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The Validation of Programming Models: The Philippine Experience

by

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ABSTRACT

The purpose of this paper is to demonstrate the need and procedure for testing sectoral programming models. The main approach pursued in investigating the consistency of the programming model is to compare the former's estimates of endogenous variables to carefully selected base period parameters. The actual framework used to achieve this objective is an operational, static, deterministic, and highly aggregate programming model of Philippine agriculture. Alternative formulations of the Philippine model were undertaken to detect possible data errors in the consumption, production, and objective function sets of the former.

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Introduction

In recent years, there has been a rise in the use of programming models to analyze the economic implications of supply and demand shifts confronting the agricultural sector of the various developing countries. The most notable sector programming models built are those by Duloy and Norton [4]; Pomareda [16]; Cappi, Fletcher, et al. [3]; Miller, et al. [14]; and Heady [9]. By the nature of the modal objective function of such models, the market type simulated pertains to that of a competitive market.

Despite the substantial investment in the form of technical skills and data-processing inputs involved, the validation of sector program-

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ming models are rarely discussed explicitly. The earliest explicit concern in testing the reliability of programming models was expressed by Nugent [15]. The central theme of his work is basically centered in two propositions, i.e.:

(a) If a market in the real world closely approximates a competitive condition, then any deviation of the results of a programming model for that market from the existing observable empirical data base represents model specification errors.

(b) If the programming model approaches a competitive market solution while the real world does not, then market imperfections are likely responsible for some deficiencies in the predictive ability of the programming framework.

Recent works by Duloy and Norton [4] and Kutcher [13] have accounted for both propositions in validating the Mexican agricultural sector (CHAC) model. Later research undertaken by Shumway and Talpaz [17] concentrated on proposition (a) by examining merely the output results of a programming model of major crops in California.

In this paper, the first proposition was invoked to validate the optimal levels of production, exports, and imports and the shadow prices of commodities and resources of a programming model depicting the various activities of the Philippine agricultural sector. It is the main objective of the research reported in this paper to empirically illustrate the various validity tests conducted on the above-mentioned programming model (which is known as MAAGAP[1/]).

The Structure of the Philippine Model

The current version of the Philippine (MAAGAP) model is a highly aggregate, static, and deterministic programming model. The model includes rice, corn, sugar, coconuts, vegetable and livestock products which account for about 90 percent of the total gross value added of agricultural commodities in 1976. Detailed discussion of the actual data set used in generating the programming matrix can be found in Kunkel [10].

The initial version of MAAGAP was developed in Project ADAM (Agricultural Diversification and Markets) in 1974. Project ADAM is in the Bureau of Agricultural Economics (BAEcon), Philippine Ministry of Agriculture (MA), and it consists of both Filipino and United States agricultural economists. It is jointly financed by the United States and Philippine governments.

Project ADAM, and MAAGAP, have the following objectives:

(a) To obtain an integrated picture of Philippine agriculture within which various policy goals can be formulated and analyzed.

[1/] MAAGAP is a Filipino w[illegible]hich means alert and stands for Mathematical Analysis of Agricultural Adjustments in the Philippines.

(b) To analyze the various constraints limiting farm income, employment, and productivity in the country.

(c) To develop the economic data and analysis needed to identify realistic agricultural production and market opportunities at the farm, regional, national, and international levels in order to increase and stabilize income from farms, increase farm contributions to national growth, and increase employment and foreign earnings.

(d) To develop in the Philippines continuous analyses and reevaluations of these opportunities and alternatives as production and market conditions change through the combined efforts of the Ministry of Agriculture, the University of the Philippines, and the U.S. Department of Agriculture.

The MAAGAP model is an important part of the agricultural policy analysis system within the Bureau of Agricultural Economics (see Figure 1). Since 1974, the MAAGAP model has been used for several policy analyses, such as fertilizer subsidy analysis and evaluation of supply and demand projections estimated by the National Economic Development Activity (NEDA). Professional papers have also been written on the various aspects of model development. The most important ones are those by Kunkel, Gonzales, and Hiwatig [11]; Atkinson and Kunkel [1]; Gonzales, Atienza, Kunkel, and Rodriguez [8]; Kunkel,

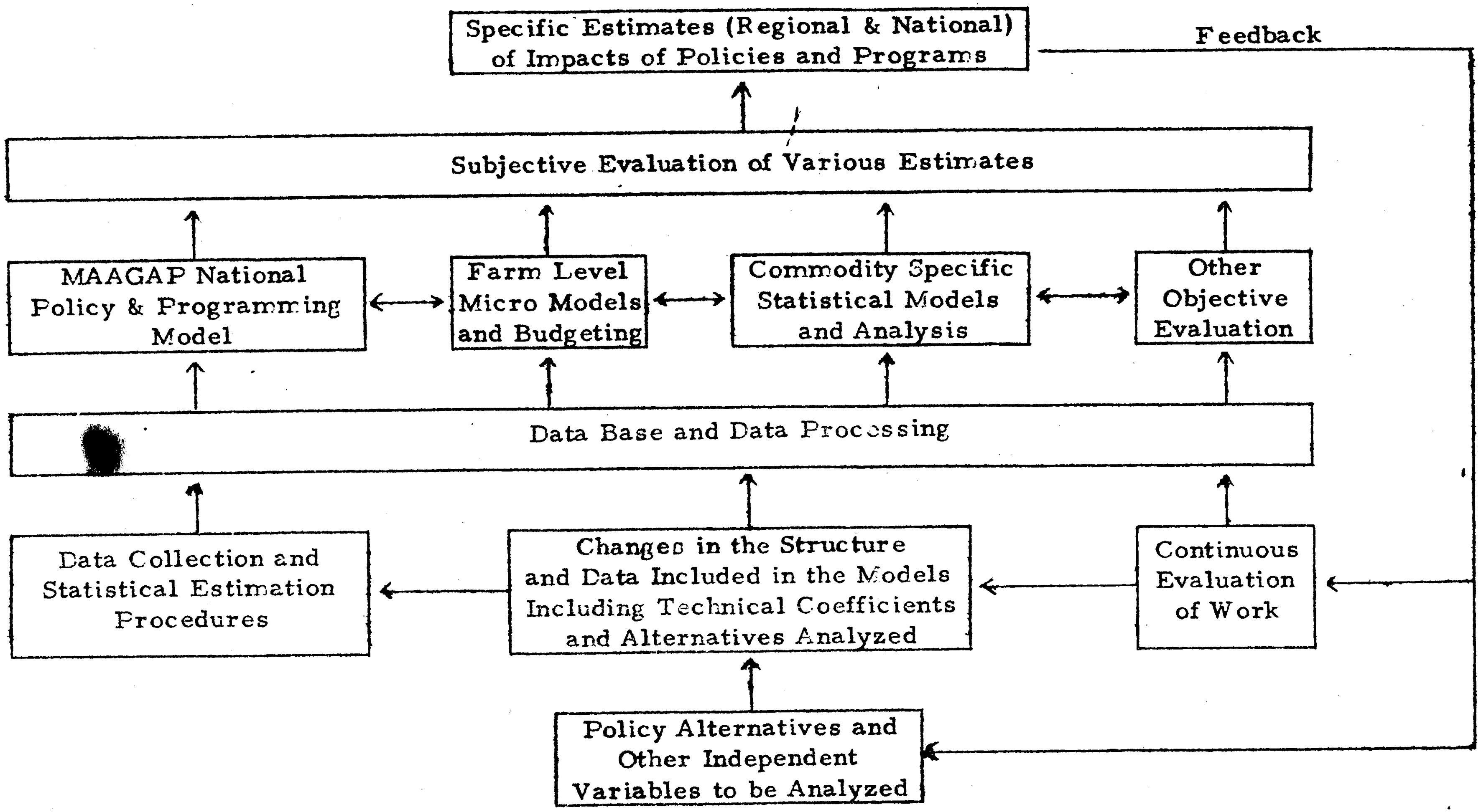

Figure 1. Agricultural Quantitative Policy Analysis System at the Bureau of Agricultural Economics, Philippine Ministry of Agriculture

Gonzales, and Sharples [12]; Ferrer [6]; Atienza and Kunkel [2]; Foote [7]; and Encarnacion [5].

The model's objective function is:

$$\text{Max } f(W) = \sum_{j} \int^{C_j^u} P_j dC_j + \sum_{j} v_j E_j - \sum_{j} u_j I_j - \sum_{n} C_n X_n$$

$$- \sum_{k} W_k R_k - \sum_{t} f_t F_t - \sum_{j} g_j 0_j - \sum_{m} b_m M_m \qquad (1)$$

where:

$P_j = f(C_j, Y)$ is the inverse demand function for the j^{th} final product,

C_j is the domestic consumption of the j^{th} product,

Y is the income level measured as GNP,

v_j is the export price of the j^{th} product,

E_j is the quantity of the j^{th} product exported,

u_j is the cost of importing the j^{th} commodity,

I_j is the amount of the j^{th} commodity imported,

C_n is the miscellaneous cost of the n^{th} production activity (includes depreciation costs and other fixed costs)

X_n is the production levels of the n^{th} production activity,

W_k is the input cost of the k^{th} input supplying activity,

R_k is the amount supplied of the k^{th} input,

f_t is the unit cost of the t^{th} feed-mixing activity,

F_t is the amount of the t^{th} feed ration supplied,

g_j is the unit marketing margin of the j^{th} final product,

0_j is the activity level of the j^{th} final product transferred from the m^{th} processing activity,

b_m is the unit processing cost for the m^{th} processing activity,

M_m is the level of the m^{th} processing activity.

Equation (1) is simply the sum of the area under the demand curve plus the value of exports minus the costs of imports, production, processing, feed-mixing, marketing, and input supply. The rationale for the selection of the objective function defined in (1) is to simulate a perfect competitive market solution. Earlier proofs of such a contention have been provided by Duloy and Norton [4].[2/] At the micro-level, the existence of such an objective function implies the following individual behavioral assumptions, i.e.:

(i) Farmers are technically efficient and governed by profit maximizing behavior

(ii) Farmers are price-takers in the input and commodity markets

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[2/]Majority of the proofs utilized the Kuhn - Tucker conditions and duality theorems.

(iii) Farmers are confronted with a finite production set

Furthermore, although the income variable appears in the demand function (P_j), income shifts are considered exogenous to the model. This arises because of the static nature and "partial equilibrium" (with regards to income effects)[3/] of the latter.

Another assumption refers to the international trade market confronting the Philippines. Export (v_j) and import (u_j) prices are considered as constants since the Philippines is in general a price-taker in international markets.

Also, for simplicity, the term P_j does not contain any cross-price elasticity terms. The inclusion of the latter within the model can easily be done through aggregation of commodities into composite groups. Substitution possibilities can be allowed within the group but not across groups. At the moment, our initial solutions in a model structure with substitution possibilities in the consumption set are not significantly different from one without. The objective function is maximized subject to constraints defined by equations (2) to (8).

The resource utilization constraint is:

$$B_r + \sum_k a_{r_k} R_k + \sum_t a_{r_t} F_t \geq \sum_n a_{r_n} X_n + \sum_m a_{r_m} M_m \qquad (2)$$

The above equation states that the amount of the r^{th} resource used for

[3/] The model does not capture the income impacts on the farmers' and other sectors' expenditure pattern within a finite time period.

primary production and processing activities is less than or equal to the amount available (B_r) plus the amount provided via the input-supplying and/or feed mixing activities.

The commodity balance equation for primary products is:

$$\sum_n q_{1n} X_n \geqq \sum_m q_{im} M_m + \sum_t q_{it} F_t \tag{3}$$

Equation (3) states that the amount produced of the i^{th} primary product is either processed or used for feed. The output balance for intermediate and final products is:

$$\sum_m D_{jm} M_m + O_i I_j \geqq \sum_t d_{jt} F_t + O_j \tag{4}$$

Equation (4) states that the amount of the j^{th} commodity processed or imported is either used for feed or transferred to final demand.

The demand-supply foreign balance equations are:[4/]

$$- \sum_s C_{js} S_{js} - E_j - O_i I_j \geqq - O_j - I_j \tag{5}$$

$$1 \geqq \sum_s S_{js} \tag{6}$$

Equation (5) means that the amount of commodity transferred or imported is either consumed domestically or exported. We will note

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[4/] Equation (5) is somewhat redundant. It, however, plays a pivotal role when regions are added to the current national model.

that equations (3), (4), (5) are not merely accounting identities but are market clearing equations in the commodity markets. It is easy to show via the dual that the shadow price vectors obtained from such rows are the equilibrium commodity market prices. The corresponding market clearing equation in the input markets is provided by equation (2). Equation (6) is the convex combination constraint which limits the amount that can be consumed through any segment of the demand curve.

The processing capacity and other technical constraints are specified as:

$$H_{\mu} \geq \sum_{n} a_{mn} X_n \qquad (7)$$

The usual non-negativity condition is:

$$E_j,\ I_j,\ X_n,\ R_k,\ F_t,\ O_j,\ M_m,\ C_j \geq 0 \qquad (8)$$

A basic limitation arising from the use of a programming model depicted by equations (1) to (8) for policy analysis is the sensitivity of its solution (particularly the shadow price of fixed resources) to specification and measurement errors. To illustrate, by the dual property we have for the non-zero n^{th} primary product in the basis, the following relation:

$$(9) \quad \sum_{n*} a_{r_{n*}} \lambda_i + \sum_{n*} a_{m_{n*}} Z_i + C_n = \sum_{n*} a_{l_{n*}} U_i$$

where

λ_i, Z_i, U_i are the respective shadow prices (or imputed costs). If Z_i is biased due to measurement errors, then λ_i and U_i are also affected. Estimation errors commonly arise due to data "compromises" made by researchers. For example, when either input supply or product demand levels are fixed a priori due to the absence of "reasonable" econometric estimates, the P_j or W_k (equation (1)) is set subjectively at pre-determined levels. The main "theoretical" effect of such a compromise is that the proximity of the shadow price set to the actual market price levels crucially depends on resource constraints which are binding. This renders, therefore, the validation of model results against a base period as a research necessity.

Validating the Philippine Model[5/]

In general, the model validation procedure pursued is to compare the MAAGAP model results to actual base period levels for the set of endogenous variables (Table 1) considered in the model frame work. The base period used for this purpose was 1976. Since we are dealing with a particular cross-section base data, this in effect implies that we are not validating the ability of the model to capture the actual turning points embodied in the relevant time path of the endogenous variables considered. Theoretically, this means that only one point on each of the input demand and supply; and product transforma-

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[5/] The various validation tests performed in the Philippine model were partly influenced by the earlier work of Kutcher dealing with the consistency tests of the Mexico Pacific Northwest Regional Model.

tion and demand curves implicit and incorporated in the model is validated.

However, due to data limitations, it was difficult to determine the consistency of the majority of the optimal resource levels and resource shadow prices (R_k, F_t, and π_{z_j} of Table 1). For example, land prices (which are really acquisition cost and not really in terms of rate of return) are usually under valued by owners to evade taxes. At the most, the only major input which can be subjectively validated pertains to the magnitude of fertilizer use. In the ensuing discussion, the endogenous variables, which were subjec ted to a close scrutiny were P^*, E_j, I_j, and X_n.

The first test involves a check on the production capacity (implicitly involving also the input-output coefficients) of the model. This is accomplished by fixing a priori final domestic commodity demand at their 1976 levels, and by permitting exports and imports of commodities at unlimited levels and at fixed world price levels. Hence, if a given commodity is partially or totally imported (when in fact it is not imported in the base period) as determined by the model, this implies an under-capacity of our production set, that is, the relevant production vectors may be too "expensive". The reverse holds true in the case of "excessive" exports of a given commodity.

The second validation test entails redefining the model's objective function to be the minimization of the costs of producing the base period domestic output levels[6/] that is, the terms P_j and v_j are dropped in equation (1). The shadow prices generated in the commodity balance equations (that is, (3), (4), and (5)) are marginal costs. These costs can then be compared with the base period market prices to validate the model's assumption of a competitive market structure and to detect any serious data estimation errors.

The last test is a straightforward comparison of the full model (as defined by equations (1) to (8)) results with those of the base period being simulated. In all these validation tests, the numerical measures used in judging how closely the model approximates the base period major agricultural commodities and prices are:

(i) The correlation between the model-derived commodity outputs and prices and those of 1976.

(ii) A simple regression of the form:[7/]

$$Y_o = a + b\,Y_m \tag{10}$$

where Y_o is the observed value, and

Y_m is the model-estimated value

[6/] In terms of equation (5), this means: $\sum_s C_{js}S_{js} + E_j = \bar{Y}^*$ where $\bar{Y}^*$ is the 1976 domestic output levels.

[7/] The regression form $\ell_n Y_o = \ell_n a + b\,\ell_n Y_m$ was also estimated to determine non-linear biases. A serious limitation arising from using equation (10) (or its log transform) is that formal statistical tests of significance cannot be applied to the regression parameters because the model estimates are not independent. Such parameters should merely then be interpreted as informal measures of goodness of fit and model bias.

Ideally, the model results and real world data on the various agricultural commodity outputs and prices will have a correlation of one (or equivalently E(a) = O and E(b) = 1 in (10)) if the objective function, production, consumption, and constraint sets of the model are identical to the real one.

However, the determination of the critical value (based on (i) or (ii)) that separates "pass" from "fail" depends largely on the utility function of the researcher. If the subjectively-determined critical value of the researcher indicates a "failing mark" for the model's results, a logical criteria which the researcher can used in the termination of the validation process is the equality of the marginal returns from the model's improvement and the value of the marginal effort - - a familiar concept!

The major crop output and price results of the various alternative model formulations together with the corresponding available base period data are given in Table 2. The regression and correlation parameters based on Table 2 are given in Tables 3 and 4. The linear regression results (Table 3) indicate two types of directional biases manifested by the laternative model formulations used for the various validation runs. The first type (T_1 of Figure 2) is that for small values of the relevant base period data (Y_o), the model's estimates are biased downwards. The reverse is true for larger values of Y_o. The second type (T_2 of Figure 2) is that all the model's estimates are skewed and biased downward. As indicated by Table 3, the full and fixed demand models' estimates of crop prices belong to ghe second bias type.

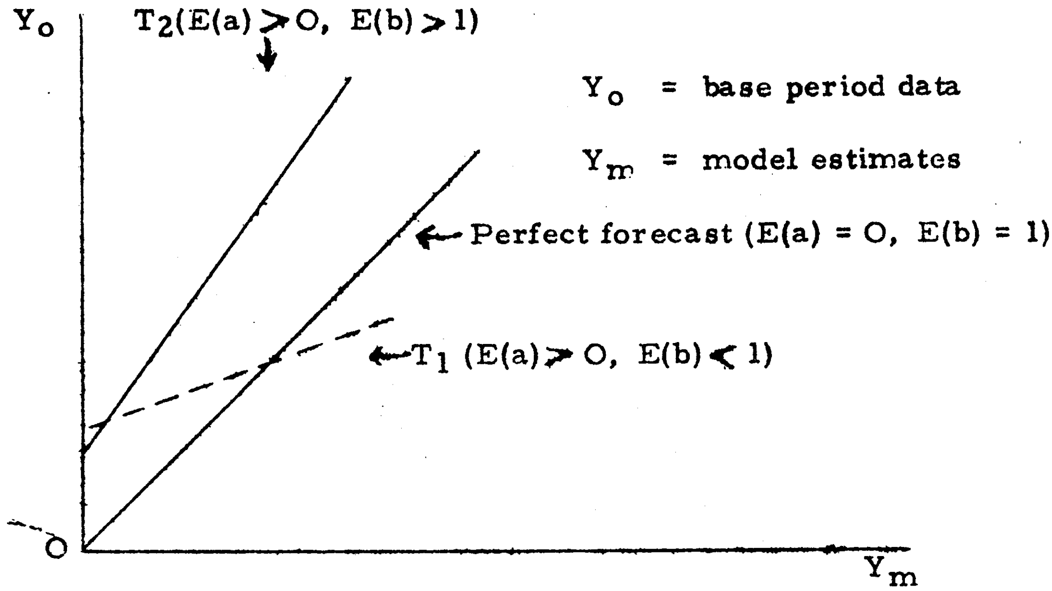

Figure 2. Illustration of Linear Directional Biases

The same holds true for the full model's estimate of crop production. However, the crop area and production estimates of the fixed demand model are of the first bias type. The latter type is also present in the full model's determined crop area and in the cost minimization model's generated crop prices. Judging from the standard errors for b and the correlation coefficient (r) of Table 3, the full model seems to outperform the other model formulations. The log linear regression results (Table 4) indicate three types of biases as shown in Figure 3. For example, the full and fixed demand models' estimates of crop areas belong to V_1, that is, they are biased upward for small values of $\ell_n Y_o$.

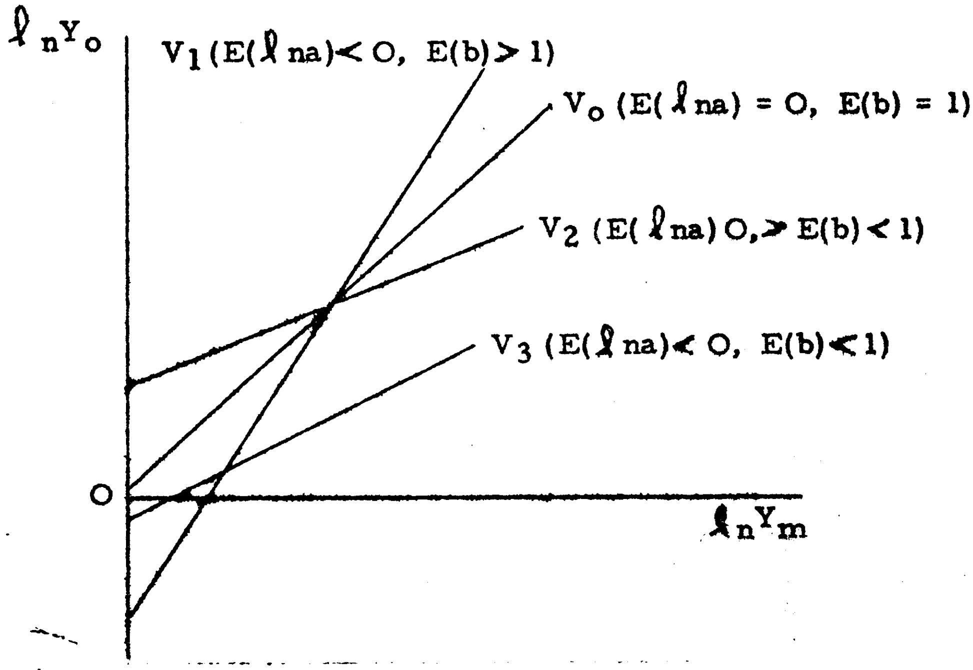

Figure 3. Illustration of Log Linear Directional Biases

We can observe also from Tables 3 and 4 the high correlation between the crop prices estimated from the cost minimization model and the actual ones for 1976. This supports the plausibility of the competitive market structure assumption of the Philippine model. However, a closer comparison of the implicit costs of commodities derived from the cost minimization model with those of the base period (Table 2) showed a large gap in the case of coconuts. This can be attributed to data errors which we found to be:

(i) The conversion rate of 5 instead of 4.5 nuts per copra (coconut meat) was used

(ii) The domestic coconut oil demand was over-estimated by 65 percent

(iii) Coconut hectarage constraint was under-estimated by 5.3

(iv) The export levels set up for coconut oil and copra may be too high due to the absence of any stock adjustments

Since we are dealing with an equilibrium model, the shadow prices of other major agricultural commodities will likely be affected by the coconut data misspecification, for example, sugarcane.

On the other hand, a general reason for the deviations of the implicit prices of the cost minimization model from the actual commodity prices is that by dropping the first and second terms of equation (1), we are in effect utilizing the relevant model structure information less efficiently. Graphically, this means that if we disregard D_1 in Figure 4, the probability of achieving the "true" market price (P_1) is very low because we have lesser degrees of freedom in estimating it. The error in price estimation if S_2 is the implicit supply function generated by the cost minimization model is the area abP_1P_2 (Figure 4).

The low marginal cost for corn (₱0.50 per kg.) compared to the base period price of ₱0.94 per kg., can be attributed to a possible downward bias in the cost of producing corn. Part of our problem lies in determining the appropriate spatial aspects of the corn production vectors due to data constraints.

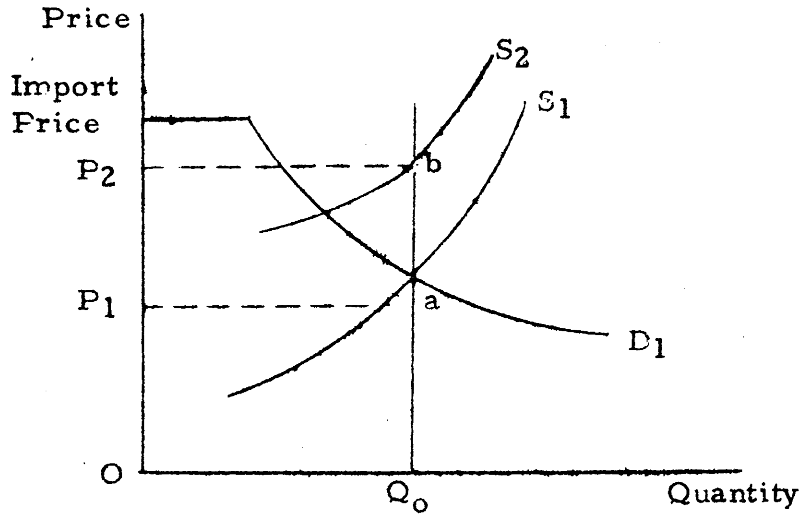

Figure 4. Market Equilibrium in the Cost Minimization Model

For the production capacity test, the fixed demand model solution registered 40.8 thousand metric tons of commercial broiler imports. Since there were no broiler imports in 1976, the previous finding indicates that the domestic commercial broiler production activities incorporated in the Philippine model may be too expensive, that is, implies an upward bias in the pricing of such activities. Comparison of the export levels of coconut and sugar products with the base levels indicates an "over-capacity" in the case of centrifugal sugar (1.72 vs. 1.455 million metric tons), while the reverse holds for molasses (.657 vs. .792 million metric tons) and copra meal (.170 vs. .497 million metric tons).

The fertilizer usage levels obtained from the various model formulations are given in Table 5. All model types over-estimated the levels of fertilizer use. However, the full and the fixed demand models performed better than the cost minimization model in predicting nitrogen[8/] and potash consumptions in 1976.

Summary

Despite their wide applications, programming models are rarely subjected to validation tests. This paper has shown (via a static and competitive programming construct) that conducting consistency checks on the shadow price of programming solutions is an indispensable research task because any misspecifications in resource constraints or prices will tend to have an error spill-over effect in the entire set of shadow prices generated.

Also, the actual validation process conducted on a programming model of Philippine agriculture was demonstrated. The empirical tests were designed to reveal any possible biases in the production, consumption, constraint, and objective function sets of the latter. The validation procedure pursued was to compare the commodity output and price estimates of three model formulations (that is, full, fixed de-

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[8/] Nitrogen is considered as the most important fertilizer nutrient in the Philippines. Experiments conducted by the Bureau of Soils (BS), Philippine Sugar Commission (PHILSUCOM), and the International Rice Research Institute (IRRI) show that the majority of the crops are strongly responsive to nitrogen compared to potash and potassium.

mand, and cost minimization models) to the actual 1976 levels. Each model framework represents a particular unique theoretical structure to obtain information on any inconsistencies of a particular component of the Philippine model. To illustrate, the fixed demand model results indicate possible significant biases in the crop production vectors for commercial broilers, corn, and copra meal. Also, the wide disparity between the cost minimization determined coconut shadow price and the actual one in 1976 aided us to identify data measurement errors.

The numerical measures used in judging how well a particular programming model variant approximates the real Philippine agricultural conditions prevailing in 1976 are the simple correlation coefficients and regression of actual versus model results. Based on these latter indices, the full model outperformed the other formulations.

The validation of the resource usage and price levels of the MAAGAP model was limited to that of fertilizer use. This was dictated more by the availability of the basic data on farm inputs. Comparison of the estimated fertilizer nutrients by the three model formulations with the 1976 levels indicate that all of them over-estimated the latter. Nevertheless, the full and fixed models yield nitrogen and potash consumption levels which were far better than those determined from the cost minimization model.

Table 1. Classification of Variables in the Philippine Programming Model

I. Endogenous Variables

(a) P^* = agricultural commodity equilibrium price vector

(b) C_j = domestic consumption of the j^{th} product

(c) E_j = quantity of the j^{th} product exported

(d) I_j = amount of the j^{th} commodity imported

(e) X_n = production levels of the n^{th} production activity

(f) R_k = amount supplied of the k^{th} input

(g) F_t = amount of the t^{th} feed ration supplied

(h) O_j = activity level of the j^{th} final product transferred

(i) M_m = activity level of the M^{th} processing activity

(j) $\Pi_{\ell j}$ = shadow prices of various absolute land classes (which is derived from equation (7)).

II. Exogenous Variables

(a) Y = income level

(b) V_j = export price of the j^{th} product

(c) U_j = import price of the j^{th} commodity

(d) W_k = input cost of the k^{th} input supplying activity

(e) f_t = unit cost of the t^{th} feed-mixing activity

(f) g_j = unit marketing margin of the j^{th} final product

(g) b_m = unit processing cost for the m^{th} processing activity

(h) C_n = miscellaneous cost of the n^{th} production activity

Table 2. Crop Area, Production, and Prices of Alternative Model Formulations

Crops	Actual Base Period	Area: Full Model	Area: Fixed Demand	Actual Base Period	Production: Full Model	Production: Fixed Demand	Actual Base Period	Prices: Full Model	Prices: Fixed Demand	Prices: Cost Min.
Units	1,000 has.			1,000 m.t.			Pesos/kg.			
Palay (Rough Rice)	3,579.3	4,198.0	4,173.2	6,159	6,705	6,710	.94	1.01	1.09	1.18
Corn	3,257.0	3,169.3	3,144.0	2,767	3,119	2,960	.94	.52	.33	.50
Sugarcane	533.0	538.6	538.6	2,514	2,455	2,455	1.94	1.89	1.89	2.64
Coconut	2,521.2	2,387.0	2,387.0	10,662	8,619	1,730	1.85	1.63***	1.63***	3.35***
Banana	298.7	244.7	224.5	3,068	954	875	.41	.38	.38	.50
Cabbage	8.1	15.1	18.0	54	64	69	1.53	1.46	1.44	1.51
Pechay*	4.5	6.7	7.3	37	25	27	1.40	1.35	1.20	1.49
Tomatoes	21.0	21.9	26.6	153	79	96	2.04	1.53	1.56	1.63
Eggplant	16.2	26.5	32.1	82	99	120	.97	1.13	1.09	1.16
Camote**	192.3	196.0	243.3	781	687	745	.42	.64	.61	.61
Cassava**	118.0	150.5	163.3	621	464	503	.38	.33	.33	.38

*Leafy vegetable

**Root vegetable

***Copra equivalent price

Note: ₱7.30 = $1.00

Table 3. Linear Regression[1] Results for Actual vs. Model Levels

	a	b	r
Production			
Full Model	148.80	1.086 (.09615)	.9665
Fixed Demand	1051.69	.9410 (.45356)	.5688
Area			
Full Model	32.49	.9304 (.03736)	.9928
Fixed Demand	24.93	.9377 (.10941)	.9927
Prices			
Full Model	.00138	1.0787 (.13411)	.9370
Fixed Demand	.0965	1.0180 (.14888)	.9157
Cost Minimization	.4032	.5608 (.12024)	.8413

[1] Based on Table 1

Note: Numbers in parentheses are standard errors

Table 4. Log Linear Regression[1/] Results for Actual vs. Model Results

	n ma	b	r	t-value of b	Standard Error of b
Area					
Full Model	-.23109	1.07245	.99674	37.06061	.02893
Fixed Demand	-.33934	1.10404	.99533	30.93003	.03569
Production					
Full Model	.16104	.97464	.97883	14.34569	.06793
Fixed Demand	-.03468	1.06178	.94449	8.62437	.12311
Prices					
Full Model	.02570	.95581	.91955	7.01989	.13615
Fixed Demand	.03976	.81689	.85335	4.91047	.16635
Cost Min.	-.03492	.80039	.88987	5.85153	.13678

[1/]Based on Table 1

Table 5. Fertilizer Usage Levels of Major Input Under Alternative Model Assumption

Resource	Unit	Model Formulation: Model	Model Formulation: Fixed Demand	Model Formulation: Cost Minimization	Actual 1976
Fertilizer					
Nitrogen (N)	1,000 m.t.	178	180	195	152[a]
Phosphorous (P_2O_5)	1,000 m.t.	92	84	92	38[a]
Potash (K_2O)	1,000 m.t.	68	68	103	55[a]

[a] Fertilizer and Pesticides Authority

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