expensive to operate on computers.
- (3) Optimizing models are usually more expensive to operate than non-optimizing models.
- (4) Model development costs tend to go up much faster than the model size.

7.8.3 Model Specification

The building-block approach is most suitable for construction of system simulation models. For example, Figure 7.5 is a diagram of a complex simulation model developed for agricultural sector policy analysis which uses a variety of modelling approaches: the national economy component uses a 16-sector input-output model; the population component utilizes a cohort-survival model; the crop technology change component follows a production function approach; the resource allocation component is based on a recursive linear programming model; and the demand/price/trade component operates as a simultaneous-equation, market-clearing model. The interested reader is referred to Chapters 5-10 in Rossmiller (1978) for further background and descriptions of the overall system model and its components.



Source: Carroll and Rossmiller (1978).

Figure 7.5 - A five-component agricultural sector simulation model

7.8.4 Data Sources and Requirements

In general, the aggregation levels decided upon in the model specification stage for commodities, population groups, or geographic regions heavily influence a model's specific data requirements, data sources, and procedures for estimation. For example, depending on the country and the purposes for the model, it might be important to treat rice, corn, wheat, beef, and milk as separate commodities (although even these products are aggregates of components with different characteristics), while grouping other commodities, such as fruits, vegetables, and industrial crops.

As an illustration, Table 7.4 shows a few of the data requirements of the agricultural sector simulation model described above and in Figure 7.5. The sources used to fulfill these requirements (also indicated in the table) include measurement instruments discussed in Chapters 5 and 6, results of separate analyses, and experimental assumptions. For each of the five component models, selected data requirements are listed in three major categories:

- (1) initial conditions of internally computer variables;
- (2) values of parameters measuring the strengths of technical, institutional, and behavioural relationships; and
- (3) values, for each time period to be simulated, of exogenous variables such as government decisions.

Sensitivity testing is an important method for determining how much the outputs of the model are influenced by possible errors in the model's data series and parameter values. It involves making systematic changes in appropriate data and parameters, based on the degree of uncertainty regarding their accuracy, and then examining the effects of those changes in one or more model outputs. Sensitivity testing helps set priorities on efforts to improve the parameter estimates and data in the model, thereby allocating scarce resources for data collection and analysis in a cost-effective manner.

7.8.5 Computer Implementation

Solving a model refers to the process of determining the behaviour of the endogenous variables over time, given particular initial conditions of those variables and values of input variables (e.g., policies, weather conditions) over time. In the case of simple models, it may be possible to apply mathematical techniques such as calculus and