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AN ECONOMIC MODEL FOR ANALYZING DEMAND FOR PHILIPPINE COCONUT PRODUCTS[1]

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This paper presents an analytical framework of the market for Philippine coconut products and an economic model showing price and demand relationships. Some statistical considerations and methods of estimating structural parameters of the simultaneous equation system are also discussed. In addition, it shows how the model can be used to measure quantitatively the impact on the coconut market of changes in the exogenous variables.

Theoretical Framework and Economic Model

The overall economic structure of the market for Philippine coconut products is shown in Figure 1. Coconuts in the country are fundamentally a commercial crop with a small portion retained for seeds, feeds, and home consumption; the remaining production may be considered the commercial supply for any year.

After coconuts are harvested they are distributed among three major outlets: (1) foodnuts and nuts used for homemade oil, (2) copra, and (3) dessicated coconut. Copra is then processed to produce oil and meal. The proportion alloted to each of the major products depends upon their corresponding prices which in turn are determined by the interaction of the supply and total demand. Along with a host of other

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[1] This article was based on the author's Ph.D. dissertation, "An Analysis of the International Demand for Philippine Coconut Products" done at the University of Minnesota, 1971. The author wishes to aknowledge the valuable help provided by James P. Houck, Professor in Agricultural and Applied Economics, in developing the model.

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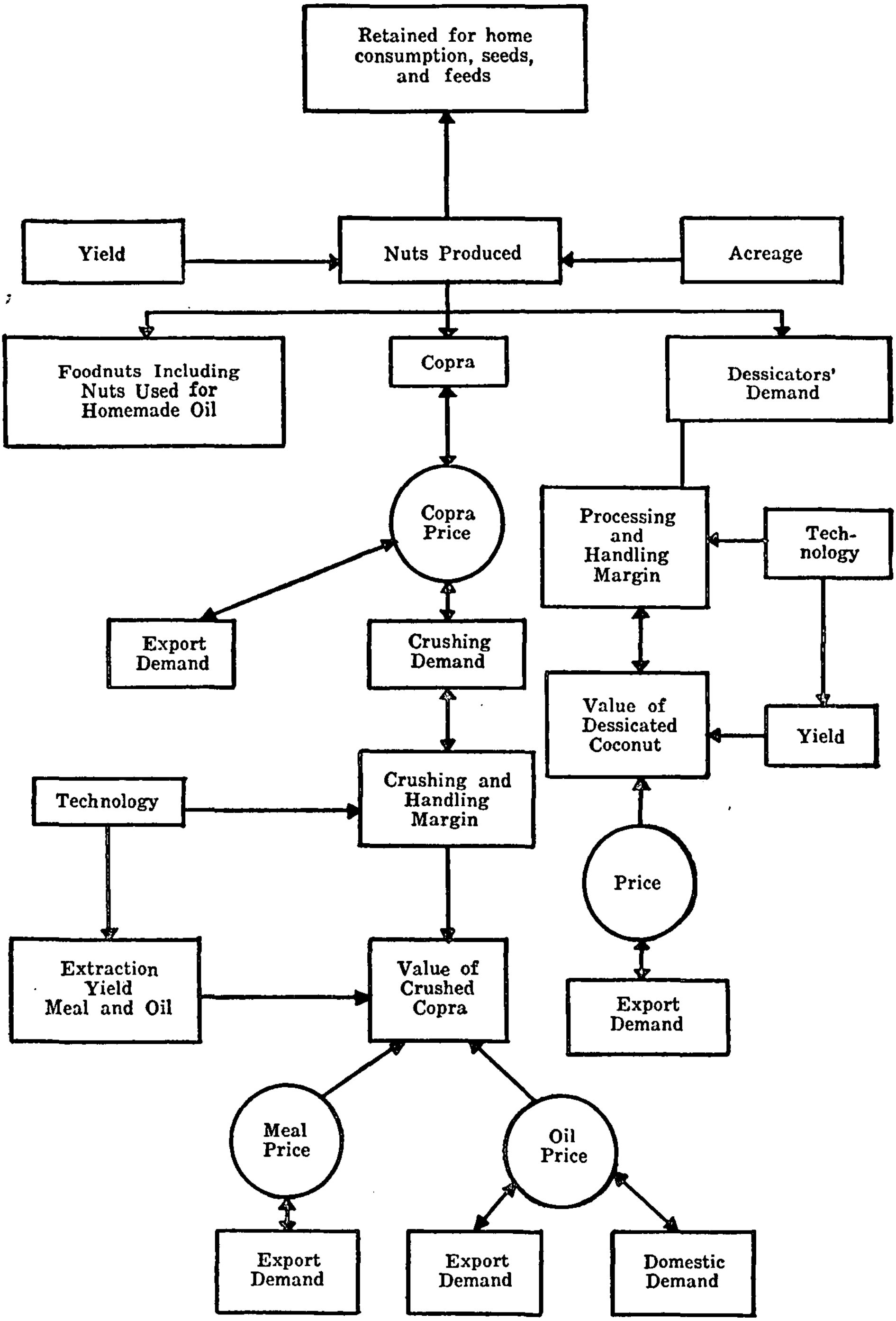

FIG. 1. Structure of the Philippine Market for Coconut Products

factors, e.g., input prices, technology, weather, etc. The prices farmers expect to receive affect their anticipated production. Due to the lagged nature of production after planting, planned output may be more accurately reflected by newly planted trees.[3] Moreover, since about 90 per cent of total coconut production is converted into copra, copra price may be the more relevant price influencing farmers' decision to plant more trees. Furthermore, majority of farmers convert coconut meat into copra and sell the product in this form.

Many nuts, both young and mature, are consumed as such in the country. Oil is extracted from coconut meat in many households. However, in comparison with total nut production, the quantity apportioned to these uses may be considered minor and for simplicity sake will be excluded from the analysis.

The market demand for copra consists of the demand by copra crushers in importing countries and the demand by domestic processors. A metric ton of copra yields 1,411 pounds or 64 per cent of coconut oil and 772 pounds or 35 per cent of copra cake/meal, a recovery rate which has remained fairly constant over the years. As might be expected the technology in copra processing would affect the value of crushed copra. More importantly, this value depends upon the oil and meal prices which are determined by an interplay of forces affecting the demand and supply of these products. Coconut oil enters both domestic and foreign markets while virtually all copra meal produced in the country is exported. The difference between the value of crushed copra and the prices received by farmers constitutes the crushing and handling margin.

The other product is dessicated coconut, the dehydrated shredded coconut meat used mainly for baked goods and confectioneries. Dessicators purchase nuts, process them, and export the dessicated product, the value of which depends upon its price and the physical rate at which coconut meat is shred-

[3] In A. J. Nyberg, *The Philippine Coconut Industry*, Ph.D. dissertation, Cornell University, 1968, number of newly planted trees per year was used as dependent variable in estimating the supply response of coconut farmers in the Philippines.

ded and dehydrated. The price is determined by the interaction of the export demand and the quantity produced.[4]

A simplified model of the market for copra, coconut oil, and copra meal is presented in Figure 2. It indicates the relationships between prices and quantities of various coconut products assuming a static economy and all other factors held constant. Section A shows the export demand (which is equal to total demand) for copra meal while Sections C and D represent the domestic and export demands for coconut oil and add horizontally to produce the total oil demand in Section B. The oil and meal markets may be considered as independent of each other since they operate in different sectors, oil in the fats and oils market and meal in the feed livestock sector but being products with a common origin their prices and quantities are linked together in the copra crushing demand (Section F). The revenue derived by processors is composed of the revenues from oil and meal which are produced in fixed proportions from every unit of copra crushed. The average revenue function, AR, in Section F is the vertical summation of the oil and meal demand functions and shows the revenue per unit as the quantity of copra processed increases and for each combination of oil and meal prices.[5] To derive the demand for copra at the farm level, marketing charges must be subtracted from the average revenue.

The copra market is divided into two sectors: the demand for domestic crushing and the export demand (Section E); the horizontal summation of the two forms the aggregate demand for copra (Section G). Copra prices are assumed to

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[4] In the economic model that follows, dessicated coconut was excluded. The demand for this product was analyzed independently of copra, coconut oil, and copra meal in A.E. Recto, *An Aanalysis of the International Demand for Philippine Coconut Products,* Ph.D. dissertation, University of Minnesota, June 1971, pp. 120-123.

[5] For a graphical analysis of joint products see (1) J. P. Houck and J. S. Mann, *An Analysis of Domestic and Foreign Demand for U. S. Soybeans and Soybean Products,* University of Minnesota Agricultural Experiment Station Technical Bulletin 256 (1968) and (2) P. A. Samuelson, "Contrast Between Welfare Conditions for Joint Supply and for Public Goods," *The Review of Economics and Statistics,* Vol. 51, No. 1 (Feb. 1969), pp. 26-30.

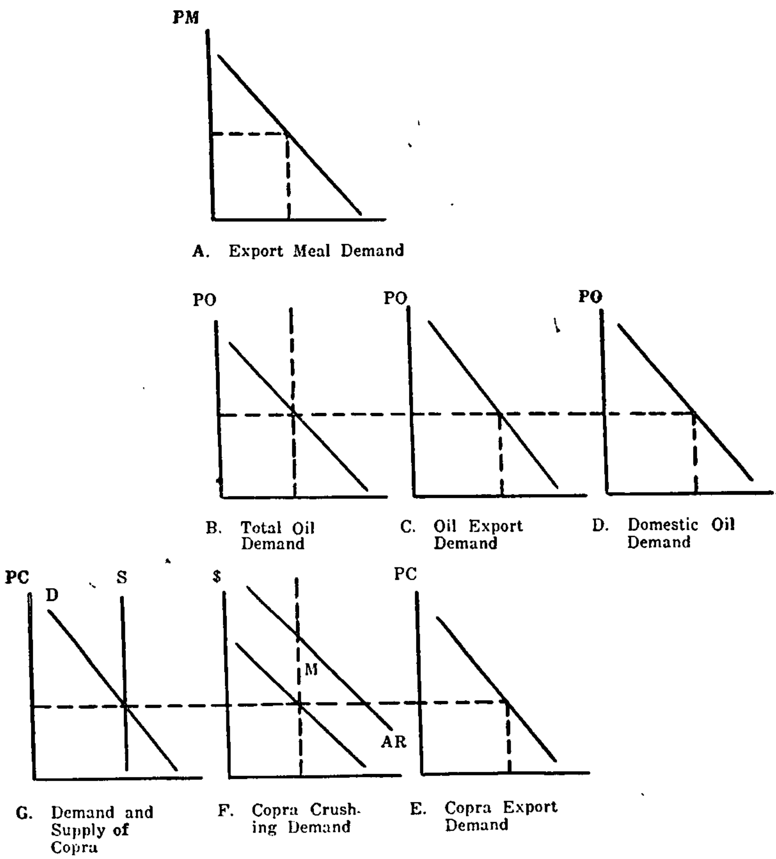

FIG. 2. A Simplified Graphic Model of the Philippine Coconut Market.

affect production in a lagged fashion, hence, the supply for any marketing year is completely inelastic with respect to current prices.

The theoretical framework developed above forms the basis for a nine equation simultaneous model that depicts the major price determining forces in the coconut market. The model consists of four behavioral and five technical relationships and identities all assumed to be in linear form. Specification of the variables in the stochastic equations was based on economic theory and an extensive preliminary analysis.

In generalized form the functions are:

Behavioral Relationships

1. Export Oil Demand: $QOX_t = f_1 (PO_t, PSC_t, PPK_t I_t, DV_t, u_1)$
2. Domestic Oil Demand: $QOD_t = f_2 (PO_t, IP_t, DV_t, u_2)$
3. Copra Export Demand: $QCX_t = f_3 (PC_t, PPK_t, QSBU_t, T_t, DV_t, u_3)$
4. Meal Export Demand: $QMX_t = f_4 (PM_t, PSM_t, L_t, DV_t, u_4)$ Technical Relationships

Technical Relationships

5. Oil Production: $QOP_t = YO.QCC_t$
6. Meal Production:[6] $QMX_t = YM.QCC_t$
7. Price Linkage: $PC_t = YO.PO_t + YM.PM_t - M$
8. Market Clearing, Oil: $QOP_t = QOX_t + QOD_t$
9. Market Clearing, Copra: $QCP_t = QCC_t + QCX_t + SC$

The variables are:

QOX — quantity of coconut oil exported by the Philippines

PO — price of coconut oil

[6] The quantity of meal exports was assumed equal to the quantity produced.

PSC	—	weighted average index of prices of soybean and cottonseed oils
PPK	—	price of palm kernel oil
I	—	weighted average index of real national income of countries importing copra and coconut oil from the Philippines
DV	—	dummy variable defined as 1961 = 1 and other years = O
QOD	—	quantity of coconut oil consumed domestically in the Philippines
IP	—	real national income of the Philippines
QCX	—	quantity of copra exported by the Philippines
PC	—	price of copra
QSBU	—	quantity of soybeans produced in the United States
T	—	time trend
QMX	—	quantity of copra meal exports of the Philippines
PM	—	price of copra meal
PSM	—	index of soybean meal price
L	—	total animal units in importing countries
QOP	—	quantity of coconut oil produced in the Philippines
YO	—	oil yield for every metric ton of copra crushed (=.64)
QCC	—	quantity of copra crushed in the Philippines
YM	—	meal yield for every metric ton of copra crushed (=.35)
M	—	marketing margin
QCP	—	quantity of copra produced in the Philippines
SC	—	a residual defined as the quantity of copra pro-produced minus the sum of copra crushed and exported

u_1, u_2, u_3, u_4 — disturbance terms

The subscript t indicates the current calendar year.

Demand for Coconut Oil

The market demand for coconut oil is a derived demand and is composed of several segments, (1) the demand for crude coconut oil by refineries which in turn supply manufacturers of margarine, shortening, and other oil-using foods and, (2) the demand by soap and chemical manufacturers and other industrial users. Important factors that affect the quantity of oil demanded in the foreign market are the price of coconut oil expressed as a jointly determined variable and price of substitute oils and income both exogenous variables. Coconut and palm kernel oils have a high lauric acid content and are highly substitutable in many uses. Soybean and cottonseed oils are two of the most important oils in the world market. Being the largest producer and world supplier of soybean and cottonseed oils both on commercial and concessional bases and at the same time the largest importer of Philippine coconut oil, United States prices were used. The income variable reflects a measure of the real national income of copra and coconut oil importing countries weighted by their relative importance in the world fats and oils market.

In international markets, major policy changes like the devaluation of an exporting country's currency would affect the flow of products. The devaluation of the Philippine peso[7] played a significant role in the growth of coconut exoprt of the country. The increase in the peso value of the dollar provided higher earnings for the exporters and therefore was a major factor in determining the quantity exported. To take account of this devaluation, a dummy variable was added to the equation.

The domestic demand for coconut oil in the Philippine is also a derived demand. The quantity of oil consumed was expressed jointly as a function of its price and two other variables — real national income and a dummy variable.

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[7] The Philippine peso went through a process of gradual devaluation starting in April 1960 and completed in 1965. The value of the peso declined from 2 pesos in 1960 to 3.87 pesos per U.S. dollar in 1965.

Demand for Copra

The total demand for copra is the sum of the foreign demand and the crushing demand by domestic processors, the latter being derived from the meal and oil demand functions since the quantities of oil and meal are fixed by the amount of copra crushed. Copra is a raw material in processing operations, thus the foreign demand for copra is derived from the demand for oil-and-meal-using products faced by foreign processors. With a 64 per cent oil yield its demand is overwhelmingly dominated by the oil sector. The quantity demanded, therefore, is influenced by the price and supply of competing oils and oilseeds. Preliminary analysis showed that world palm kernel oil price and soybean production in the United States significantly influenced the demand for Philippine copra. The soybean variable entered in quantity terms. The use of soybeans rather than either oil or meal captures the effect of the competition from both oil and meal. Being a source of copra meal, it might be expected that trends in feeding practices and livestock production in importing countries would affect the demand for copra. Livestock units did not appear significant but livestock feeding technology and other factors were represented by time trend.

Just as in coconut oil, a dummy variable was included as one of the explanatory variables in the copra export demand function to reflect the significance of the devalution of the Philippine peso.

Demand for Copra Meal

Since practically all copra meal produced in the Philippines is sold in the foreign market, total demand was assumed to be the same as the export demand. The export meal demand is derived from the demand for manufactured and farm mixed livestock feeds in importing countries. The quantity exported was expressed jointly in a function with the meal price and two exogenous variables: livestock numbers and price of other oilseed meals. Livestock units in importing countries include cattle, hogs, poultry, and sheep which were combined into one unit based on the protein consumption of each type of animal. The price of soybean meal appeared as a deflator for price of copra meal. A dummy variable to capture the effect of the devaluation was also added in the copra meal export demand equation.

Identities and Technical Relations

The yields of oil and meal, YO and YM, respectively, are assumed as technological constants with a magnitude of 640 and 350 kilograms per metric ton of copra crushed The quantity of oil produced is equal to the oil yield times the quantity of copra crushed. Similarly, the quantity of meal produced (which is equal to the quantity exported) equals the quantity of copra crushed multiplied by the meal yield.

In Figure 2 the vertical line connecting the meal demand, the total oil demand, and the crushing demand shows the linkage between the prices of the two products obtained from copra processing. This linkage is described by equation (7).

To derive the demand for copra at the farm level, marketing costs, M, must be subtracted from the sum of the two products, YO·PO and YM·PM, which gives the average revenue from the sale of oil and meal by processors. In this model, the margin was assumed a predetermined variable.

Equations (8) and (9) are market clearing equations, one for oil and another for copra. The annual quantities of copra crushed in domestic mills were estimated using the series on copra meal export and applying a meal yield of 350 kilograms per metric ton of copra crushed. The supply of copra was assumed to be the same as the quantity produced and since the latter does not equal the sum of copra crushed and exported a residual, SC, was added to represent stocks, unrecorded exports, and possible errors in measurement.

In the model, nine variables are considered endogenous, namely: QOX, QOD, QOP, PO, QCC, QCX, PC, QMX, and PM. All others are assumed exogenous.[8] The system, therefore, is

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[8] Endogenous variables are the jointly determined variables so called because their values are determined within the model by the simultaneous interaction of all relations in the system. Exogenous variables are those whose values are determined outside the structure

complete since there are as many equations as there are jointly determined variables. With fixed values of the coefficients, the system may be solved uniquely for the values of the endogenous variables in terms of the exogenous variables and the disturbances.

Methods of Estimation

After the economic model is formulated and the stochastic equations properly specified, the next step is to determine a procedure by which the structural parameters could be estimated. The choice of a particular methodology depends upon the "identification" of the equation, that is, whether the model is sufficiently restrictive so that when it is confronted with the data just one hypothesis is consistent with the model and the data. It indicates whether a unique or non-trivial solution to the structural parameters can be derived. If a unique solution exists the equation is said to be just identified. An infinite set of solutions results when the equation is underidentified and trivial or multiple estimates occurs when the equation is over-identified.[9]

A necessary though insufficient condition for an equation to be just identified is that the number of exogenous variables which appear in the system but not in the equation is one less than the number of endogenous variables in the equation. This is called the "order" condition and involves only a counting of the number of variables in a particular equation and in the entire system. The necessary and sufficient condition,

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and can be assumed to be determined or known in advance when explaining the endogenous variables.

The distinction between these two broad classifications is artificial and elusive because in economic systems all variables probably affect each other to some extent. (See Houck and Mann, *Op. cit.*, p. 10.) However, there are variables which significantly influence a particular sector but which are negligibly affected in return. Which variables are classified endogenous and which are exogenous depends upon the nature and the theoretical assumptions underlying the economic model.

[9] T. D. Wallace and E. G. Judge, *Discussion of the Theil-Basmann Method for Estimating Equations in a Simultaneous System.* Oklahoma State University, Dept. of Agricultural Economics, Processed Series p-301 (Aug. 1958), p. 5.

called the rank condition for identification, is that at least one non-zero determinant of order G-1, G being the number of endogenous variables in the system, can be formed from the coefficients of the variables which enter into the system but not in the equation.[10]

The equation is overidentified when the number of exogenous variables in the system but not in the equation is greater than the number of endogenous variables in the equation minus one. If the number of exogenous variables that do not appear in the equation is less than the number of endogenous variables in the equation minus one, then the equation is underidentified.

Each of the stochastic equations in the model is over-identified. In the oil export demand equation, for example, there are two jointly determined and four exogenous variables. For the whole system, there are nine endogenous variables, hence the number of exogenous variables appearing in the system but not in the equation is greater than the number of endogenous variables which actually appear in the equation minus one, that is, $8 > 2\text{-}1$. Repeated application of this rule reveals that all four behavioral equations in the model are over-identified.

A number of methods can be employed in estimating structural parameters of systems of simultaneous equations. Some procedures can be applied to obtain the coefficients of single equations in a model while others are used to estimate simultaneously all parameters of all equations in the system. The former is called single equation approaoch and the latter, system estimation.

One method is ordinary least squares (OLS). For this procedure to yield unbiased and consistent coefficients the disturbance terms must be independently distributed with zero mean and constant variance. The independent variables and the disturbances must be statistically independent, a condition which can be satisfied if the former are a set of fixed numbers

[10] G. Tintner, *Econometrics*, New York: John Wiley & Sons, Inc. (1952), pp. 161 and 167.

or are random variables distributed independently of the disturbances.[11]

If only one endogenous variable appears in the equation, statistically consistent and unbiased estimates of the structural coefficients can be obtained by fitting a least squares regression function. However, there are two endogenous variables in each of the four behavioral equations in the model thus violating the assumptions of least squares. Whichever is chosen as dependent variable, the remaining endogenous variable will be correlated with the error term in that equation.

Where there are more than one endogenous variable, each variable could alternatively be expressed in reduced form. Here, each endogenous variable is expressed as a function of the predetermined variables[12] in the system, hence the ordinary least squares could appropriately be applied. The coefficients of the reduced form equations are unbiased and from them, estimates of the structural parameters of the simultaneous equation system could be derived. The technique is called the indirect least squares, however, it is feasible only for exactly identified equations.

A method which is of more general applicability and can be used to estimate the parameters of a single equation whether it is just identified or overidentified is the limited-information single-equaton maximum-likelihood method often called the limited information method developed by Anderson and Rubin.[13] The likelihood function is maximized subject only to the a priori identifying restriction imposed on the equation being maximized. In addition to the specification of the single equation being estimated one merely has to know what predetermined variables appear in the other equations of the system

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[11] J. Johnston, *Econometric Methods,* McGraw-Hill Book Co. (1963), p. 232.

[12] Predetermined variables are exogenous variables and lagged endogenous variables.

[13] T. W. Anderson and H. Rubin, "Estimation of the Parameters of a Single Equation in a Complete System of Stochastic Equations." *Annals of Mathematical Statistics*, Vol. 20 (1949), pp. 46-63.

without making assumptions as to their specification.[14] However, the computations involved in the limited information approach are complicated, cumbersome, and lengthy.[15]

Although comparisons of ordinary least squares and limited information estimates are not conclusive, Christ observed that where the two estimates differ by a large magnitude the limited information coefficients more frequently are unreasonable in sign and magnitude.[16] Drake and West employed this method in estimating demand and supply functions for meat, other food, and various fats and oils in the United States but the estimates obtained were in many cases inconsistent with postulated behavior. The standard errors of the coefficients were often greater than the coefficients themselves. They, therefore, concluded that the limited information single-equation method was not a "fruitful approach for investigation of the economic relationships of the minor or by-product commodities".[17]

A technique which is closely related to the limited information approach and is computationally less complicated[18] is the two stage least squares (2SLS) procedure developed by Theil and later independently by Bassmann.[19] It can handle overidentified equations within a simultaneous system and provides statistically consistent estimates. Moreover, the coefficients obtained have exactly the same asymptotic variances as the limited information estimates.[20] The former has large

[14] C. F. Christ, *Econometric Models and Methods*, New York: John Wiley & Sons, Inc. (1966), p. 412 and Johnston, *Op. cit.* pp. 254-255.

[15] *Op. cit.*, p. 255.

[16] C. F. Christ, "Simultaneous Equation Estimation: Any Verdict Yet?" *Econometrica*, Vol. 28, No. 4 (Oct. 1960), p. 838.

[17] A. E. Drake and V. I. West., *Econometric Analysis of the* Edible *Fats and Oils Economy*, University of Illinois Agricultural Experiment Station Bulletin 695 (June 1963), p. 48.

[18] Wallace and Judge (*Op. Cit.*) p. 2.

[19] H. Theil, "Estimation and Simultaneous Correlation in Complete Equation Systems," Central Plan Bureau, the Hague, June 23, 1953 (*Mimeographed*) cited in R. L. Basmann, "A Generalized Classical Method of Linear Estimation of Coefficients in a Structural Equation," *Econometrica*, Vol. 25, No. 1 (Jan. 1957), pp. 77-83.

[20] *Ibid*, p. 83.

sample properties similar to the latter and has shown better small sample properties in Monte Carlo experiments.[21]

In 1962 Zellner and Theil developed another technique for a simultaneous estimation of parameters of simultaneous equations, the three stage least squares (3SLS) method. This procedure gives consistent and asymptotically normal estimates and yields higher asymptotic efficiency than the 2SLS depending upon the correct specification of the complete model.[22] While the 2SLS gives estimates of coefficients of single equations in a simultaneous system, the 3SLS estimates all structural parameters of the entire system simultaneously.

Both the 2SLS and the 3SLS technique were used in estimating the demand for Philippine coconut products. The unknown disturbances were assumed to be jointly normally distributed with zero means and have a non-singular co-variance matrix, statistically independent from year to year, and statistically independent of each predetermined variable.

The steps in the 2SLS can be described briefly as follows:[23] (1) From among the jointly determined variables in the equation, select one as the dependent variable for the second stage. (2) Express each of the other endogenous variables as a function of *all* th predetermined variables in the system. These are the reduced form equations. Then compute the least squares coefficients of the reduced form equations and from these, the predicted values of each of the endogenous variables. (3) Substituting these calculated values for the endogenous variables designated as independent, compute the least squares regressions of the original equations.

From the four behavioral equations, QOX, QOD, QMX, and QCX were selected as dependent variables and PO, PC, and PM as independent variables in the first stage of the

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[21] C. Hildreth, "Simultaneous Equation: Any Verdict Yet?" *Econometrica*, Vol. 28, No. 4 (Oct. 1960), p. 847.

[22] A. Zellner and H. Theil, "Three Stage Least Squares: Simultaneous Estimation of Simultaneous Equations," *Econometrica*, Vol. 30, No. 1 (Jan. 1962), pp. 54-78.

[23] See Johnston, *Op. cit.* pp. 258-260 and 266-268, Christ (1966), *Op. cit.* pp. 432-453, and Zellner and Thiel, *Op. cit.*

process. The endogenous variables appearing in the right hand side of these equations, PO, PC, and PM, are correlated with the error term because of the simultaneous nature of the relations. The essential idea in 2SLS is to replace their actual by their estimated values based on the least squares regression of each of these variables on all the predetermined variables in the entire system. These predicted values are nonstochastic and therefore uncorrelated with the disturbances in which case application of OLS to the equations would yield unbiased and consistent estimates.

The 3SLS procedure begins by estimating the structural parameters of the whole system by 2SLS which are then used to calculate residuals of each structural equation. These residuals are used to estimate the variance-covariance matrix of the structural disturbances to which Aitken's generalized least squares[24] is applied to obtain estimates of all equations simultaneously. This constitute the third stage in the process.

Measuring the Impact of Changes in Exogenous Variables

Although the framework presented here is static it can be used to analyze the probable effect of changes in any of the variables influencing the market. For example, a shift to the right of the supply function for copra due to, say, improvement in technology with the demand functions remaining the same would result in a reduction in the copra price. This implies an increase in the quantity of copra demanded for crushing as well as for exports. Since the oil and meal demands are linked together in the crushing sector the supply of oil and meal would also expand. Consequently, the prices of the two products will decline and the quantities demanded domestically and internationally also would increase.

Another illustration is the effect of an increase in the income of importing countries. If copra and coconut oil are normal goods this growth in income will result in an expansion

[24] A. C. Aitken, "On Least-Squares and Linear Combination of Observations," Proceedings of the Royal Society of Edinburgh, Vol. 55 (1934-35), pp. 42-48.

in the quantities demanded of these products. Since the total oil demand is the horizontal summation of the export and domestic demands, an increase in the former implies an outward shift in the total oil demand. With the oil supply fixed by the quantity of copra crushed, the oil price goes up resulting in a reduction in the quantity demanded domestically but still a larger amount exported. Even if the price and quantity of meal exports remain unchanged, the rise in oil price would still increase the average revenue in the copra crushing sector and if marketing margins stay the same the crushing and aggregate demands for copra will shift to the right. With a fixed copra supply this implies a subsequent rise in copra price, the rate of increase depending on the shift in the crushing and export demands.

The impact on each of the endogenous variables of specific changes that may occur in the exogenous variables may be measured quantitatively using the coefficients of the solved reduced form equations. The unrestricted reduced form equations representing the first stage of the 2SLS and 3SLS express each of the jointly determined variables as a function of all the predetermined variables in the system. The coefficients are estimated directly by ordinary least squares. On the other hand, the solved reduced form equations involve an estimation of the structural parameters from which the reduced form coefficients are derived. The solved reduced form estimates incorporate all the constraints on the structure and therefore preserve the simultaneity and the physical identities in the model.

Equations (1) to (4) of the generalized functions on page 6 can be rewritten as follows:

(1.1) $QOX_t = b_{10} + a_{11}PO_t + b_{11}PSC + b_{12}PPK_t + b_{13}I_t + b_{14}DV_t + U_1$

(1.2) $QOD_t = b_{20} + a_{21}PO_t + b_{24}DV_t + b_{25}IP_t + U_2$

(1.3) $QCX_t = b_{30} + a_{32}PC_t + b_{31}PPK_t + b_{34}DV_t + b_{36}QSBU_t + b_{37}T_t + U_3$

(1.4) $QMX_t = b_{40} + a_{43}PM_t + b_{47}PSM_t + b_{44}DV_t + b_{48}L_t + U_4$

Equations (1.1) to (4.1) and (5) to (9) can be manipulated mathematically such that all endogenous and exogenous variables appear in the left hand side and the disturbances at the right hand side, that is, (10) $AY + BX = U$,

where Y = a 9 x 1 vector of jointly determined variables consisting of QOX, QOD, QOP, PO, QCX, QCCC, PC, QMX, and PM

X = a 12 x 1[25] vector of exogenous variables consisting of PSC, PPK, I, DV, IP, QSBU, T, PSM, L, M, SC, and QCP

A = a 9 x 9 matrix of coefficients of the jointly determined variables

B = a 9 x 12[25] matrix of coefficients of the exogenous variables

U = a 9 x 1 vector of disturbance terms

By further manipulation of equation (10), the reduced form becomes

$$(11) \quad Y = -A^{-1}BX + A^{-1}U$$

Estimating equation (11) directly by OLS yields the coefficients of the unrestricted reduced form. To obtain the solved reduced form coefficients the structural parameters are first computed by, say, 2SLS or 3 SLS. Then

$$(12) \quad \hat{A}Y + \hat{B}X = \hat{U}$$

where $\hat{A}$ and $\hat{B}$ are matrices of estimated and actual structural coefficients of the behavioral equations and the identities. The predicted values of the jointly determined variables are:

$$(13) \quad \hat{Y} = [-\hat{A}^{-1}\hat{B}]X$$

where Y is a vector of estimated values of the endogenous variables.

[25] 13 x 1 including the constant term.

The elements of the matrix $-\hat{A}^{-1}\hat{B}$ are the coefficients of the solved reduced form. Each of these elements indicate the change in the endogenous variable as a result of a one unit change in the exogenous variables after the interdependence among the jointly determined variables is taken into account and therefore may appropriately be called "multipliers".[26] These coefficients are useful in analyzing the effect of a shift in a particular function, e.g. the coconut oil export demand, with the other relationships remaining unchanged. Since the functions in the model were assumed linear the solved reduced form equations can also be used to analyze the impact of simultaneous shifts in two or more functions.

Summary

A nine equation simultaneous model was constructed for the Philippine market for copra, coconut oil, and copra meal. Four distinct features can be discerned from the model: (1) Multiplicity of markets. Copra moves into either domestic crushings or exports; coconut oil encompasses both domestic and export markets; and ignoring the small amount of copra meal consumed locally, this product is disposed in the international market. (2) Joint production aspects of oil and meal and the linkage of their prices in the copra processing sector. Coconut oil and copra meal are obtained in fixed proportions from the crushing of copra. (3) The simultaneous determination of prices and quantities of the products that flow into the different markets. (4) The interdependence of coconut products with other sectors of the economy. The market for coconut products extends to at least three sectors: the fats and oils, the food market, and the feed livestock sector. Copra is one of the many sources of vegetable oils and feed meals and competes with numerous other oilseeds in the world market. Coconut oil has innumerable uses in the manufacture of many food and non-food products where other oils can to some extent be substituted.

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[26] A. S. Goldberger, *Econometric Theory*, New York: John Wiley & Sons, Inc. (1964), p. 369.