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In This Issue

As a "house journal" the *Journal of Agricultural Economics Research* (JAER) is a mirror of both agency and profession. The mirror is multi-faceted, each issue reflecting a new problem, new method, or simply a new angle on an old problem or method. This issue, in particular, reveals the methodological diversity in the Economic Research Service. The articles contain elements of the pragmatism, positivism, and normativism described in Glenn Johnson's new book on methodology (see Paul's review). Articles range from an analysis of the effects of an agricultural program on a specific input to a fairly esoteric comparison of three types of quantitative procedures.

In the first article, Kuchler and Vroomen examine the impact of the 1983 Payment-in-Kind (PIK) program of agricultural supports on farm inputs, specifically farm tractors. Their intervention analysis produced the interesting result that the PIK program discriminated against sales of large tractors, in favor of mid-sized tractors. If Kuchler and Vroomen's analysis is correct, the program would then also have discriminated against U.S. manufacturers who produce large tractors and favored, say, European manufacturers who produce smaller tractors.

Another form of domestic-foreign interaction of food policy is analyzed by Kim, Bolling, and Wainio in their article on feed grain imports in Venezuela. Efforts to increase domestic production of sorghum through subsidies were not so strong as the foreign exchange rate inducements to import sorghum. Kim, Bolling, and Wainio employ a fairly sophisticated model accounting for welfare of both meat consumers and feed grain producers, but they add caveats about the consistency of data and government policy.

But for analysis of models *per se* we turn to Huang, Eswaramoorthy, and Johnson. Out of a problem in formulating a welfare function when cross-price effects are not the same over all commodities, they develop a strategy for selecting modeling and computational procedures.

JAER reflects not only what we write, but what we read. In some ways, reading may be more important than writing because writing reveals current or past research, whereas reading suggests an investment in future ideas and inquiries.

In this issue, Paul reviews Johnson's *Research Methodology for Economists.* He nicely summarizes Johnson's interpretation of positivism, normativism, and pragmatism as methodological bases for research. Although textbookish in style, Johnson's book provides useful perspectives for practicing researchers. To complement Paul on Johnson, I have included a mini-review of Ladd's new book, *Imagination in Research.*

In the far corner of pragmatism, Doyle's *Altered Harvest,* reviewed by Schor, is far from a methodological piece, but does provide a thorough, stimulating basis for challenging social science research. On the other hand, Walter's *Adaptive Management of Renewable Resources* is methodologically oriented. According to reviewer Crutchfield, Walters exhorts his colleagues to examine larger resource issues rather than many of the detailed investigations oriented toward "analytical methods they learned in the university or find popular among colleagues."

Global perspective is added to the book reviews by Dommen and Vollrath. Dommen reviews *Accelerating Food Production in Sub-Saharan Africa* by Mellor and others. The core of the book, says Dommen, are the chapters on development and adoption of suitable technology. Anthropologists have shown better aptitudes than economists in describing the obstacles to technology adoption, according to the authors. Vollrath has deftly reviewed the mammoth proceedings of the International Agricultural Economics Association, *Agriculture in a Turbulent World Economy.* By concentrating on the keynote address by Amartya Sen, Vollrath provides a sweeping view of food, hunger, and the possible role of economists in dealing with problems such as famine.

Gene Wunderlich

Impacts of the PIK Program on the Farm Machinery Market

Fred Kuchler and Harry Vroomen

Abstract. *Many analysts have claimed the record number of crop acres taken out of production in 1983 as a result of the Payment-in-Kind (PIK) program affected the already declining sales of farm tractors. The authors use intervention analysis, a particular form of a transfer function, to model and test for hypothesized changes in processes. Three time series (two two-wheel drive monthly sales classifications and one four-wheel drive sales classification) were modeled as univariate Autoregressive-Integrated-Moving-Average (ARIMA) processes. These models were modified to incorporate the expected form of the PIK effects. Results showed that PIK significantly reduced unit sales of four-wheel drive tractors, but there was no statistical evidence of reduced sales for two-wheel drive tractors.*

Keywords. *Intervention analysis, Payment-in-Kind program, tractor sales.*

The Payment-in-Kind (PIK) program of 1983 idled over a third of the acreage normally planted to program crops, amounting to the largest annual program-induced reduction in plantings (*20*).[1] Participating farmers received in-kind payments in the form of Government-owned commodities on condition that they put land into conserving use rather than into production in 1983. The effects of the program went far beyond the farm gate, reducing demand for most farm inputs (fertilizer, pesticides, seed for program commodities, energy, and farm machinery). Although the U.S. Department of Agriculture (USDA) made initial estimates of PIK impacts, followup studies were not conducted (*25*). Followup studies validating initial assessments are useful for policy purposes because similar progams could be implemented in the future. Conditions precipitating PIK—excessive Government stocks, mounting commodity program costs, weak export demand, and increased production—persist.

This article examines the impacts of PIK on the domestic farm tractor market. We analyze domestic sales of farm tractors as three separable markets: 40-99 horsepower (hp) two-wheel drive tractors, 100-and-over hp two-wheel drive tractors, and four-wheel drive tractors. Initial assessments of PIK impacts by both industry and USDA predicted that the farm tractor industry would suffer a loss in sales (*4, 19, 25*). Some USDA forecasts were quite accurate, predicting the farm tractor industry would suffer less than other farm input industries, with only a 2-3 percent loss in sales, whereas other USDA analyses suggested that PIK would raise commodity prices and farm income, leading to an increase in machinery sales (*20, 26*). Here we provide evidence that the shortrun industry effects were relatively minor, as forecast. However, one segment of the farm tractor market experienced substantial sales losses despite the minor aggregate effects. The four-wheel drive tractor market exhibited losses comparable to those forecast for other farm inputs, whereas sales of two-wheel drive tractors were not significantly affected.

We use a particular form of a transfer function, often called intervention analysis, to model monthly sales patterns for the three farm tractor categories and the changes in those series resulting from PIK (*2, 3*). We use monthly sales series to separate PIK impacts from drought impacts, another major event in 1983 that may have reduced the demand for farm machinery. Unlike an annual econometric model, which might not make explicit the extent to which each of these factors was responsible for sales losses, intervention analysis allows us to test hypotheses about the magnitude and speed of adjustment to specific events.

Background

Large-to-record crop harvests in 1981 and 1982, combined with declining foreign demand for U.S. agricultural commodities, resulted in record commodity surpluses and lower commodity prices in the

The authors are agricultural economists with the Resources and Technology Division, ERS. They thank Michael Hanthorn, Roger Conway, John McClelland, Richard Nehring, Robert Heckard, Stan Daberkow, and the anonymous reviewers for their comments on various drafts.

[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

fall of 1982. To remedy this situation, the Government announced voluntary acreage reduction (ARP) and paid land diversion (PLD) programs for the major program crops for the following growing season. These programs alone were incapable of substantially improving commodity prices or of reducing Government commodity stock levels and storage costs.

Reducing acreage further through the ARP and PLD programs would have entailed far higher Government outlays at a time when Government deficit spending was becoming a serious problem. Consequently, the Government announced the PIK program for corn, wheat, grain sorghum, upland cotton, and rice on January 11, 1983, to supplement the previously announced ARP and PLD programs. With PIK, farmers received in-kind payments of commodities that would otherwise have been grown on PIK-idled acreage.

The response to PIK was overwhelming as enrollment far exceeded expectations (*19*). PIK and related acreage reduction programs idled 77.6 million acres in 1983, the largest amount of land ever taken out of production in one season by U.S. commodity programs (table 1). Although only 48.2 million of the 77.6 million acres idled could be directly attributed to PIK, this amount actually underestimates PIK's impact on total idled acreage because of the program's provisions. To participate in PIK, corn producers were required to participate in the 10-percent ARP and 10-percent PLD, whereas wheat produers were required to participate at levels of 15 and 5 percent, respectively (*12, 28*). Participation in the ARP and PLD for corn and wheat was consequently greater in 1983 than it would have been without PIK.

Futhermore, a decline in soybean acreage from 70.9 million acres in 1982 to 63.8 million acres in 1983 was partly due to PIK. Although soybeans were not included in the PIK program, a significant amount of 1982 wheat acreage double-cropped with soybeans in the Southeast was set aside under PIK. Abandoned cotton land that was planted to soybeans in 1982 was either planted or set aside under PIK. And, although many growers substituted soybeans for corn on corn-base acreage (the acreage upon which corn program payments are based) in 1982, farmers participating in PIK had a strong incentive to use their entire corn base for program purposes, precluding substitution of soybeans for corn in 1983 (*27*).

Table 1—Idled acreage, 1983

Crop	ARP[1]	PLD[2]	PIK[3]	Total
	Million acres			
Corn	4.4	5.9	21.9	32.2
Wheat	8.7	3.5	17.6	29.8
Cotton	2.7	0	4.1	6.8
Sorghum	.8	1.3	3.6	5.7
Rice	.5	.2	1.0	1.7
Barley	.5	.6	0	1.1
Oats	.1	.2	0	.3
Total	17.7	11.7	48.2	77.6

[1]ARP = acreage reduction program.
[2]PLD = paid land diversion program.
[3]PIK = Payment-in-Kind.

Sources: (*18, 21, 23, 31*).

Planted acreage of some small grains increased sharply in 1983 because cover crops were required for idled acreage. Planted oats acreage increased 45 percent from 1982 to 1983, even though oats were not included in PIK. Acreage planted to barley increased 9 percent.

The direct and indirect effects of the 1983 PIK program resulted in a record drop in area planted to the principal crops, from about 359 million acres in 1982 to roughly 309 million acres in 1983, the lowest level since 1972. With substantially fewer acres planted, farmers used less seed, fertilizer, pesticides, farm machinery, and fuel.

Methods of Measuring Program Impacts

From a practical perspective, two obvious methods of measuring or estimating PIK impacts on the farm machinery market are unworkable. An econometric model would suffer from several problems. A major drought in 1983 reduced the expected harvest of many commodities and may have thereby affected demand for farm machinery in the latter half of 1983. Thus, an annual model identifying 1983 as unique, by incorporating a dummy variable in a farm tractor demand equation, might not separate PIK from drought impacts on farm machinery sales unless Government programs or weather influences on producer durables were already incorporated into the model. Econometric models of the farm machinery market have typically been built with annual data (*6, 13, 16*). Data availability precludes building a model identifying major farm machinery components based on more narrowly spaced data. Formally modeling all the influences of Government commodity programs or the effects of weather is likely to be impossible with the limited data implicit in an annual model. Government programs change in form and magnitude, year by year, requiring many variables to adequately describe those programs. This description could easily use up more observations than exist. Regional or national weather indexes pose similar problems in construction and additional difficulties in interpretation because weather influences are locationally heterogeneous at any given time.

A second approach, a formal statistical analysis, might compare preintervention and postintervention sales, perhaps using a t-test for a change in mean levels or other parametric or nonparametric methods. Box and Tiao noted problems with any such procedure:

> However, the ordinary *t* test would be valid only if the observations before and after the event of interest varied about means μ_1 and μ_2, not only normally and with constant variance but *independently* (*3*, p. 70).

Data on monthly farm machinery sales violate these conditions (*10*). First and second moments depend on time, for all three series. Autocorrelation patterns exist even after the series are made stationary. Thus, the data do not support the assumptions required to employ classical statistical tests (*10*).

The methodology used here, known as intervention analysis, is an extension of the univariate autoregressive-integrated-moving-average (ARIMA) methods of time-series analysis of Box and Jenkins. The ARIMA noise model extension defined by the intervention analysis incorporates the impact of a specific event such as a Government policy change or a natural disaster—namely, events for which the onset timing and duration are known. Intervention analysis differs from other types of transfer functions because the form of the impact can be postulated and tested, rather than determined empirically. If observations were taken more often than once a year, the PIK and drought effects might also be separated. Intervention analysis has been used for a variety of social science applications (*1, 8, 11, 33*). McCleary and Hay summarize various results of applications to both the social and biological sciences (*14*). To estimate the impact of PIK on the domestic farm tractor market, we examine January 1973-December 1985 monthly sales data for the three major categories of tractors. Data were provided by the Farm and Industrial Equipment Institute.

The Model

We follow the approach developed by Box and Tiao, building a stochastic model for each of the three series while including the possibility of change of form specified *a priori*. That is, the models consist of both a deterministic element, within which the nature of the impact of a change in Government policy can be modeled, and a stochastic component, specifying background variation or noise. This procedure is iterative, proceeding by successive use of identification, estimation, and diagnostic checking. As Wichern and Jones note, there are four attractive features of model building with intervention analysis:

1. The lag structure (dynamics) linking the dependent variable to a given set of independent variables can be identified from the data and is not determined arbitrarily as common practice frequently dictates.
2. The appropriate noise structure is easily identified.
3. The final model will generally be a parsimonious representation of the data.
4. Comprehensive tests of model adequacy are available (*33*).

Each series is independently modeled in which:

$$y_t = f(\delta, \omega, I, t) + N_t$$

where:

- y_t is the response variable or some appropriate transformation of the response;
- $f(\cdot)$ can allow for deterministic effects of time, t, and the effects of exogenous variables, I, that are specified here as interventions;
- N_t represents the stochastic background variation or noise; and
- δ and ω are unknown parameters.

We suppose the noise model:

$$N_t = y_t - f(\delta, \omega, I, t)$$

may be modeled as a mixed autoregressive moving-average process:

$$\Phi(B)N_t = \Theta(B)a_t$$

where B is the backshift operator, {a} is a sequence of white noise, and $\Phi(B)$ and $\Theta(B)$ are polynominals of finite degree. The process is stationary in a small number of seasonal and nonseasonal differences. Seasonal autoregressive and moving-average effects can be factored multiplicatively, so the observed data are the realization of successively filtering {a} through a nonseasonal and then a seasonal filter. One can develop the noise model by analyzing the autocorrelations and partial autocorrelations of the response variable.

The noise model is modified by certain *a priori* specifications to incorporate the effects of intervention. The effects of intervention variables can be specified in the form:

$$f(\delta, \omega, I, t) = \sum_{i=1}^{k} Y_{ti} = \sum_{i=1}^{k} ((\omega_i(B)/\delta_i(B))I_{ti} \quad t = 1, 2, \ldots, n$$

The final output minus the noise component is represented by the sum of transferred inputs. The transfer Y_i to the output from I_i is generated by a linear difference equation. That is, the dynamics of the system are specified as:

$$\delta_i(B)Y_{ti} = \omega_i(B)I_{ti} \quad i = 1, 2, \ldots, k$$

where $\delta_i(B)$ and $\omega_i(B)$ are polynominals of finite degree in B. The variables I_i are indicator variables taking values of 0 or 1 denoting the interventions, that is, the occurrence or nonoccurrence of a set of events.

We use a single transfer Y_t to the output from the input I_t where, in this case, I_t is a step function:

$$I_t = \begin{cases} 0, & t < T \\ 1, & t \geq T \end{cases}$$

such that T is the period in which policy changed. The appropriate transfer function is therefore:

$$Y_t = \frac{\omega(B)}{\delta(B)} I_t$$

Form of the Intervention

The theory developed for our analysis is based on the impact patterns Box and Tiao discussed. These patterns can be described by two characteristics, onset and duration. The onset of an impact can be either abrupt or gradual, whereas the duration can be either permanent or temporary. Three forms of interventions can be parismoniously modeled: (1) an abrupt and permanent change in the series, (2) a gradual and permanent change, and (3) an abrupt and temporary change. We hypothesized that, if PIK had an impact on farm tractor sales, it was of the latter form. Other applications of the abrupt and temporary change form of intervention include estimating impacts and speed of recovery from natural diaster (*5*).

One would expect that the duration of the impact was temporary because the program was implemented only for the 1983 growing season. The onset of the impact must have been abrupt because the program surprised farmers, commodity demanders, farm machinery manufacturers, and dealers, and it required immediate decisions by farmers. A PIK program was considered by the Administration and Congress during the fall of 1982, but no action was taken (*24*). Instead, the Secretary of Agriculture announced the program on January 11, 1983. Corn cash and nearby futures prices increased 30-35 cents a bushel by mid-February. Had the program been anticipated, such a rapid movement would have been unlikely; prices would have risen before the announcement, rather than immediately after.

Compared with PIK programs in the sixties, the 1983 program covered more commodities and gave larger benefits to farmers, inducing a rapid signup. Program signup for most commodities was terminated before the end of February (*30*). Farmers who agreed to PIK conditions needed far fewer farm machinery services in the 1983 crop year. Because PIK-idled land did not produce marketable crops, many major soil-preparing, planting, and harvesting operations were not done on the land. At the time of program signup, the needs of program participants for many types of farm machinery would have been projected a year into the future. Thus, demand should have fallen abruptly with the announcement of PIK. However, a gradual recovery during the year might have been expected if dealers lowered prices, trying to recover some of their lost sales and minimize inventory expenses.

Farm tractors in the three categories examined here have different uses. Four-wheel drive tractors are primarily used in the production of grains, and, to a lesser extent, in the production of the major row crops. Larger two-wheel drive tractors can be used for both these activities and for other types of farming. The impact of PIK on the larger two-wheel drive series, therefore, should be smaller than that on the four-wheel drive series. The smallest impact would be expected on the small two-wheel drive tractors, used less to produce crops idled by PIK.

One can model the abrupt but temporary impact as a distributed lag response by using a first-order transfer function; the backshift operator appears to the power 1. The abruptness of the transfer requires the intervention input variable to be modified. A unit pulse is defined as:

$$(1 - B)I_t = \begin{cases} 1, & t = T \\ 0, & \text{otherwise} \end{cases}$$

Applying the first order transfer function to $(1 - B)I_t$ implies the following impact assessment model:

$$y_t = \frac{\omega}{1 - \delta B}(1 - B)I_t + N_t$$

The immediate impact ω decays at a rate δ.

A Stochastic Model for the Noise Component

The first step in the model-building procedure is to develop models that adequately describe the stochastic behavior of each time series studied. More precisely, these models must account for the sources of variation or "noise" in the response variable. The sources of noise, quite common in monthly economic time series, are trend, cycle, seasonality, and random error. If unaccounted for, the first three of these noise sources could obscure the intervention under analysis.

We fit each ARIMA noise model using the entire data series. Where the autocorrelation function (ACF) and the partial autocorrelation function (PACF) are overwhelmed and distorted by the impact of an intervention, one generally uses the preintervention series to identify the noise component, avoiding biased estimates. The intervention component then can be added for reestimation of all parameters, with estimation made over the entire (preintervention and postintervention) time series. In the three series examined, however, there was no evidence that the two-stage estimation procedure was required. Preintervention ACF's and PACF's were nearly identical to their postintervention counterparts. Parameter estimates from the noise model were changed little by the addition of the intervention component. A logarithmic transformation was made to each series because the natural logs displayed more spatial homogeneity.

Appropriate models for the 100-and-over hp two-wheel drive and the four-wheel drive tractor series were identified as ARIMA(0,1,2) $(0,1,1)_{12}$:

$$N_t = \frac{(1-\Theta_1 B - \Theta_2 B^2)(1-\Theta_{12} B^{12})}{(1-B)(1-B^{12})} a_t$$

Intercept terms were not used because they did not significantly differ from zero.

The noise model for the 40-99 hp two-wheel drive series was slightly more complicated and was identified as:

$$N_t = \frac{(1-\Theta_1 B - \Theta_2 B^2)(1-\Theta_{12} B^{12} - \Theta_{20} B^{20})}{(1-B)(1-B^{12})} a_t$$

Table 2 shows maximum-likelihood estimates and associated diagnostic statistics of the ARIMA models. The estimate of Θ_1, Θ_2, Θ_{12}, and Θ_{20} are all statistically significant and lie within the bounds of invertibility. Respective Q-statistics for each model are not statistically significant at the 95-percent level, indicating that the residuals of each model do not differ from white noise.

Table 2—ARIMA model results, unit sales of two- and four-wheel drive tractors, Jan. 1973–Dec. 1985

Parameter	Estimated coefficients	Standard error	t-statistic	Q-statistic[1]
		Measure		
Two-wheel drive, 40–99 hp				11.65
Θ_1	0.5633	0.0809	6.96	
Θ_2	.2551	.0813	3.14	
Θ_{12}	.5742	.0804	7.14	
Θ_{20}	.2417	.0825	2.93	
Two-wheel drive, 100-and-over hp				14.40
Θ_1	.5849	.0805	7.26	
Θ_2	.2449	.0816	3.00	
Θ_{12}	.6395	.0778	8.22	
Four-wheel drive				11.90
Θ_1	.3751	.0826	4.54	
Θ_2	.2128	.0831	2.56	
Θ_{12}	.6655	.0834	7.98	

Blanks indicate not applicable.
[1]Value of Q-statistic based on 24 residual autocorrelations.

Estimating the Impact Model

The impact model is the sum of the intervention and noise components. The estimated impact model for the two series of larger tractors is:

$$y_t = \frac{\omega}{1-\delta B}(1-B)I_t + \frac{(1-\Theta_1 B-\Theta_2 B^2)(1-\Theta_{12}B^{12})}{(1-B)(1-B^{12})} a_t$$

The estimated model for the small tractor series is:

$$y_t = \frac{\omega}{1-\delta B}(1-B)I_t + \frac{(1-\Theta_1 B-\Theta_2 B^2)(1-\Theta_{12}B^{12}-\Theta_{20}B^{20})}{(1-B)(1-B^{12})} a_t$$

The impact model was estimated with the PIK impacts beginning in the first full month following the announcement, February 1983 (table 3). The 40-99 hp two-wheel drive series shows no observable PIK impact. T-statistics on both impact parameters show that the null hypothesis (no impact) cannot be rejected. The 100-and-over hp two-wheel drive series shows no evidence of an immediate impact. The rate-of-decay parameter exceeds the bounds of system stability; even though its t-statistic is large, it fails to suggest an impact. Again, a conclusion of no impact is warranted. The four-wheel drive series supports the hypothesis of an immediate, but not long-lived, impact. Both impact coefficients are significant at the 99-percent confidence level.

Month-to-month variability in all three series is so severe as to preclude identifying PIK impacts simply by visual inspection of the series or their transformations. Examining monthly inventory-to-purchase ratios, however, supports the PIK impacts shown statistically (7). This ratio jumped from 0.82 in January 1983 to 0.94 in February 1983 for four-wheel drive tractors. The jump was one of the largest 1-month changes in the history of the series. The ratio stayed at historically high levels throughout 1983, but by October had returned to levels comparable to the

Table 3—Impact analysis results, unit sales of two- and four-wheel drive tractors, Jan. 1973–Dec. 1985

Parameter	Estimated coefficients	Standard error	t-statistic	Q-statistic[1]
		Measure		
Two-wheel drive, 40–99 hp				10.88
Θ_1	0.5620	0.0812	6.92	
Θ_2	.2459	.0815	3.02	
Θ_{12}	.5670	.0813	7.01	
Θ_{20}	.2343	.0856	2.74	
ω	.0966	.1121	.86	
δ	.0516	1.2069	.04	
Two-wheel drive, 100-and-over hp				14.28
Θ_1	.5703	.0808	7.06	
Θ_2	.2599	.0823	3.16	
Θ_{12}	.6657	.0771	8.64	
ω	−.0021	.0093	−.22	
δ	−1.1279	.1585	−7.12	
Four-wheel drive				14.46
Θ_1	.4033	.0848	4.76	
Θ_2	.1989	.0857	2.32	
Θ_{12}	.6347	.0857	7.41	
ω	−.5388	.1883	−2.86	
δ	.6369	.2536	2.51	

Blanks indicate not applicable.
[1]Value of Q-statistic based on 24 residual autocorrelations.

previous year. The inventory-to-purchase ratio for other series showed no observable impacts.

Interpretation of Model Results

Calculating PIK impacts on four-wheel drive sales would require nothing more than the impact parameter estimates, if the log transformation were not required. The intervention component:

$$Y_t = y_t - N_t$$

can be rearranged as:

$$Y_t = \delta Y_{t-1} + \omega(1-B)I_t$$

Prior to the intervention, this formulation results in:

$$Y_t = \delta(0) + \omega(0) = 0$$

Applying this formulation to the postintervention series yields the following sequence:

$$Y_T = \delta(0) + \omega = \omega$$
$$Y_{T+1} = \delta(\omega) + \omega(0) = \delta\omega$$
$$Y_{T+2} = \delta(\delta\omega) = \delta^2\omega$$
$$\ldots$$

where each postintervention effect is:

$$Y_{T+i} = \omega\delta^{i-1} \quad i = 1, 2, \ldots$$

and:

$$\lim_{i \to \infty} Y_{T+i} = 0, \ |\delta| < 1$$

Using the log metric, however, amounts to estimating a model of the form:

$$\ln y_t = Y_t + \ln N_t$$

in which the intervention component represents the percentage difference between the series level and the level of the series in the absence of PIK. Thus, estimating results in the raw metric requires exponentiating the full impact assessment model. When the noise component is exponentiated, the additive shocks are converted into multiplicative shocks. Using the noise component as a model of the preintervention process allows it to be used as a benchmark from which the PIK impacts can be measured. The noise process represents the levels tractor sales might have reached without the PIK program. The impact component of the model merely multiplies the existing process and:

$$\frac{\text{postintervention series level}}{\text{preintervention series level}} = \frac{\exp(\ln Y_t)\exp(\ln N_t)}{\exp(\ln N_t)}$$

$$= \exp(\omega\delta^{i-1}) \quad i = 1, 2, \ldots$$

In this form, retrieving the impact in terms of the raw metric is accomplished once the noise process levels are established. To calculate the raw metric noise process benchmark, we first exponentiated one-step-ahead full model conditional expectation forecasts (*15*). For notational purposes, let $y_t(1)$ denote the forecast of y_{t+1} made in period t, namely, the one-step-ahead forecast.

Then, the one-step-ahead forecast error is:

$$a_t = [y_t - y_{t-1}(1)]$$

and the one-step-ahead minimum mean-square-error forecast is:

$$z_{t-1}(1) = \exp[y_{t-1}(1) + 0.5\sigma^2_{a_t}]$$

Finally, the impacts of the loss in unit sales are calculated as the noise model forecast minus the full model forecasts:

$$z_{T-1+i}(1)/\exp(w\delta^i) - z_{T-1+i}(1) \qquad i = 0, 1, 2, \ldots, 9$$

Table 4 shows these latter estimates.

The mean absolute percentage error (MAPE) can be used to show that the intervention component makes the model's predictive ability return to its pre-1983 levels. If one compares actual sales with one-step-ahead sales forecasts from the noise model, the MAPE in the period up to and including January 1983 is 17.4 percent. The MAPE jumps to 23.6 percent for the 10 months from February to November 1983. Reestimating the model with the intervention component lowers the average error to 15.4 percent for the 10-month period affected directly by PIK.

The results also show, as maintained earlier, one can distinguish between the impact of PIK and that of the drought. The intervention model, estimated with monthly data, permits us to determine the source of the sharp drop in the sales of four-wheel drive tractors. The 1983 drought hit the corn crop in July, the most critical month for temperature and moisture in the five Corn Belt States (*22*). The hot, dry weather resulted in the lowest average per-acre corn yield in the Nation since 1974.

Table 4—Estimated loss in unit sales of four-wheel-drive tractors due to the Payment-in-Kind (PIK) program

Month	Actual sales[1]	Full model forecast	Projections without PIK	Sales loss	
	Unit sales			Percent	Unit sales
February	193	192	330	41.7	138
March	389	356	502	29.0	146
April	393	534	665	19.6	131
May	416	334	384	13.0	50
June	462	392	429	8.5	37
July	351	402	426	5.5	24
August	286	324	336	3.5	12
September	506	421	431	2.3	10
October	777	689	698	1.4	9
November	459	445	449	.9	4
Total	4,232	4,089	4,650		561

Blanks indicate not applicable.
[1]Source: (*9*).

However, these estimates indicate that PIK's impacts on sales of four-wheel drive tractors had already dropped to less than 6 percent by July. Furthermore, the 1983 wheat crop was not affected by the drought as record yields were recorded for hard red winter wheat in many areas of the Great Plains (*29*). We can infer from the timing of the drought and the decline in the effects of PIK that the PIK program was responsible for the estimated reduction in unit sales.

Table 4 shows the calculated effects of PIK on sales of four-wheel drive tractors. Actual sales appear with one-step-ahead forecasts from the full (noise + intervention) model. The column showing percentage losses reveals what we anticipated: the initial effects diminish quickly so that within 10 months the impact is less than 1 percent. Converting the percentage losses into units and adding them to the one-step-ahead forecasts from the full model provides an estimate of the number of four-wheel drive tractors that could have been sold in the absence of the PIK program. Sales losses due to PIK are estimated at 561 units, or 12 percent of sales for the February through November 1983 period. We conclude that the 561 units represent lost sales rather than merely postponed sales. Had the PIK program altered only the timing of purchases, the postintervention sales pattern would have differed from the observed pattern. Instead of returning to the preintervention pattern, a relatively higher pattern would have been observable. No such chance can be observed. Noise model parameters are almost insensitive to the addition of post-PIK observations.

An approximation of PIK's dollar cost to the farm machinery industry (or, at least to the farm tractor portion of the industry) can be estimated. July 1984 prices of different-sized, but comparably equipped, farm tractors are available from *Stark's Off-Highway Ledger* (*17*). These prices would likely approximate 1983 prices, as prices reported by USDA for 170-240 power take-off (PTO) or belt hp showed less than a 0.5-percent increase from June 1983 to June 1984 (*32*). USDA prices include larger two-wheel drive tractors, diluting the price changes for four-wheel drive tractors, but the absence of a significant price change indicates that list prices were changed little.

Discounting could take a variety of forms other than lower list prices. However, if major discounting would not have been in effect without PIK, then the list price provides an appropriate opportunity cost. Stark's 1984 dealer prices for four-wheel drive tractors ranged from $70,300 to $83,900. List prices ranged from $91,250 to $108,900. Thus, a sales loss of 561 units translates into $51-$61 million in lost revenues, evaluated at list prices. These prices show a 29-30-percent markup from dealer to list price, suggesting a similar split in lost revenues to the farm tractor industry.

Conclusions

The effects of PIK on the farm machinery industry were modest, as other analysts forecast. However, the effects were not homogeneous throughout the industry. It is not surprising that the portion of the industry specializing in machinery used primarily for program crops was negatively affected. Sales of four-wheel drive tractors, already declining, fell by an estimated 561 units, or by revenues of $51-$61 million. Because the program effects on sales were transitory, disappearing within a year, we conclude that program-induced effects had few real long-term effects. For example, inventories of four-wheel drive tractors rose with the announcement of PIK and remained at historically high levels, suggesting that employment in the farm machinery industry did not absorb the entire effect of reduced sales.

One reason for studying the impact of past policy changes is to better forecast impacts of future ones. Estimates of these policy impacts yield information applicable to future shortrun policies. Because the PIK program was unexpected, one can capture its effects on the farm machinery industry by examining changes in a single variable. Had PIK been expected, other adjustments might have occurred, either in manufacturing levels or in sales incentives. Uncovering the effects of a better anticipated program would be more difficult. That is, properly timed sales incentives could maintain sales in the face of an acreage reduction program. Because some sales incentives might be offered to counteract program impacts, these incentives must be considered as transfers from sellers to buyers and, therefore, as real program effects. Such changes in relative prices are sometimes difficult to measure. Because program opportunity costs here are obvious, inferences about future policies are possible.

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In Earlier Issues

Earlier Technology

Because of the computer's limited drum surface and its associated storage-capacity restrictions, a complete program for the solution of simultaneous equations using the limited-information method is not feasible. Certain areas of computation have been adapted to the machine thus far. At present, the best that can be hoped for is to continue to section off various phases of computation and link them into a program series similar to the one established for least squares.

Hyman Weingarten
Vol. 12, No. 1, Jan. 1960

Import Demand for Feed Grains in Venezuela

C.S. Kim, Christine Bolling, and John Wainio

Abstract. *Domestic food and agricultural policies of individual importing and exporting countries significantly affect international trade in grains. This case study focuses on Venezuela's import demand for sorghum. It investigates the tradeoffs in a country's decision to import or to produce feed grains in an environment of agricultural price supports and subsidies to feed millers. This study also develops a consumer and producer maximization model with government expenditure and foreign exchange constraints.*

Keywords. *Feed grain imports, price policy, Venezuela.*

The domestic food and agricultural policies of individual importing and exporting countries significantly affect the international grain trade. The domestic pricing policies of many importing countries alter the level of international trade. High support prices tend to increase domestic production and reduce imports at the expense of consumers, whereas low consumer prices tend to increase domestic consumption, and perhaps imports, at the expense of domestic producers. In the long run, however, a government must bear the cost of its domestic pricing policy. Several econometric models have been developed to evaluate the impact of various types of government intervention on international trade and prices (*1, 4, 10, 11, 12*).[1]

A common aspect of these studies is that the models developed are extremely general. Their lack of detail prevents one from forming an accurate picture of the goals and consequences of government price policies in different countries and for different commodities, where prices are used as a proxy for government intervention. The specification of an import demand for feed grains must also differ, at least in theory from that for food grains. A model that examines a specific commodity of a given country in depth, particularly with respect to policy, rather than a general model imposed across a wide variety of commodities and countries, can be far more revealing.

In recent studies of the international food grain trade, researchers have recognized the importance of including both government expenditures for subsidies and foreign exchange allocation in modeling import demand (*6, 7*). In cases where domestic consumer and producer prices are insulated from international prices, factors like size of government expenditures for subsidies, the allocation of these subsidies among consumers and producers, and the foreign exchange allotment are important policy variables that should be incorporated into estimating import demand functions. In this article, we examine the effects of Venezuela's price policies and the financial constraints on the import demand for feed grains. We highlight the elements of official policy that affect demand and incorporate them into a welfare maximization model. We apply this model to Venezuela's import demand for sorghum. Finally, tradeoffs between government expenditures for subsidies and foreign exchange allocation are drawn with respect to the results provided by the model.

Venezuela's Policy in the Feed Grain Sector

Sorghum has been the leading U.S. feed grain export to Venezuela since 1970. Venezuela has used sorghum primarily to develop its poultry industry. Imported corn competes with sorghum somewhat. The corn, sorghum, and poultry industries are subject to considerable government intervention through administered prices and import restrictions. Since 1970, the Venezuelan Government has maintained control over the marketing of basic agricultural commodities like sorghum and poultry through the Corporacion de Mercadeo Agricola (CMA), whose most important function has been to control sorghum prices and imports. Throughout most of the seventies, the CMA set the farm price of sorghum well above the world market price to encourage farmers to increase production. They also set a reference price, between the farm

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[1]Italicized numbers in parentheses refer to items in the References at the end of this article.

price and the import price, at which feed manufacturers would purchase both imported and domestically produced sorghum.

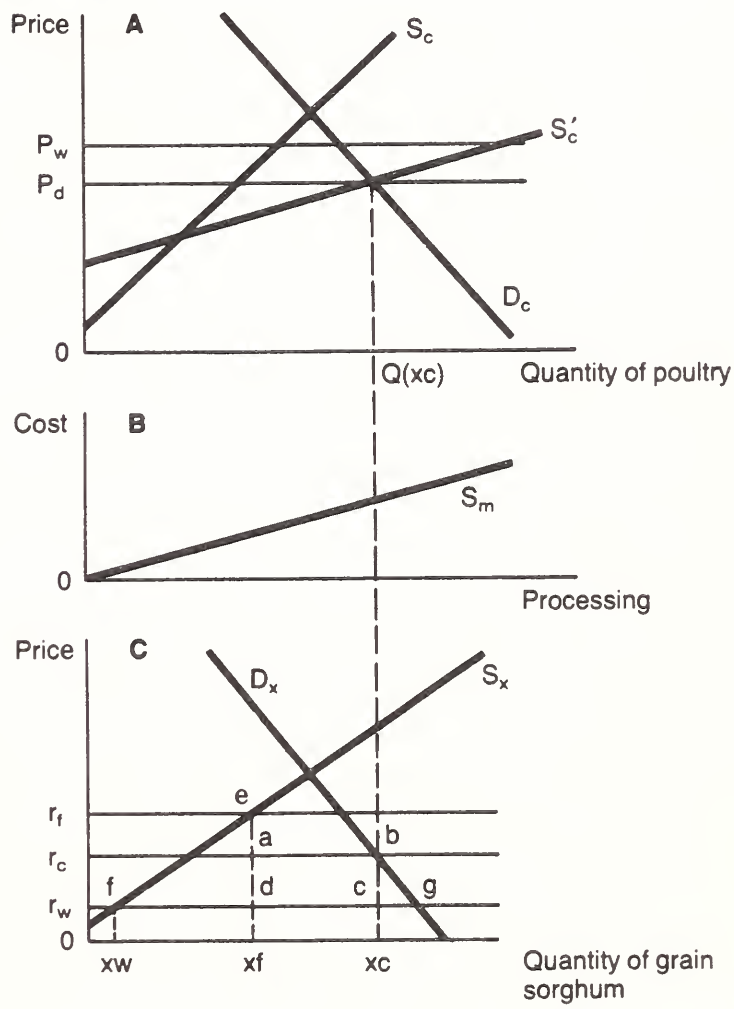
The relationship between the sorghum and poultry sectors and the impacts of Venezuela's pricing policies on international trade can be represented with a multi-paneled diagram such as that found in figure 1 (*3*). Panel (C) represents the sorghum sector. Venezuela produces sorghum for use in the domestic production of poultry. The domestic supply function is S_x. Domestic sorghum supply can be supplemented, if necessary, by imports at the fixed world price, r_w. Prices r_f and r_c are the officially set producer and reference prices. Panel B represents the domestic, nontradeable processing sector. The function S_m is the domestic supply curve of processing services.

There are two poultry supply curves in panel A. The first, Sc, is the vertical addition of S_x and S_m. Hence, S_c is the supply of poultry when autarky prevails in the sorghum market; all sorghum and processing services are obtained domestically. The function S_c' is the vertical addition of r_c and s_m. It is the supply of poultry when either foreign or domestic supplies of sorghum, at the official reference price, r_c, are combined with processing services. At reference price r_c, sorghum quantity xc would be used to produce Q(xc) of the poultry, satisfying domestic poultry demand at price p_d. With the producer price officially set at r_f, domestic production of sorghum would equal xf. The difference between xc and xf would be imported by the CMA at world price rw. In the absence of Government intervention, Venezuela would only produce a small quantity of sorghum, xw, at world price rw and would import the remainder of its needs.

The amount of Government expenditures needed to subsidize sorghum producers, given this price policy, depends on both the relative changes in the world, reference, and farm prices, and on the quantities produced and imported. During the early seventies, when world prices were relatively low and domestic sorghum production was small, the cost of subsidizing domestic producers, the area bounded by $r_f edr_w$ in panel C could be absorbed by Government revenues collected from millers, the area $r_c bcr_w$. During these years, there was a simple transfer of funds from millers to producers through the CMA. Since then, domestic production has grown and the farm-to-miller price spread has increased. As a result, the transfer of funds to domestic sorghum producers is no longer covered by Government revenues collected from millers. At this point in panel C, abcd would be smaller than $r_f ear_c$. This situation has meant that large Government budget outlays have been necessary to subsidize domestic producers. By the early

Figure 1

Venezuelan poultry and grain sorghum sectors



eighties, these subsidies were of considerable concern to the Venezuelan Government, because 70 percent of Venezuela's sorghum production was marketed through CMA, resulting in burdensome Government outlays to cover these direct subsidies and the eventual dissolution of CMA in 1984.

The Model

In deriving a feed grain import demand model, we assume that the Government attempted to maximize both the social welfare of consumers of meat products and producers of feed grains. Let the demand for the ith meat product and the supply of the jth grain be represented in linear form as equations 1 and 2, respectively:

$$P_i = a_i - b_i Q_i \quad a,b > 0 \quad (i = 1, 2, ..., n) \qquad (1)$$

where Q_i is the quantity of the ith meat product, and P_i is a unit price of Q_i:

$$rf_j = c_j + d_j xf_j \quad c_j \quad 0 \text{ and } d_j > \quad (j = 1, 2, ..., m) \qquad (2)$$

where xf_j is domestic production of the jth feed grain, and rf_j is the unit price of xf_j. Consumer surplus (CS) is then measured by:

$$CS = \sum_{i=1}^{n} \left(\int_0^{Q_i} (a_i - b_i Q)\, dQ - P_i Q_i \right)$$

$$= \sum_{i=1}^{n} (a_i - P_i) Q_i - 0.5 \sum_{i=1}^{n} b_i Q_i^2 \qquad (3)$$

Producer surplus (PS) associated with feed grain supply can be measured by:

$$PS = \sum_{j=1}^{m} \left(rf_j \cdot xf_j - \int_0^{xf_j} (c_j + d_j \cdot xf_j)\, dxf_j \right)$$

$$= \sum_{j=1}^{m} (rf_j - c_j) xf_j - 0.5 \sum_{j=1}^{m} d_j \cdot xf_j^2 \qquad (4)$$

Therefore, the social welfare the Government attempts to maximize can be given as follows:[2]

$$W = CS + PS$$

$$= \sum_{i=1}^{n} ((a_i - P_i) Q_i - 0.5\, b_i\, Q_i^2)$$

$$+ \sum_{j=1}^{m} ((rf_j - c_j) xf_j - 0.5\, d_j \cdot xf_j^2) \qquad (5)$$

The social welfare function (equation 5) is then maximized subject to the following constraints represented in equations 6, 7, and 8:[3]

$$\sum_{i=1}^{n} P_i Q_i \leq Y \qquad (6)$$

where Y is the aggregate disposable income allocated for livestock and poultry products Q_i ($i = 1,2,\ldots,n$):

$$\sum_{j=1}^{m} ((rf_j - rw_j) xf_j - (rc_j - rw_j) xc_j) \leq G \qquad (7)$$

where G represents Government expenditures for subsidies to feed grains xf_j:

$$\sum_{j=1}^{m} rw_j \cdot xm_j \leq FE \qquad (8)$$

where xm_j is excess demand of the jth feed grain, rw_j is the unit price of xm_j, and FE is foreign exchange alloted to import feed grains.

Equation 6 states that consumer expenditures for meat products must not exceed disposable income allocated for livestock and poultry products. The first and second terms in the left side of the inequality in equation 7 represent Government subsidies to producers and Government revenue collected from millers. Therefore, equation 7 limits Government subsidies to producers less Government revenue collected from millers at a level not to exceed Government expenditures for subsidies. In cases where the world price (rw_j) is greater than the millers' price (rc_j), $-(rc_j - rw_j)$ represents the Government subsidy to millers for one unit use of xc_j. Therefore, the interpretation of equation 7 is that Government subsidies to producers and millers should not exceed Government expenditures for subsidies. Equation 8 states that import purchases of feed grains must not exceed the foreign exchange allotted to pay for these imports. For equations 5 through 8, the Lagrangian equation to be maximized is given by:

$$L = \sum_{i=1}^{n} ((a_i - P_i) Q_i - 0.5\, b_i Q_i^2)$$

$$+ \sum_{j=1}^{m} ((rf_j - c_j) xf_j - 0.5\, d_j \cdot xf_j^2)$$

$$+ \lambda_1 (Y - \sum_{i=1}^{n} P_i) Q_i$$

$$+ \lambda_2 (G - \sum_{j=1}^{m} ((rf_j - rw_j) xf_j - (rc_j - rw_j)\; xc_j))$$

$$+ \lambda_3 (FE - \sum_{i=1}^{m} rw_j \cdot xm_j) \qquad (9)$$

Solving a set of Kuhn-Tucker conditions for the social welfare maximization, one can drive the reduced-form equation of xm_j such that:[4]

$$xm_j = xm_j (P_1, P_2, ..., P_n, rc_1, rc_2, ..., rc_m, rf_1, rf_2, ... rf_m,$$

$$rw_1, rw_2, ..., rw_m, Y, G, FE) \qquad (10)$$

In cases where $rc_i = rf_i = rw_i$, as it is under free trade with no transportation costs, the import demand equation 10 becomes:

$$xm_j = xm_j (P_1, P_2, ..., P_n,$$

$$rw_1, rw_2, ..., rw_m, Y, FE) \qquad (11)$$

[2]The Government may attempt to reduce social costs associated with the subsidy program, where social costs (that is, deadweight losses) are represented by the triangles fed and cbg in panel C of figure 1. However, Venezuela's price policy is to increase domestic production of sorghum; therefore, we have not considered deadweight losses in the model (*5*).

[3]It is implicitly assumed that the utility the Government received from consumer and producer welfare is weakly separable. Under this assumption, disposable income, government expenditures, and foreign exchange are allocated in a way that allows them to maximize social welfare.

[4]Since the welfare function 4 is concave and the constraint equations 6, 7, and 8 are linear, the Kuhn-Tucker conditions are sufficient, as well as necessary, conditions.

Note that the variable representing Government subsidies, G, does not appear in equation 11. However, in cases where the producer and consumer prices are not equal to the world price and are partially adjusted to the world price at the border, equation 10 becomes:

$$xm_j = xm_j(P_1, P_2, \ldots, P_n, rw_1, rw_2, \ldots, rw_m, G, Y, FE) \qquad (12)$$

Government Expenditures and Foreign Exchange Allotments

Venezuela can meet millers' demand for sorghum by increasing imports or by increasing domestic production through increased producer subsidies. The Government's choice between increasing expenditures for producer subsidies and increasing foreign exchange to import can be derived from the Kuhn-Tucker conditions for maximization of the Lagrangian equation 9. Partial differentiation of equation 9 with respect to xf_j is given by:

$$\begin{aligned}\frac{\partial L}{\partial xf_j} \le & - \sum_{i=1}^{n} ((a_i - p_i)(\frac{\partial Q_i}{\partial xc_j}\frac{\partial xc_j}{\partial xf_j}) \\ & - b_i Q_i(\frac{\partial Q_i}{\partial xc_j}\frac{\partial xc_j}{\partial xf_j})) - (rf_j - c_j) \\ & + d_j \cdot xf_j + \lambda_1 \sum_{i=1}^{n} (\frac{\partial Q_i}{\partial xc_j}\frac{\partial xc_j}{\partial xf_j}) P_i \\ & + \lambda_2 (rf_j - rw_j) - \lambda_2 (rc_j - rw_j) \\ = & \ \lambda_1 \sum_{i=1}^{n} rc_j + \lambda_2 (rf_j - rw_j) \\ & - \lambda_2 (rc_j - rw_j) \end{aligned} \qquad (13)$$

Following McCarl and Spreen (*8*), we can interpret the Lagrangian multiplier λ_1 as the marginal social welfare of disposable income spent to purchase one unit of the ith meat product, Q_i, and λ_2 can be interpreted as the marginal social welfare of Government expenditures for subsidies. Therefore, equation 13 explains that the marginal social welfare resulting from one unit of production of xf_j must be equal to or less than the sum of the marginal social welfare of disposable income contributed to the purchase of one unit of xf_j and the marginal social welfare of net Government expenditures to subsidize producers for one unit of production of xf_j. Partial differentiation of equation 9 with respect to xm_j is given by:

$$\begin{aligned}\frac{\partial L}{\partial xm_j} \le & - \sum_{i=1}^{n} ((a_i - p_i)(\frac{\partial Q_i}{\partial xc_j}\frac{\partial xc_j}{\partial xm_j}) \\ & - b_i Q_i(\frac{\partial Q_i}{\partial xc_j}\frac{\partial xc_j}{\partial xm_j})) + \lambda_1 \sum_{i=1}^{n} (\frac{\partial Q_i}{\partial xc_j}\frac{\partial xc_j}{\partial xm_j}) P_i \\ & - \lambda_2 (rc_j - rw_j) + \lambda_3 rw_j \\ = & \ \lambda_1 \sum_{i=1}^{n} rc_j - \lambda_2 (rc_j - rw_j) + \lambda_3 rw_j \end{aligned} \qquad (14)$$

The negative Lagrangian multiplier λ_2 can be interpreted as the marginal social welfare of Government revenue collected from Venezuelan millers for the use of one unit of xm_j. The Lagrangian multiplier λ_3 can be interpreted as the marginal social welfare of foreign exchange spent to import one unit of xm_j. Therefore, equation 14 explains that the marginal social welfare resulting from the use of one unit of xm_j must be equal to or less than the sum of the marginal social welfare of disposable income contributed to the purchase of one unit of xm_j by the millers and the marginal social welfare of foreign exchange allotted to import one unit of xm_j less the marginal social welfare of Government revenues collected from the millers for one unit of xm_j. If one compares equation 13 with equation 14, the Government's choice between increasing imports or increasing domestic production depends on the following marginality conditions. The marginal social welfare of Government expenditures spent to subsidize producers for one unit of production of xf_j must be equal to the marginal social welfare of foreign exchange spent to import one unit of xm_j at the equilibrium.

Figure 2 illustrates the relationships between Government expenditure for subsidies and foreign exchange allotments. It also illustrates whether Government expenditures are used to subsidize producers in one case or consumers in the other. In panel A of figure 2, the Venezuelan Government is assumed to subsidize feed grain producers. For this case, the Government can make a tradeoff between Government expenditures and foreign exchange to meet domestic demands. In panel B of figure 2, the Government is assumed to subsidize millers. For this case, Government expenditures for the subsidy and foreign exchange allotment are complementary. The shape of tradeoffs and complement curves depends on the import demand elasticities of Government expenditures and foreign exchange variables.

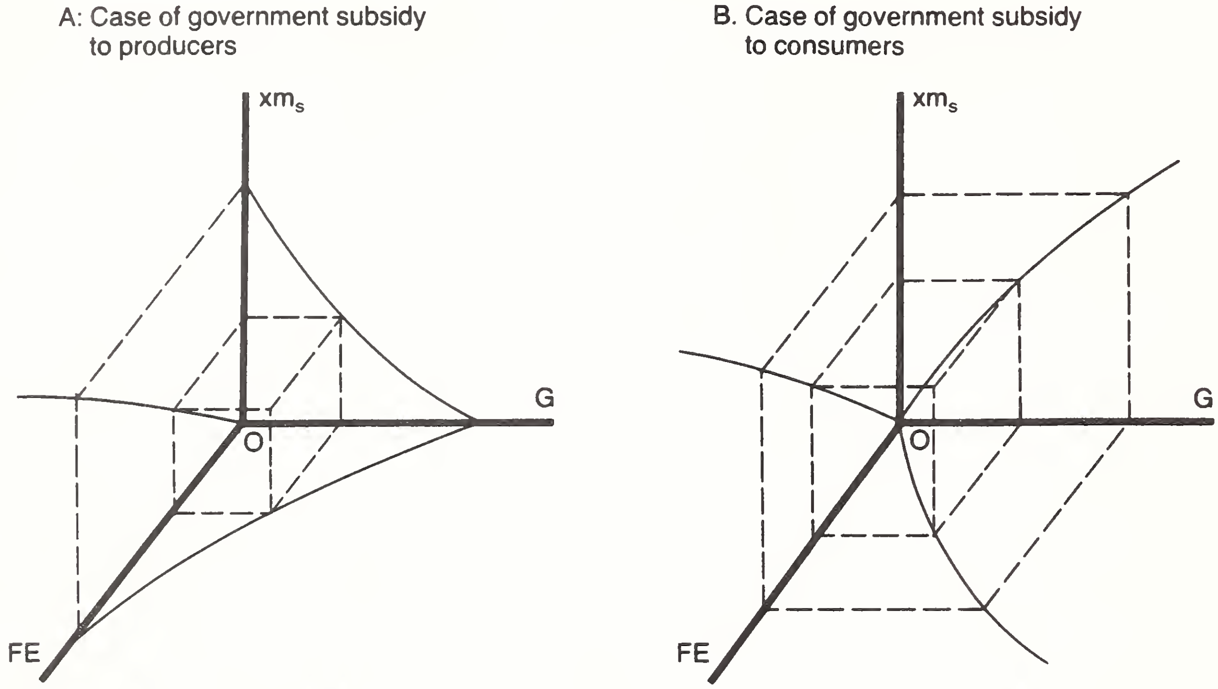
The relationship between Government expenditures for producer subsidies and imports in panel A of figure 2 may be given in the general form:

$$xm_s = a_0 G^{-a_1} \qquad a_0, a_1 > 0 \qquad (15)$$

where a_0 and a_1 are constants.

Figure 2

Relationship between government expenditures for subsidy and foreign exchange allotment for importing



Similarly, relationships between foreign exchange and imports may be given by:

$$xm_s = b_0\, FE^{b_1} \qquad b_0, b_1 > 0 \tag{16}$$

where b_0 and b_1 are constants.

Combining equations 15 and 16, one can obtain a tradeoff equation between Government expenditure for producer subsidies and foreign exchange such that:

$$FE = (a_0/b_0)^{1/b_1} \cdot G^{-a_1/b_1} \tag{17}$$

The marginal rate of substitution between Government expenditures and foreign exchange is then given by:

$$\frac{d\,FE}{d\,G} = (a_0/b_0)^{1/b_1} \cdot (a_1/b_1)\, G^{-(a_1+b_1)/b_1} \tag{18}$$

The Case of Sorghum in Venezuela

We will examine the 1970-82 period since Venezuela began to develop its own poultry industry in the early seventies with the use of imported sorghum. When domestic miller prices are adjusted to the world price and producer prices are subsidized by the Government, equation 12 is the relevant equation. Sorghum is used mainly for poultry production, so we consider only the consumer price for chicken in this model.

An important issue is how exchange rates are incorporated into the model. Chambers and Just reviewed both the theoretical and empirical results in the agricultural economics literature on how changes in exchange rate affect international grain trade:

> A more pragmatic alternative which has been used is to treat the exchange rate as a price index for all other traded goods.... In addition to the above discussion relating to separability, the Orcutt hypothesis tends to suggest that it may be appropriate to include the exchange rate directly in excess demand and import equations to allow for the differential effects of exchange rate and price fluctuations (*2*).

Because exchange rates influence sorghum trade between the United States and Venezuela, a variable representing the exchange rate is inserted into the import demand function for sorghum in Venezuela:

$$xm_s = xm_s\,(P_{ch}, rw_s, rw_c, EX, Y, G, FE) \tag{19}$$

where P_{ch} is the retail chicken price; rw_s and rw_c are the import prices of sorghum and corn, respectively;

EX is the real exchange rate; Y is the aggregated disposable income; G represents Government expenditures to agriculture; and FE represents foreign reserves. Because reliable import prices of corn and sorghum are not available for the entire study period, U.S. gulf prices are used for rw_s and rw_c. All variables expressed in mandatory terms are converted into Venezuelan bolivares and then deflated by the Venezuelan consumer price index (1980 = 100). A list of variables follows:

- xm_x = Imports of grain sorghum (1,000 metric tons (MT)),
- rw_s = World price of grain sorghum (1980 bolivares/MT),
- rf_s = Producer price of grain sorghum (1980 bolivares/MT),
- rc_s = Miller price of grain sorghum (1980 bolivares/MT),
- rw_c = World price of corn (1980 bolivares/MT),
- P_{ch} = Retail price of chicken (1980 bolivares/MT)
- EX = Exchange rate (1980 bolivares per 1980 U.S. dollar)
- Y = Personal disposable income (million 1980 bolivares),
- G = Government expenditures in agriculture (billion 1980 bolivares),
- FE = Foreign reserves (million 1980 bolivares), and
- Q = Domestic consumption of chicken (1,000 MT).

Statistical results indicate that the disturbance term associated with observations in a given period carry over into the future. Therefore, we corrected problems associated with serial correlation using the Cochrane-Orcutt procedure:[5]

$$\log xm_s = 1.7911 - 11.1993 \log rw_s + 11.6015 \log rw_c$$
$$(2.2725)\ (-3.2502)\qquad (3.2939)$$

$$+ 3.6118 \log P_{ch} - 7.7250 \log EX - 0.5476 \log Y$$
$$(3.9780)\qquad (-2.4769)\qquad (-1.0650)$$

$$- 3.1553 \log G + 2.0840 \log FE$$
$$(-3.4793)\qquad (4.0745)$$

$$\text{Adjusted } R^2 = 0.96 \qquad (20)$$

Numbers in parentheses below the coefficients are estimated t-values. The signs on all variables in equation 20, except disposable income, are consistent with *a priori* expectations. The parameter estimate associated with the disposable income variable is negative, but statistically insignificant.[6] The parameter estimates for the world sorghum price and world corn rice variables indicate that the feed millers and Government purchasing agents were willing to substitute corn for sorghum when the sorghum price rose or the corn price fell in the world market. The estimated world sorghum price elasticity (e = 11.2) is quite high. Considering that sorghum is a feed grain rather than a staple food grain and that corn is a good substitute for sorghum in chicken production, high direct- and cross-price elasticities are expected. Venezuela's import share of U.S. sorghum exports rose from 4 percent in 1970 to nearly 10 percent in 1982. This increase in Venezuela's imports is consistent with the high import price elasticity. The impact of the retail chicken price on sorghum imports is significant. The disposable income variable appears to have no significant impact on sorghum imports in Venezuela. Government authorities set domestic chicken prices lower than the free trade price and consumers favor beef over chicken. These factors may account for the insignificant impact of income on sorghum imports.

The parameter estimate of the exchange rate variable shows that the impact of the exchange rate on sorghum imports is significant. Venezuela increasingly overvalued its currency against the U.S. dollar during the study period. The overvalued Venezuelan currency made imported sorghum cheaper and thereby encouraged millers to use more imported sorghum. Consequently, Venezuela could reduce its sorghum imports substantially by devaluing its currency against the U.S. dollar.

The estimate of the Goverment expenditures variable shows a strong inverse impact on imports, indicating that the growth of Government subsidies to sorghum producers increased domestic production. Foreign exchange significantly and directly affected sorghum imports in Venezuela, indicating that low foreign reserves can serve as a constraint on imports.

When equation 20 is collapsed on the geometric means of all variables except xm_s and G or FE, one can obtain the following equations:

$$xm_s = (2{,}208{,}102 \times 10^{14})/G^{3.1553} \qquad (21)$$

$$xm_s = (183 \times 10^{-9})\, FE^{2.0840} \qquad (22)$$

[5]The Cochrane-Orcutt procedure requires dropping the initial time period. To save a degree of freedom, we transformed the first-period observations as suggested by Pindyck and Rubinfeld (*9*).

[6]Because the import demand equation 20 represents the reduced-form equation, the disposal income variable is retained in the model even though it is statistically insignificant.

$$\frac{d\,FE}{d\,G} = 1.5141 \left(\frac{(2{,}208{,}102 \times 10^{14})}{(183 \times 10^{-9})}\right)^{1/2.084} \cdot G^{-2.5141} \quad (23)$$

If one uses equation 23, the rate of tradeoff between Government expenditures and foreign exchange allotment at the mean value, 5,100 bolivares, of Government expenditures is:

$$\frac{d\,FE}{d\,G} = -9.7 \quad (24)$$

During the study period, Venezuela's exchange rate policy provided strong inducements to use foreign exchange to import sorghum. These inducements were stronger than those provided farmers to increase domestic production through the use of subsidies.

One must apply econometric techniques to developing countries like Venezuela with caution. First, one must be aware of the unreliability and meager availability of data to support sophisticated analysis. Second, in a controlled economy, government policy can ultimately determine the course of events. Policy decisions are erratic and can undermine the assumptions and, thereby, the theoretical models. With this caveat and with the data available from published sources, we have identified the marginal rate of substitution between Government expenditures and foreign exchange and have attempted to quantify those results. Incorporating this information into an econometric model gives us one more tool to evaluate import decisions by developing countries like Venezuela.

Conclusions

Empirical modeling of international grain trade flows will undoubtedly continue to include government intervention as an endogenous variable whose value is determined by the values of other variables in the model. We have presented a feed grain import demand model where government prices vary over time and are affected by government expenditures for subsidies. A Venezuelan sorghum variable was statistically significant. The estimated import demand elasticity on the exchange rate (E = 7.725) indicates that Venezuela's sorghum imports could be substantially reduced if it devalued its currency. However, expansion or contraction of sorghum imports was greatly affected by world prices of corn and sorghum, the exchange rate, and Government expenditures for subsidies. Impacts of foreign exchange, retail chicken prices, and disposable income on sorghum imports were less significant.

We derived a tradeoff equation between government expenditures for subsidies and foreign exchange to imports. The rate of tradeoff between Venezuela's Government expenditures and foreign change allotment was −9.7, indicating that Venezuela encouraged domestic producers to produce sorghum by using subsidies during the study period.

Note that the reliability and availability of data do not adequately support sophisticated analysis. Furthermore, Venezuela's policy decisions were erratic and might undermine the assumptions and the predictive power of our model.

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In Earlier Issues

Each element of marketing charges and cash costs of production is a channel through which influences originating primarily in the nonfarm economy may be transmitted into the net income statements of farm operators. The size of each such element for a given commodity is a presumptive indicator of the vulnerability of its producers to changes in a particular segment of the nonfarm economy. . . .

Modern techniques of analysis, such as the input-output or "interindustry relations" approach of Leontief and the "linear programming" methods of Dantzig, Koopmans and others, are creating a demand for more accurate data of this type. These methods seem to hold much promise for the appraisal of governmental programs and for the general study of interrelationships between different sectors of the economy. Electronic computers can handle the formidable calculations required for such studies, but the accuracy of the final results must depend on that of the basic data.

Karl A. Fox and Harry C. Norcross
Vol. 4, No. 1, Jan. 1952

Computing an Asymmetric Competitive Market Equilibrium

Wen-Yuan Huang, K. Eswaramoorthy, and S.R. Johnson

Abstract. *Demand and supply are often asymmetric; that is, cross-price effects are not equal over all commodities. Because of asymmetry, conventional surplus maximization formulations cannot be employed to compute a competitive market equilibrium. This article compares alternative formulations under a system of equation, optimization, and iterative procedures for computation. A general strategy for selecting an appropriate procedure is presented. The iterative procedure is recommended for structural or complex nonlinear demand systems or for extremely large (size) problems. The optimization procedure is suggested for large and medium (size) problems because of the availability of a computer solution package. The system of equation formulation is suggested for modeling various types of economic behavior because of its flexibility.*

Keywords. *Asymmetric demand and supply, market equilibrium.*

For measuring social welfare as affected by farm policy, economists use social surplus or net social payoff, which is the sum of the consumer surplus and producer surplus (*28*).[1] The social surplus is the area below the demand function and above the supply function. Samuelson (*28*) shows the equivalence of a maximization of social welfare problem to the general non-normative problem of market equilibrium among spatially separated markets as formulated by Enke (*6*). Takayama and Judge (*33*) reformulate Samuelson's model into a quadratic programming problem and suggest an efficient algorithm to compute competitive equilibrium. Because of advances in computation, the maximization of the social surplus method has become a powerful tool in policy analysis.

Many quadratic programming models and, in some situations, nonlinear programming models of higher order, with maximization of the social welfare as the objective function, have been applied to agricultural policy analysis. CHAC (*5*), USMP (*12*), and CARD (*22*) are three large-scale nonlinear programming models that are used extensively. Numerous other small-scale models are found in the economic literature.

The welfare function used in these models is derived from a symmetric demand or supply function that satisfies the integrability condition. This assumption of a symmetric demand and supply function implies that the cross-price effects are equal over all commodities. That is, the effect of income on consumption is identical across all included commodities or is zero.

The demand function is often not symmetric (*16*); therefore, it is not integrable.[2] Under this situation, the welfare function cannot be formulated.[3] Thus, formulation of the welfare maximization problem cannot be established.[4] The convenient equivalence between the market equilibrium problem and the surplus maximization problem, therefore, is not available

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[1]Italicized numbers in parentheses refer to items in the References at the end of this article.

[2]The integrability used here differs from that commonly used in consumption theory in which the demand functions are said to be integrable if they can be derived from a utility function (*17, 37*). Integrability here is concerned mainly with the mathematical relation from the demand functions to the welfare function. It is implied that the order of integration of a sum of definite integrals is "path independent." A unique solution is found regardless of the path selected. Mathematically, we can find a unique welfare function W(p) from demand function $D_i(p)$ by $\delta W(P)/\delta P_i = D_i(P)$ if the following condition exists: $\delta D_i(P)/\delta P_i = \delta D_i(P)/\delta P_i$. This condition implies that the demand functions are symmetric and all cross-price effects are equal over all commodities.

[3]Some asymmetric demand systems can be integrated. Carey (*2*) showed that some asymmetric demand functions are "factor integrable." That is, they are integrable on being multiplied through by some nonzero factor so that the resulting functions become integrable. However, there is no test that can be applied to discover whether it is possible to transform a set of nonintegrable functions into a set of integrable functions.

[4]Many excellent articles show conditions of deriving the surplus function from observable ordinary (Marshallian) demand functions that are asymmetric. Two representative articles are by Chipman and Moore (*3*) and by Hausman (*9*).

(*10*). Alternative methods of computing the competitive equilibrium solution should be employed. We compare several methods here.

Problem

An illustrative surplus model can be defined as problem 1a.[5] Choose Q to maximize:

$$Z = W(Q)$$

subject to:

$$CG \le B$$
$$Q \ge O \qquad (1)$$

where W is a surplus function that is the sum of W_i $(q_1,...,q_n)$; Q is a $n \times 1$ vector with elements $q_1,...,q_n$: G is a $m \times n$ technical input-output matrix; and B is a $m \times 1$ vector with elements $b_1,...b_m$ representing available fixed resources. By assuming that the inverse demand function $P_i = D_i(Q)$, $i=1,...,n$, and the inverse supply function $P_i = S_i(Q)$, $i=1,....,n$ are symmetric, we can express the surplus function as:

$$W(Q) = \sum_i \int D_i(Q)dq_i - \sum_i \int S_i(Q)dq_i \qquad (2)$$

where $\int$ means line integration.

The supply function $S_i(Q)$ is frequently not used in practical application. Instead, an activity model is used to represent the supply function. A surplus model in such situations may be defined as *problem 1b*. Maximize:

$$Z = \sum_i \int D_i(Q)dq_i - C'X$$

subject to $GX \le B, \quad HX = Q, \quad Q \ge O, \qquad (3)$

where X and C are $k \times 1$ vectors of production activities and their corresponding costs, respectively, and H is an $m \times n$ transfer matrix relating production activties X to final output Q. The formulation of problem 1a often appears in trade analysis, whereas the formulation of problem 1b appears mostly in production and resource allocation studies. Here, we use primarily the formulation of problem 1a to develop alternative computational methods. We include the formulation of problem 1b mainly for exposition.

If one is to derive the surplus function equation, the demand function $D_i(Q)$ and the supply function $S_i(Q)$ must meet integrability conditions. We consider the following two sets of linear demand functions:[6]

$$Q_{n\times1} = v_{n\times1} + V_{n\times n}P_{n\times1} \qquad (4)$$
$$P_{n\times1} = d_{n\times1} + D_{n\times n}Q_{n\times1} \qquad (5)$$

where Q is a vector of quantities of commodities demanded; P is a vector of the price of commodities; and v, d, D, and V are parameters of the direct demand function (equation 4) or the inverse demand function (equation 5).[7]

We also assume that the supply function can be expressed as a marginal cost function MC:

$$MC_{n\times1} = s_{n\times1} + S_{n\times n}Q_{n\times1} \qquad (6)$$

where s and S are parameters of supply functions. If D and S are symmetric matrices, the objective function in equation 1 can be expressed as:

$$W(Q) = A'Q + 1/2\, Q'EQ \qquad (7)$$

where $A' = (d-s)'$ and $E = (D-S)$. Note that by substituting equation 7 for the objective function in equation 1, we have a quadratic programming problem that can be solved readily by a nonlinear programming solver (such as Minos, 5.0) (*29*) or by the use of grid linearization available in the IBM-MPSX370 system.

The condition for a symmetric demand function can be stated as:

$$\frac{\delta^2 W(Q)}{\delta q_i \delta q_j} = \frac{\delta D_i(Q)}{\delta q_i} = \frac{\delta D_j(Q)}{\delta q_i} = \frac{\delta^2 W(Q)}{\delta q_j \delta q_i} \qquad (8)$$

A similar condition can be expressed for symmetric supply functions. The condition (equation 8) is called the integrability condition. When it is violated, the surplus function (equation 2) cannot be formulated as equation 7. Thus, we need alternative methods to derive a competitive equilibrium solution from sets of asymmetric demand and supply functions.

We review and discuss three categories of alternative formulations that one can use to find the competitive equilibrium solution for asymmetric demand and supply functions: (1) a system of equations, (2) optimization, and (3) iterative procedures.

[5]To simplify the discussion, we use only less-than or equal-to constraints. Additional equality and greater-than constraints can be included, if desired.

[6]For simplicity, we use linear demand and supply functions and assume that demand and supply substitution matrices are definite.

[7]Note that the set of equations 4 and 5 can be estimated independently of each other, or one can be deried from the other, if the inverse of V or D exists.

System of Equations

Problem 1a can be formulated as a system of equations from which the competitive equilibrium can be solved. The Lagrangian method and the complementary formulation are presented.

Lagrangian Method

The Lagrangian method formulates a surplus maximization problem by a system of equations and obtains the competitive solution by solving this system. Express the surplus maximization problem 1a.

Maximize:

$$Z = \sum_i W_i(q_i)$$

$$\text{subject to } \sum_i g_{ij}\, q_i \leq b_j \text{ and } q_i \geq 0 \qquad (9)$$

The Lagrangian function of this maximization problem is expressed by:

$$L = \sum_i W_i(q_i) + \sum_j \mu_j(\sum_i g_{ij}\, q_j + t_j - b_j)$$
$$+ \sum_i \alpha_i(q_i - y_i^2) + \sum_j \Theta_j(t_j - u_j^2) \qquad (10)$$

The first-order conditions of the Lagrangian function gives the following system of equations (see *24* for derivation) as problem 2:

$$W'_i(q_i) + \sum_j \mu_j g_{ij} + \alpha_i = 0 \quad \text{for } i = 1,\ldots,n \qquad (11)$$

$$\sum_i g_{ij}\, q_i + t_j - b_j = 0 \quad \text{for } j = 1,\ldots,m \qquad (12)$$

$$\alpha_i q_i = 0 \quad i = 1,\ldots,n \quad \text{and} \qquad (13)$$

$$\mu_j t_j = 0 \quad j = 1,\ldots,m \qquad (14)$$

where μ_j, α_i and Θ_j are Lagrangian multipliers, and where t_j, y_i, and u_i are slack variables. Thus, solving problem 1a is equivalent to solving the system of equations in problem 2.

First, we note that $W'_j(q_i)$, which is a partial derivative of $W_i(q_i)$ with respect to q_i, in equation 11 is a marginal net return function, which is the difference between demand price (p_i) and supply price (marginal cost, mc_i):

$$W_i'(q_i) = p_i - mc_i \qquad (15)$$

Thus, if p_i and mc_i are available regardless of whether they are in a nonlinear or asymmetric structure, we can formulate equation 11 as:

$$P_i(q_i,\ldots,q_n) - MC_i(q_i,\ldots,q_n) + \sum \mu_j g_{ij} + \alpha_i = 0 \qquad (16)$$

$$i = 1,\ldots,n$$

By solving the system of equations 12, 13, 14, and 16 we can find the exact competitive equilibrium solution (q_i^*, p_i^*).

Second, to solve the system of equations is to solve n + m equations 12 and 16 with 2n + 2m unknowns (n q's, n α's, m μ's, and m t's). However, n+m of these variables have a zero value from equations 13 and 14. Thus, equations 12, 13, 14, and 16 provide 2^{n+m} sets of n+m linear equations in n+m variables, and one of these sets will yield the solution. The computation can get out of hand very quickly, even for problems with a modest number of variables. Nevertheless, for a smaller number of variables (fewer than five) this procedure is a useful tool, especially when a computer package for the solution is not available.

Complementarity Formulation

Takayama and Uri (*35*) illustrated that quadratic programming (QP) models are a subset of linear complementary programming (LCP) models, and they suggested the use of LCP formulation when the coefficient matrix of the demand or supply function is asymmetric. For a certain class of LCP models, the principal pivoting method or the Lemke method (*19*) leads to a solution. We now construct a LCP problem using Kuhn-Tucker conditions for a competitive equilibrium solution of the surplus model, with linear asymmetric demand and supply functions.

Given the demand and the supply equations 5 and 6, the Kuhn-Tucker condition for problem 2 can be expressed as:

$$(d + DQ) - (s + SQ) + G'\mu \leq 0 \qquad (17)$$
(marginal revenue ≤ marginal cost)

$$GQ - B \leq 0 \qquad (18)$$
(resource use ≤ resource available)

By using α and t as vectors of slack variables, we can formulate an LCP problem as problem 3:

$$\begin{bmatrix} \alpha \\ t \end{bmatrix} = \begin{bmatrix} d-s \\ B \end{bmatrix} + \begin{bmatrix} D-S & G' \\ G & 0 \end{bmatrix} \begin{bmatrix} Q \\ \mu \end{bmatrix}$$
$$\begin{bmatrix} \alpha \\ t \end{bmatrix} \begin{bmatrix} Q \\ \mu \end{bmatrix} = 0, \begin{bmatrix} \alpha \\ t \end{bmatrix} \geq 0, \begin{bmatrix} Q \\ \mu \end{bmatrix} \geq 0 \qquad (19)$$

We can solve the LCP equation by using Lemke's algorithem described by Zangwill and Garcia (*38*). By including both G and G′ matrices, the LCP formulation increases the size of the problem to be solved. This method may not be an efficient tool for solving a large-scale problem.

Because the matrix in the LCP formulation is generally sparse, efficient computation methods to exploit the sparsity have been developed (*19, 21, 36*). Rutherford (*27*) has reported on the application of the LCP formulation and algorithm to a large empirical model of the Norwegian economy. Furthermore, because market behaviors can be formulated as problems of complementarity, researchers have made considerable progress in developing an efficient algorithm (*18, 23*).

Optimization Formulation

We describe three alternatives for building an optimization model equivalent to problem 1a: the average, the Plessner-Heady, and the minimum rent methods.

Average Method

Carey (*2*) has suggested the average (AV) method, if the off-diagonal elements of matrices D and S are similar or the off-diagonal elements are relatively small in comparison with the diagonal elements. That is, income effects are similar or small for all goods. The AV method involves averaging the off-diagonal elements (d_{ij}, d_{ji} for all $i \neq j$); that is:

$$(d_{ij} + d_{ji})/2 = \bar{d}_{ij} \text{ and } (s_{ij} + s_{ji})/2 = \bar{s}_{ij} \qquad (20)$$

and entering the average values of $\bar{d}_{ij}$ and $\bar{s}_{ij}$ in the off-diagonal positions d_{ij} and s_{ij} of matrices D and S to form the new matrices $\bar{D}$ and $\bar{S}$.

The newly constructed symmetric matrices $\bar{D}$ and $\bar{S}$ then replace D and S in the welfare function (equation 7). The problem becomes a quadratic programming problem and can be solved. This method alters the marginal cost and price relationship, so the Kuhn-Tucker first-order conditions of the problem are no longer valid. Thus, the solution from this method can only roughly approximate the competitive equilibrium solution.

Other methods, such as imposed integrability as a condition in estimating the demand function, are used by Pressman (*26*) and by Littlechild and Rousseau (*20*). The imposition of symmetric conditions in estimating the systems of the demand function is also popular in economics to reduce the number of parameters to be estimated.

Plessner-Heady Method

Analysts have extensively used Plessner and Heady's (PH) primal-dual formulation (*25*) to find the competitive equilibrium solution. This formulation does not require using the surplus function, which cannot be formulated under the asymmetric condition. Their objective function is formulated instead as maximization of the difference between net return and imputed costs of fixed, binding resources. The constraints include both the primal and the dual formulation of an optimization model.

The PH formulation equivalent of problem 1a can be expressed as problem 4 (see *22* for detail).

Maximize:

$$Z = P'(v+VP) - Q'(s+SQ) - B'\mu$$

subject to:

$$v + VP - Q \leq 0$$
(supply ≥ demand),
$$-B + GQ \leq 0$$
(resource use ≤ resource available) and
$$P - (s+SQ) - G'\mu \leq 0$$
(marginal revenue ≤ marginal cost) (21)

When the competitive equilibrium is reached, the value of the objective function becomes zero. Takayama and Judge (*32, 34*) also use the primal-dual method for spatial market equilibrium problems.

The PH formulation includes primal and dual components and thereby increases the size of the model. For large-scale problems, the primal-dual formulation becomes expensive to solve. For a medium-scale problem, however, this formulation is a practical tool and has been applied extensively (Stoeker (*31*) and Bhide (*1*) are two typical applications).

Minimum Marginal Rent Method

The minimum marginal rent (MR) method is derived from the PH method. Given a PH formulation as described in problem 4 and assuming $Q > 0$ (this assumption is valid, especially if Q is referred to as aggregate national production of major commodities), we have:

$$P - (s + SQ) - G'\mu = 0 \qquad (22)$$

Further, because demand is equal to supply when a competitive equilibrium solution is reached (in the situation of limited resource, the market price > marginal cost, but demand = supply), we have:

$$v + VP - Q = 0 \tag{23}$$

Substituting:

$$B'\mu = Q'G'\mu \tag{24}$$

in the objective function of equation 21 we have:

$$Z = P'(v + VP) - Q'(s + SQ) - Q'G'\mu \tag{25}$$

By combining equations 22, 23, and 25 and by assigning $R = G'\mu$, we can formulate the MR problem as problem 5.

Maximize:

$$Z = P'(v + VP) - Q'(s + SQ) - Q'R$$

subject to $v + VP - Q = 0, \quad -B + GQ \leq 0,$

$$P - (s + SQ) - R = 0, \tag{26}$$

Problem 5 is a nonlinear programming problem. If we further use βR to replace the term $Q'R$ in the objective function and we assign an arbitrarily large constant number for β, which should be greater than the Q^* of optimal solution, we will have a nonlinear separable programming formulation that can be solved by a linear programming technique. We use a large constant value for β the objective function to minimize rents while maximizing the returns. This method has been applied in land use study (*15*).

Because the MR formulation does not include the production technology data matrix G, its size can be much smaller than the PH formulation. However, it is difficult to apply this method to the activity model (problem 1b) in which the supply function is not explicitly formulated.

Iterative Procedure

The iterative procedure is a computational method of solving a market equilibrium model. To use the procedure, one divides the surplus model into demand and supply submodels. An iterative procedure is then used to interact between these two submodels until the process converges. To illustrate the procedure, we reformulate problem 1b as problem 6:[8]

[8]We use problem 1b, instead of problem 1a, because the iterative procedure is applied to the activity model in most practical applications.

Demand submodel $\bar{Q} = v + VP$

Supply submodel — choose X to minimize:

$$Z = C'X$$

subject to $HX = Q, \quad GX \leq B, X \geq 0$ (27)

Equilibrium condition $-P = MC$

where MC is an optimal dual-variable vector (shadow price vector) corresponding to the demand balance constraint $HX = Q$. We can start an iterative procedure by assigning an initial value for P in the demand submodel and by obtaining Q, which is then used as the right-side value of the demand balance constraint in the supply submodel. We then solve the supply component for the value of MC. If P = MC, we reach the equilibrium solution. Otherwise, we use MC as P in the demand submodel for the next iteration.

One can use iterative procedures to deal with noncomputable surplus functions in two ways. The first way approximates the value of the surplus at each iteration and locates the equilibrium through the iterative process. The second way uses the assumed market adjustment process or search technique in iteration until the market price in a demand submodel is equal to the supply price in the supply submodel. This method thereby avoids direct formulation of the surplus function.

A typical example of the first method is the iterative procedure described in the Project Independence Evaluation (PIES) algorithm (*11*). At each iteration, the algorithm diagonalizes the asymmetric demand matrix to approximate the surplus function. Another example of the first method is described by Carey (*2*). A typical example of the second method is the use of the tatonnement procedure which adjusts the price in response to the excess demand (*7, 8, 30*). Another example is the use of search algorithms, such as fixed-point, Jacobian, Gauss-Seidal, and gradient methods (see *3* for a discussion of these methods). One major problem with the tatonnement procedure is uncertainty in convergence of the iterative process. The major disadvantages with the search method are inefficiency (fixed point), uncertainty in convergence (Jacobian and Gauss-Seidal), and difficulty in the approximation of derivation (gradient) in each iteration. Huang (*13*) discusses convergence conditions for some of these procedures. Another problem is in the application of these methods to find the equilibrium of problem 5 when resources are limited. Huang and Heady (*14*) suggest an iterative procedure to locate the equilibrium by using dual variable information obtained in the solution at each iteration. Extension of this method to large-scale models has not yet been developed.

Suggestions

Table 1 summarizes the alternative formulations discussed in three categories: (1) systems of equations, (2) optimization models, and (3) iterative procedures. We compare these three formulations in general terms. We use the LG method in the first group, the MR method in the second group, and the PIES procedure in the third group as their respective group representative to solve the following examples:

$$v = \begin{bmatrix} 100 \\ 80 \end{bmatrix} \quad V = \begin{bmatrix} -0.4 & 0.2 \\ 0.15 & -0.25 \end{bmatrix}$$

$$s = \begin{bmatrix} 20 \\ 16 \end{bmatrix} \quad G = \begin{bmatrix} 0.5 & 0.9 \\ 0.7 & 0.5 \end{bmatrix} \text{ and } B = \begin{bmatrix} 70 \\ 50 \end{bmatrix}$$

In this example, S is a null matrix and H is an identity matrix. The equilibrium solution for this problem is:

$$q_1^* = 26.32 \quad p_i^* = 311.26 \quad \mu_i^* = 55.39$$
$$q_2^* = 63.16 \quad p_2^* = 254.11 \quad \mu_2^* = 376.52$$

To solve this problem by the LG method, we use 16 (2^4) possible sets of simultaneous equations. One set yields the equilibrium solution; the rest of the solutions are either infeasible or suboptimal.

Table 1—Problem size and solution method

Type of formulation	Row	Column	Slack variables	Total variables	Solution method
			Method		
1. System of equations:					
LG	2n+2m	n+m		2n+2m	Solve at most 2^{n+m} sets of simultaneous systems of equations
LCP	2n+m	n+m		2n+m	Lemke's algorithm by solving at most n+m set of systems of equations
2. Optimization models[1]					
AV	m+1	n	m	n+m	Separable programming or gradient method[1]
PH	2n+m+1	2n+m	2n+m	4n+2m	Separable programming or gradient method
MR	2n+m+1	3n	2n+m	5n+m+1	Separable programming or gradient method
3. Iterative procedures:					
PIES	m+1	n	m	n+m	Each iteration solves an LP model
Tatonnement and search	m+1	n	m	m+n	Each iteration solves an LP model

[1]AV, PH, MR, and PIES will have additional rows and columns for quadratic terms if the separable programming technique is used.

Source: (*29*).

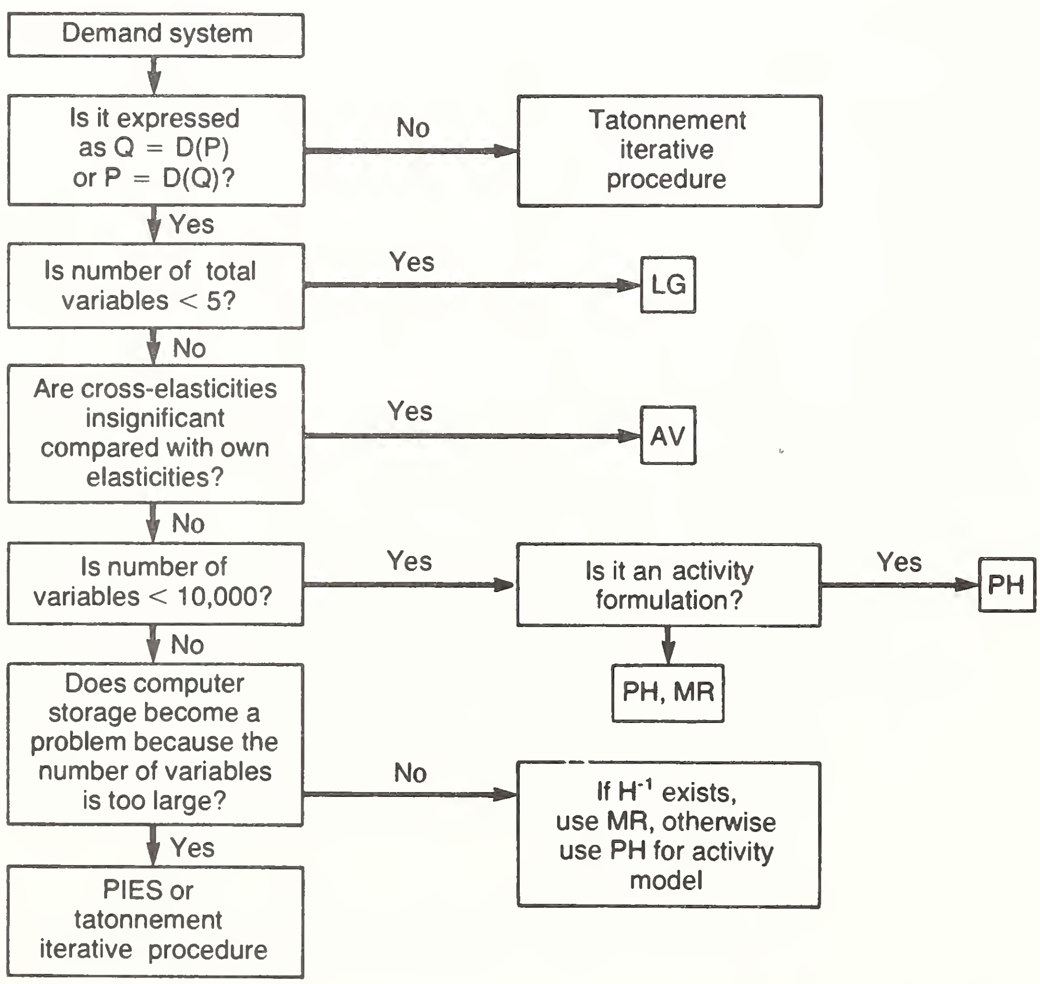
In using the MR method, we assign β = 100,000 and obtain r_i^* = 343.16 and r_2^* = 341.89. Using $r_i = \sum_{j=1}^{2} q_{ij} \mu_i$, i= and 2, we compute the value for μ_1^* and μ_2^*.[9] The PIES method takes three iterations to converge to the optimal solution. At each iteration, we formulate a diagonalized demand system $q_k = D_k(P_k)$ by substituting the initial value (or the i^{th} value computed in the previous iteration) P_i, i=k, into the demand $D_k(P_i,...,P_k, P_n)$ and then express the inverse demand matrix as $P_k = D_k(q_k)$. Using P_k, we formulate a surplus function. This surplus function and the resource constraints are used to set up a quadratic programming problem that is then solved by a separable programming technique. A new set of values of P_i, i=i,...,n, is obtained from the inverse demand function.[10] This set of P_i values is used as the initial values for the next iteration.

[9]In this case, the G is a square matrix. If not, computing unique μ_1 and μ_2 from r_1 and r_2 values may not be possible.
[10]For problem 6, the prices are the shadow prices of the demand balance constraints HX = Q.

The LG method gives the exact competitive equilibrium solution. The MR method and PIES procedure (and other methods we have mentioned here) only approximate the exact solution. In this example, the difference between the exact and the approximate solution is insignificant. In general applications, the difference is probably due to precision of computation rather than to the method used.

Selection of an optimal method of solving a given problem is decided by the three factors: (1) economic interpretation of the formulation and solution process, (2) availability of a computational package for each method, and (3) size of the problem. The justification of the optimization model rests on the meaningfulness of the objective function, whereas for the system of equations, its justification rests only on the set of conditions stipulated because equilibrium does correctly reflect market operation. The iterative procedure provides a dynamic process of market adjustment toward the equilibrium.

Strategy for selecting optimal method of deriving competitive equilibrium from an asymmetric demand system



Selection is frequently determined by the accessibility of a computer package. The computer software for the first group (system of equations) and the third group (iterative procedure) is generally not rich, but the software for the second group is available commercially. Solution techniques for solving a large-scale programming model have recently become more advanced. Thus, optimization (programming) formulation is widely used in applied research.

From a computational viewpoint, the optimization model and the system of equations formulation are equivalent. Carey (*2*) showed that the objective function of the PH method is redundant. By dropping the objective function, the PH method becomes the LCP method and, therefore, can be handled within the scope of existing LCP algorithms. Furthermore, from a practical viewpoint, the LCP is a natural way to formulate a model to reflect specific market behaviors. For these reasons, considerable research efforts are currently underway at various universities to develop an efficient algorithm for solving the LCP models.

The iterative procedures are market simulation solution algorithms. They provide a computational alternative even when the other two approaches are available. Because of the iterative process, the procedures are relatively expensive in terms of computational time. They are often used in situations where the demand system cannot be stated as $P = f(Q)$ or $Q = f(P)$, and the programming and the LCP formulations are, therefore, impossible. When the demand system is expressed in a structural form or by a system of computer language, iterative procedures are especially useful. There are many ways of developing an iterative procedure for solving a particular problem. There are many examples of using the tatonnement procedure, for which convergence has not been proven theoretically; several researchers have reported fast convergence (*4*). Finally, when dealing with an activity model as defined by problem 1b, one can choose between the PH and the MR method, depending on the relation $HX = Q$ in equation 3. The MR method is applicable only if H is a square and invertible matrix. If so, we obtain $X = H^{-1}Q$ and substitute it into the objective function in problem 1b. In reality, H is most likely to be a rectangular matrix. Under this case, the PH method should be used. Because the PH method includes the primal and dual components, size may become too large for prevailing computer computation in a large-scale modeling problem. If so, one would need to design an iterative procedure. The figure suggests a general strategy for selecting a proper method.

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Doubt

If you are convinced that we have adequate procedures for measuring price elasticities of consumer demand, you will not develop a better method. If you believe that existing theory of cooperative behavior is adequate, you will not develop a better theory. If you believe that all existing theories, models, and measures are adequate, you will not develop anything better. If you believe all significant questions have been properly asked, you will never ask a new important question. If you do not doubt something, you will have nothing to research; if you doubt nothing, you are not justified in doing research because you are doing unneeded work. Some people doubt only what they have been taught to doubt. It can prove fruitful to doubt what no one else has doubted. You will never solve a problem that you are unaware of. "Necessity is the mother of invention" is an old saying. My reading of history leads me to believe that dissatisfaction also has been the mother of many inventions.

George Ladd
Imagination in Research, 1987

(See review, p. 32)

Book Reviews

Research Methodology for Economists: Philosophy and Practice

Reviewed by Allen B. Paul

Glenn L. Johnson. New York: Macmillan Publishing Company, 1986, 252 pp., $27.50.

Kenneth Boulding in his foreword writes that this book "should cheer a lot of people up who are undeservedly rather low on the totem pole of academia" (p. xv), that is, people working on narrow problems of the real world rather than working on theories of their discipline. These researchers also do, or can do, orderly thinking. Moreover, they are usually less encumbered with methodological orthodoxy than those working on theories whose concepts have been transported from the physical to the social sciences. Johnson's book offers an antidote to the emphasis in economics on the methods of the physical sciences.

Johnson distinguishes between three types of research—disciplinary, subject-matter, and problem-solving—recognizing that economic research often blends these types. Subject-matter research and problem-solving research (together termed "applied research") are invariably multidisciplinary. They differ mainly in their span of coverge over problems and decisionmakers. Most research on human migration, for example, would be classified as subject-matter research, whereas most research on costs and benefits of importing workers for a specific employer would be classified as problem-solving research.

The three categories of research are said to be conceptually separate because they differ in the kinds of information acquired, in the methods used to acquire such information, and in their "philosophical underpinnings." This view leads Johnson to examine the nature of information, particularly the degree to which it can be objectively determined (whether or not the information is value-free), the possibility of obtaining accurate knowledge of human values (values defined here as the degree of "goodness" or "badness" that people hold with respect to "things, conditions or situations"), and the possibilities of acquiring prescriptive knowledge about the rightness or wrongness of decisions that one might make.

A third of the book is given over to explanation of the major philosophical underpinnings—positivism, normativism, and pragmatism—and to how each philosophical view is reflected in economics as a discipline. An excursion into philosophy seems necessary in a treatise on research methods, but important ideas may be obscured in the language of philosophy.

Some main ideas are these: Logical positivism is helpful, not because it always reflects the real world (which is does not), but because it can correct its mistakes. Strict adherence to positivism tends to restrict the scope of what can be usefully researched.

Some normativists have come to believe that knowledge of values can be researched in the same sense that knowledge of value-free information can be researched. Indeed, many of the basic values in a society are experienced directly by most of its members (for example, a full stomach is better than an empty one) and do not need proof. This is a key proposition that leads to investigation of the most relevant problems of a human society. On this matter Johnson concludes that:

> Our first task as disciplinarians and applied subject-matter researchers and problem solvers is to free ourselves from the shackles of logical positivism and of Pareto optimality and conditional normativism. We need to do this to get on with the important task of increasing our stock of objective disciplinary knowledge about the goodnesses and badnesses experienced as characteristics of the real world. More such objective knowledge of values is crucial if we are to improve and prevent deterioration in the structure of our economies and societies. Without this knowledge we cannot know objectively whether improvement or deterioration is taking place (p. 97).

The reviewer was formerly a senior economist with the Commodity Economics Division, ERS.

As for the pragmatic approach (wherein the truth of propositions is judged by their consequences), its strength in research is its concern with real world problems and its dependence for their solution on insights from all relevant disciplines. Pragmatism's main weakness, however, is in its very complexity and the general refusal of its proponents to subdivide problems into manageable parts as positivists and normativists do. Pragmatists' rejection of simplifying methods may prevent them from making headway in illuminating specific value-free and value-laden problems.

After this excursion into philosophy, Johnson considers six case studies (two in each of the three research categories) to illustrate the nature of information sought and the way that the research effort was mounted, administered, monitored, reviewed, and funded. He examines Leontief's input-output matrix and Schultz's studies of the role of investment in human capital in economic development for their contributions to economics as a discipline, recognizing that each effort was mounted from a concern with a real world problem.

In subject-matter research, Johnson shows that Fox's measurement of how people in a community value their time is an outgrowth of Fox's early interest in sociology and mathematics. The other study, made by the U.S. National Academy of Sciences at the request of President Ford, asks how U.S. research should be organized to help solve the world's food and nutrition problems. It cuts across many disciplines and thereby reflects the philosophical positivism of biological and technical scientists who commonly believe that knowledge of real values cannot be known. Johnson says that this 1977 report may have contributed to subsequent erosion of support for social science research.

Problem-solving research is illustrated by a Michigan Pickle Study done by university researchers under continuing dialog with the main pickle interests and by an investigation by the Michigan Public Service Commission into a rate increase that had been requested by the Consumer Power Company. The latter study elicited information mainly through adversarial hearings. The problem in both studies was to find an acceptable price for services that could be publicly controlled: Mexican nationals' wages in one case and the price of kilowatts in the other. Thus, the two studies differed in the rules under which prescribed prices were arrived at.

The remaining chapters draw together the implications of the philosophical underpinnings, methodologies, and case studies for research support, accountability, administration, conduct, review, evaluation, durability, and practical importance of economic research.

Johnson intended this treatise mainly as a textbook for graduate students in the social sciences. It is purposely repetitious in language and presentation and a bit tedious on this count. The required readings at the end of the first nine chapters, averaging about six readings per chapter covering about 50 pages, should help students, particularly those who are uninitiated in the language of philosophy, to grasp essential ideas.

It is important, I think, for economic researchers to develop their own philosophy of research just as Johnson has done. To this end, the book should serve as a sounding board against which to identify one's own biases and blind spots. It should be studied by persons concerned with promoting, administering, evaluating, or funding research in the social sciences. It is possible, as Boulding notes in the book's foreword, that the taxonomy of research commended to us by Johnson will become more widely used to advance an understanding of human society.

Imagination in Research: An Economist's View

Reviewed by Gene Wunderlich

George W. Ladd. Ames: Iowa State University Press, 1987, 146 pp., $9.95 (paper).

Where do good ideas come from? Can we make better use of our intuition? Do we know more than we know? Professor Ladd's stimulating little book on vision in research stems from, and elaborates on, his article, "Artistic Research Tools for Scientific Minds" (*American Journal of Agricultural Economics*, Vol. 61, No. 1, Feb. 1979). He missed a chance to reinforce the linkage to artistic tools by not referring to Betty Edwards' art book, *Drawing on the Right Side of the Brain.*

In the first of four parts, Ladd relates the rational, logical aspects of scientific inquiry to the speculative, creative aspects by drawing largely on the left hemisphere/right hemisphere model of the brain. The large second part consists of a series of not obviously related mini-lectures on attitude, doubt, tension, distraction, writing, and many more subjects. Most can be read independently, but together they say there are environments, conditions, and efforts that stimulate the imagination. In the third section, Ladd acknowledges luck, but points out that luck needs help. The fourth part, directed at teachers of research methods and methodology, emphasizes discovery by students and continuous revision by teachers.

The reviewer is an agricultural economist with the Resources and Technology Division, ERS.

The subtitle of the book, "An Economist's View," implies that the author will focus on imagination in economics or, alternatively, that he will show how economics can contribute to imaginative processes. He does neither. There is little in *Imagination in Research* that could not apply to any field of inquiry. It is curious that Ladd does not even suggest that economics might have something to offer imaginative processes (for example, are there cost-effective ways of doubting?). The omissions may have been intentional—and valid.

The book is oriented primarily toward the thought processes of individuals. Even when he mentions the sharing of ideas in exchange, Ladd focuses on the individual rather than the collective or institutional growth and development of ideas. It might have been useful had he explored the sources and uses of imagination in organizations. Can a society or an organization have imagination? A reasonable possibility.

Imagination in Research abounds in good ideas. There is something in it for everyone: students, seasoned researchers, and perhaps also for keepers of the research environment. You can read it in bits, and use many of those bits as launching pads for your own excursions into ideas.

In Earlier Issues

Self-appraisal—serious self-appraisal—is often recommended, rarely practiced.

O.V. Wells
Vol. 4, No. 3, July 1952

Altered Harvest: Agriculture, Genetics, and the Fate of the World's Food Supply

Reviewed by Joel Schor

Jack Doyle. New York: Viking Press, 1985, 502 pp., $25.00 (cloth), $7.95 (paper, reprinted by Penguin Books, 1986).

Altered Harvest is going to alter perceptions about the effects of biotechnology on "agriculture, genetics, and the fate of the world's food supply," to use Doyle's subtitle; it is the first book-length study to address the relationship of biotechnology to world agriculture. Though written in a journalistic, loose style, possibly designed to help carry the reader through myriad details, contradictions, and complexities, the book is principally a reference text. Yet, it provokes, disturbs, and stimulates the reader. Chapters are not written in the manner easily grooved for the historian or social scientist, although the text does provide some chronology and social analysis. Each section contains a pouch of cameo gems, glittering with insight, though there is some redundancy. Nevertheless, Doyle must be read, not simply because he discusses specific agricultural economics topics such as bovine growth hormone but because he has also opened the new genetic world of agriculture in its complexity to all readers.

He must also be read because biotechnology is currently moving through its voguish, optimistic phase. No serious accidents or personal injuries have been recorded. The public at large does not know that some experiments have been stopped by court order on the grounds of public health or that biotechnology has been wrapped in the mantle of national security. Doyle is one of a few timely, critical voices.

Like most scholars of technological change, Doyle rejects proponents' claims of unmixed socioeconomic virtue in the gene-splicing revolution. He has isolated trends older than hybrid corn and its universal acceptance, traced them forward, added biotechnology to the process, and made an overall assessment. Perhaps his biggest achievement comes from a detailed analysis of risks that society may be compelled to run as the genetic revolution, fueled by public and private research funds and an almost religious fervor, presses forward. Although it holds out a miraculous promise of insecticide/herbicide resistance to diseases and of nitrogen-fixation in plants, biotechnology is also a new myth-maker as Doyle points out.

A major theme of his book is the control of agriculture by large corporations that use biotechnology and newly expanded patent laws to control living processes. Doyle indicates in an early chapter on hybrid corn that this control follows a precedent established a generation ago by the Wallaces of Iowa, two former Secretaries of Agriculture. Such control in the extreme could render the farmer helpless. Doyle sees the farmer as less significant in formulating public agricultural policy toward biotechnology and in establishing public and private research priorities than the large seed companies, the food-processing industry, the pesticide/herbicide/fertilizer chemical firms, and the suppliers of feed, medications, and hormones to the animal industry. Doyle believes biotechnology may be the final layer of acquired power that the multinational corporation has purchased in is relentless quest to control world markets in grain, livestock, fibers, feeds, and medications. Once that premise, which he documents heavily, has been granted, certain questions follow.

Should, or can, the large multinational firms, many of whom have reputations (as Doyle points out) for poisoning the environment, fudging data before Federal agencies, and resisting the order to clean up its mess, be entrusted with biotechnology? What will such new consolidation do to the price of inputs for the American farmer? Doyle sees a world of a few multinationals owning or controlling redesigned seed that will in turn require a package of their patented chemicals, irrigation systems, and machinery. Will these giants actually reduce, or will they increase, production costs? The farmer's stake in biotechnology will turn upon the outcome. Will the farmer, no matter what size, become the hired hand of industry? Likewise, Doyle juxtaposes aspects of agricultural policy, such as the phasing out of the varietal release of seed by experiment stations, against the landscape

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of decreased competition brought on by corporate consolidation. He probes into what he documents as the marriage of industry and academia.

Biotechnology possesses unique characteristics. Previous technological revolutions in our century contained a time-lag factor, usually about a decade between basic research/breakthrough and practical application. There simply is none with biotechnology; knowledge flows directly from research laboratory to boardroom. Doyle poses and analyzes vital questions arising from the new relationship to gauge its overall impact.

Perhaps the most crucial question is: how can the public and its policymakers obtain neutral advice, if so many scientists in the field are connected in so many ways with the private sector and thereby to their personal interests? Furthermore, if so many scientists are preoccupied today with applications, who will be left to pursue the independent quest that leads to breakthroughs for tomorrow? Doyle cites manipulation of graduate students by professors to serve the private grantee, the veil of secrecy encouraged by corporate legal officers in scientific meetings, the downplay and falsifying of risks when new products are introduced, and the suppression of hostile data before regulatory bodies.

Doyle goes to the roots of American agricultural achievement, the accumulation and refinement of germplasm, usually in the form of seed, plants, animals, or cuttings. On this process we can chart our entire agricultural history. Colonial Americans found in the wilderness only berries, sunflowers, and the Jerusalem artichoke. They either adopted food crops of native Americans or imported the rest as seed. In the early nineteenth century, Henry Elsworth, head of the patent office, and officials of the U.S. Department of Agriculture after its creation in 1862 brought germplasm into America to be tested, refined, and widely dispersed *gratis.* This mechanism over time constituted the reality of Johnny Appleseed for our Nation. Germplasm is the vital stuff, the ever-dwindling gene pool, Doyle fears, that provides the basis for genetic engineering and the technology based upon it. Therefore, he calls the attention of readers to the gene banks maintained by the land-grant system, and the less-than-adequate efforts to sustain such collections and those maintained by international agencies. We have similar difficult problems in sustaining animal stocks.

Why is sustenance of the gene pool such a concern for Doyle in writing on biotechnology? His critique goes beyond the funds appropriated for seed repositories to the trend toward genetic uniformity of our plants and animals. Genetic uniformity, he knows, is risky and potentially disasterous. He points to the warnings of the seventies manifested in the Southern Corn Leaf Blight and currently to avian influenza among poultry. By sustaining the gene pool in its diversity, geneticists, animal breeders, and biotechnologists can identify genes that confer disease/herbicide/pesticide resistance. In other words, Doyle contends that genetic diversity will provide the opportunity for long-term improvement of species. Yet, will actual improvement occur if research and development is left in private hands exclusively?

Doyle is uncertain as to the outcome. He documents reductions in genetic diversity, research directed at other factors such as the quick or one-gene pesticide improvement process instead of the more time-consuming two-gene approach, which requires discovery, insertion, and expression of two genes. Research priorities, he shows, are dictated by food processors and transporters. The dry, hard tomato is an unquestioned moneymaker, regardless of its nutritional content or taste, so that is where monies are invested. In corn, the genetic factors responsible for detasseling corn also carry blight susceptibility. An inverse relationship also seems to exist between yield and nutritional content. How this dichotomy will be bridged remains the subject of debate. Doyle hopes these questions will be resolved with consumer, environmental, farmer, and corporate interests fairly represented, but his years of experience as a legislative aide on Capitol Hill cause him to have doubts. Yet, he is hopeful that the public will rally, confront the issues, demand and obtain complete candor from appropriate agencies, and prevail upon industry to honor social values.

Adaptive Management of Renewable Resources

Reviewed by Stephen R. Crutchfield

Carl J. Walters. New York: Macmillan Publishing Company, 1986, 375 pp., $36.00.

The economic, forestry, and biological literature abounds with scholarly research into the dynamics and behavior of primary resources such as timber and forest products, wildlife, marine and freshwater fisheries, and the like. Yet, despite the increasing sophistication and complexity of our bioeconomic models of these primary resource industries, economists and biologists have generally given the actual process of managing such resources only passing attention. They have often assumed, without much consideration, that some single-valued objective function such as physical yield or net economic yield is to be maximized. It is unfortunate that these researchers have paid less attention to the process of applying management objectives to living resources. Walters' book focuses on this issue: how best to design and implement models of renewable resource management.

Walters takes a somewhat unconventional view of the proper design of models of renewable resources and the role and function of resource management. Most researchers, he says, spend too much time pursuing detailed and expensive primary biological research at the expense of larger, more global, socioeconomic issues: "It is a sad but understandable fact that most scientists base their research programs not on broad analysis of uncertainties, but instead on the investigative tools. . . and analytical methods they learned in university or find popular among colleagues. This means that some ecological/economic research paths are deeply trodden, while others remain untouched" (p. 4).

Walters' second thesis is that the management of renewable resources is often misdirected, aiming at maintaining stability of the resource and its harvesters. He argues instead for an active, adaptive management process, where policy decisions are based on past system behavior ("feedback") and on the deliberate attempts of managers to disturb the system (change harvest policies) so as to force the system away from biological or economic equilibrium, thereby obtaining additional scientific and economic understanding of the processes involved.

Walters stresses the difference between "passive" and "active" feedback policies. "Passive" feedback policies are based on a continuing refinement of existing models as data become available and on marginal changes in regulations based on this new information (for instance, setting total harvest of fish based on an evaluation of last year's spawning rates) in order to promote the biological and economic stability of the industry. Walters argues that this type of regulation may cause us to miss fundamental shifts in the structure of the system, either parametric changes (increases in growth rates of the resource) or fundamental structural changes (declining habitat or changes in the ecological system). "Active" management deliberately drives the system away from equilibrium (fish the stocks harder, cut more timber) and then observes how the system responds. This process, says Walters, gives much better information about the actual biological status of the resource, and it can reduce the uncertainty and imprecision associated with the models used to regulate the resource in the first place.

The book's major contributions are its discussion of: (1) the means by which objectives, constraints, and available knowledge shape the modeling process; (2) a process for building models of renewable resource management that encompasses Walters' style of adaptive management; (3) the design of optimal feedback models; and (4) the implementation of the actively adaptive management strategies he promotes. Also discussed are biological and economic models of renewable resources, the implications and problems of dealing with uncertainty in stochastic resource models, and some examples of adaptive management for complex problems (acid rain and lake trout rehabilitation).

According to the introduction, the book is aimed primarily at resource managers and administrators, with more technical sections oriented toward

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resource analysts: modelers, statisticians, and research scientists. The first three chapters, which introduce the concept of adaptive management, and the introductory material in other chapters are suitable for general audiences. The rest of the book makes heavy use of calculus, high-level mathematics, and statistical theory. The reader should also have some familiarity with management theory and the theory of decisionmaking under uncertainty to appreciate fully some of the more technical material.

Despite its title (and a cover illustration of a tree), the book focuses primarily on fishery resources; forest and timber resources receive passing mention at best. This limitation narrows its appeal to resource economists interested in marine fishing industries. In fact, over a fourth of the book is devoted to detailed biological models of commercial fisheries. It would have had a broader appeal had Walters included models of timber harvest and models of wildlife use and management. A similar narrowness of scope is evident in the examples used to illustrate particular points or to develop specific applications. The vast majority make reference to the salmon stocks of British Columbia (Walters is a professor in the Department of Zoology at the University of British Columbia). Choosing examples of fisheries besides Pacific coast salmon would have given the book a broader applicability.

Somewhat disappointing is Walters' failure to consider economics directly in his management models. Although he clearly appreciates the importance of economic analysis in formulating management policies for renewable resources, his management models usually identify the objective or target to be met as maximum harvest or maximum dollar value of catch from the fish stocks. Walters focuses primarily on managing the biological side of the system; he pays less attention to the economic issues raised by free access to common property resources. One could argue that the principles of adaptive management can be applied to the harvesting industry as well as to resource stocks themselves. It is unfortunate that Walters omits the substantial economics literature on models of regulation of renewable resource industries.

One of the book's strong points is also one of its drawbacks. Walters writes with an acerbic, strongly opinionated style. He frequently makes pointed remarks about researchers, scientists, and resource managers. For example: "Much of the literature on feedback policy design begins by pretending the problem [of changes in the amount of information available about the resource over time] away.... This very bold pretense has been justified in two ways. First, it makes the mathematical analysis more tractable, and hence the analyst can publish more papers" (pp. 274-75). Although such comments, which appear throughout the book, make for lively reading, Walters sometimes appears to be talking down to his audience. Particularly troublesome in this regard is chapter 3, which in large measure is an advertisement for a workshop run by Walters and his colleagues to educate resource analysts and managers in adaptive management techniques.

Despite these problems I do recommend the book to resource economists interested in or familiar with fisheries issues. Given the orientation of the author toward commercial fish resources, the book will probably be less useful to economists or managers in other areas, who may find the technical material on fisheries models somewhat hard to follow. Those working in other fields may, however, find some of the other, nonfisheries material interesting or useful, particularly the chapters on management under uncertainty.

Accelerating Food Production in Sub-Saharan Africa

Reviewed by Arthur J. Dommen

John W. Mellor, Christopher L. Delgado, and Malcolm J. Blackie (eds.). Baltimore: The Johns Hopkins University Press, 1987, 417 pp., $39.50.

This volume presents 28 papers delivered at the August 1983 conference at Victoria Falls, Zimbabwe, organized by the University of Zimbabwe's Department of Land Management and the International Food Policy Research Institute (IFPRI), with the financial support of the United Nations Development Program and the Government of the Netherlands. The papers deal with broad issues like food production and food policy, and they are followed by brief commentaries. The editors have added introductory and concluding chapters.

The volume opens with a succinct review of African demographic, production, consumption, and trade trends by Paulino. He notes that, despite the deteriorating food situation in per capita terms, over half the countries in Sub-Saharan Africa increased their food output by an average 2 percent or more per year from 1961 to 1980. More than half of this growth was in eastern and southern Africa, where Africa's large-scale commercial agriculture is concentrated. The largest growth was in maize, followed by rice; millet and sorghum, two major African staples, performed relatively poorly. Growth in food production has generally depended more on expansion of cropland and labor force than on yield increases or use of modern inputs (compared with other parts of the world).

The nutritional situation in Sub-Saharan Africa is complex, as Kumar stresses. Television has made the world more aware of occasional acute African famine (which may be due to a number of causes besides drought). Undernourishment, however, is persistent and widespread in rural areas, and Kumar highlights some of its less visible dimensions, such as seasonality.

Three regional chapters written by authorities with first-hand field experience—Matlon (West African semiarid tropics), Collinson (eastern and southern Africa), and ter Kuile (the humid and subhumid tropics)—are excellent. The food problem in each of these regions differs in its manifestations, although perhaps not in its fundamentals. Food crops and diets obviously vary, but labor use in food production follows patterns that seem to transcend differences in climate and natural resource distribution. Collison's statement that the basic constraints on the development of the local farming system are land availability and soil fertility maintenance apply equally well to the two other regions.

The chapters on marketing systems, with case studies in Nigeria and Zimbabwe, are useful. They document Africa's notoriously inadequate (with a few exceptions like Nigeria and Cameroon) infrastructure, whose impact on food production and distribution would be difficult to overstate. Budget allocations, however, are subject to controversy.

The chapters on food policy tackle such perpetual riddles as what effect can policy reforms, price adjustments, and choice of investment strategies be expected to have on producers' response. African governments have a spotty record in these areas (often because of donor pressures). The authors pose fundamental questions, but provide few answers. Their only unarguable conclusion is that government intervention in Africa is all-pervasive, but it produces results that are often less beneficial than those reported from Zimbabwe. Several authors make the point that African food problems cannot be understood apart from structural factors that favor the nonagricultural sectors in the policy process.

The core of the volume consists of four studies on various aspects of technology. Technological change in African agriculture is considered "a necessary condition for achieving sustained increases in food production," the reader is warned at the outset. The search for improved technology that works in farmers' fields has been long and frustrating, as the editors recognize. The success of widespread adoption of hybrid corn by Kenyan smallholders appears to have been related to a particularly favorable set of circum-

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stances and may not be duplicatable elsewhere. Where technological packages have been developed by research stations, they run into all sorts of obstacles that anthropologists have understood better than economists. Sometimes farmers surprise researchers by adopting one part of a package and not another, as happened in the Sine Saloum project in Senegal. The pitfalls of this area of technology transfer make prescription hazardous. With regard to fertilizer, the editors warn: "We conclude that there is a potential for increased fertilizer use in specific areas, but not everywhere, and that where and when to emphasize improved input delivery systems requires careful diagnosis." Making recommendations on the basis of such analytical conclusions is difficult.

The pressure to produce prescriptions for accelerating food production in Sub-Saharan Africa comes from the international foreign aid community (including the World Bank) and from the boards of international agricultural research centers (such as IFPRI). In an obvious attempt to respond to this pressure, the editors come close to prescribing something like India's Intensive Agricultural District Program (IADP) of the sixties for Africa. In their search for quantum leaps in agricultural production, the editors seem to argue for concentrating investment in the areas with the most productive soils and dependable water supplies. Apart from the political ramifications of such a decision (which goes against the program thrust of the Organization of African Unity) and the eventual cost, this solution has two major drawbacks:

- By concentrating resources on the better endowed regions, one forfeits all the demand linkages of a broadly based growth pattern, and one risks unbalanced growth creating sharp inequalities in income. The African countries are more preponderantly rural and have less well integrated economies than the Indian states had in the sixties. Moreover, in Africa there is a lack of congruence between agricultural resource endowments and population density.

- Assuming that an IADP-type development strategy is labor-displacing rather than labor-absorbing (compare the French difficulties with recruiting labor for the Office du Niger irrigation scheme in Mali in the thirties), it will not only fail to alleviate population pressure on the more fragile soils (as the editors claim) but it will likely increase such pressure, thereby accelerating the degradation of the natural resource base. (The World Bank has recently set up a unit to monitor the environmental effects of its projects, particularly in Africa.)

A disturbing aspect of this book is that the recommendations offered by the editors in the final chapter often ignore, or actually contradict, the evidence presented elsewhere. If, as Delgado and Ranade cogently argue in their chapter on technological change and agricultural labor use, Sub-Saharan Africa faces "a fundamental structural problem for growth in labor productivity," one must question the wisdom of forging ahead with the search for land-saving technology of the type that produced the Green Revolution in Asia, where labor was in plentiful supply. How do recommendations for a commodity orientation in research and the setting up of input delivery systems accommodate to the problems arising from top-down extension service recommendations designed to boost crop yields that, according to Vallaeys, force farmers to reallocate their inputs of land, labor, and capital on a massive scale? Because Vallaeys was deputy director-general of IRAT, the French agronomic research organization with one of the longest records of work in Africa, his observation carry considerable weight.

In spite of these faults, I believe this book is the single most valuable publication on African agriculture to appear in the past 10 years for its breadth of scope and its attempt to draw lessons from evidence that is admittedly very scattered in location and uneven in quality. The book illuminates, perhaps unintentionally, the vast agenda for research remaining to be addressed before economists understand African agriculture and learn ways to help African farmers help themselves. For now, its title remains more promise than substance.

Agriculture in a Turbulent World Economy: Proceedings of the Nineteenth International Conference of Agricultural Economists

Reviewed by Thomas L. Vollrath

Allen Maunder and Ulf Renborg (eds). Aldershot, England: Gower Publishing Co., 1985, 820 pp., $55.95.

I find evidence, in this proceedings volume, that the scientific community of agricultural economists has made substantial progress toward understanding the underlying forces affecting global agriculture. As a result, we are becoming better equipped to diagnose problems of change and to analyze more thoroughly issues of growth and equity.

Sen, in his keynote address, discusses some broad questions about the economics of food and hunger and their policy implications. He warns against the use of "instant economics" when one formulates policies addressing the terrible problem of hunger and starvation affecting millions. Instant economics involves shortcuts in economic reasoning associated with the "opinions of practical people." A contemporary example is the "Malthusian optimism" whereby public concern about the food problem virtually vanished following the 1974 World Food Conference because global food output was shown to have outpaced world population. Sen notes that, although food output per capita has increased since then, hunger in some parts of the world has intensified. As an alternative to instant economics, the author advocates analyses of entitlements in studying food and hunger.

Sen relates entitlements to "acquirement," the ability to establish command over commodities based on original endowments and the "network of exchange" mappings involving production and trade. Asserting that the entitlement approach is consistent with old traditions in economics, he contends that Adam Smith would not have been either for or against intervention in the event of famine. Smith would instead have examined the issue of cash relief versus direct food relief.

Just as Sen denigrates instant economics, he applauds the wisdom of early economists such as Smith, Ricardo, and Marx who provided superior economic analyses and policy prescriptions about food and hunger problems. But what about the modern day economist? Does Sen's advocacy of the entitlement approach and his omission of any citations from the contemporary literature suggest a dim view of the current state of the economics profession?

In his paper examining the problem of malnourishment, Srinivasan comments about the difficulty of quantifying undernutrition. Instant economics would suggest that additional resources be allocated to obtain a better understanding of the extent and distribution of undernutrition. But, Srinivasan notes that, however well-defined the occurrence of undernutrition may be, its principal cause is poverty. The obvious implication is that the problem of malnournishment would be served best if analytical resources were used to examine the poverty issue. Srinivasan underscores Sen's view of the crucial role of sound economic analysis by referring to the tragedy in Africa where misguided public policies distorted producer incentives, aggravating the food and hunger problem.

Mellor, dealing with the uncertainty of growing food imbalances, points out that commercial shipments of food to developing countries help the development process because of the powerful and beneficial effects of the international market. He asserts, contrary to popular logic, that poverty is actually being reduced because of imbalances in demand and supply and because of the greater openness to agricultural trade. Mellor, however, is not willing to rely on simple prescriptions. Recognizing that the poor are not always able to retain food entitlements, he examines ways in which food aid can be used to deal with the hunger problem when the market system fails. Mellor's approach to the food and hunger problem is similar to that of Adam Smith, which Sen views so favorably. Neither Smith nor Mellor would be willing to rely exclusively on the *laissez-faire* solution. Both view the critical issue as being not whether to intervene but rather how food assistance can best be used to reduce the unacceptable human condition of hunger.

Even economic model builders are aware of failure of food markets when it comes to the financially deprived.

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Fischer and others have engaged in global simulations linking national economic models. They find that agricultural markets, while performing well for most people, do not function well for the hungry. Hunger is stubborn. It does not go away under the widely different scenarios examined in their study.

We can achieve food security either by becoming self-sufficient through increased production or by relying on the market, exchanging commodities as determined by comparative advantage. DeJanvry's preferred strategy is a mix of both approaches. He believes that open market prices are best used to serve as guides for the efficient allocation of resoures, but within an institutional context molded by structural interventions. According to deJanvry, additional policy instruments, such as land reform, new technology, and infrastructural investments, provide the means to "elasticize" the market response of the economically disenfranchised.

But well-intentioned government regulations and reforms can go awry. Commenting about economic forces shaping the future in South and Southeast Asia, Hayami contends that "...direct importation of ... policies from the developed countries without due recognition of major differences in underlying economic forces and in social and institutional environments is often counterproductive...." He notes, for example, that prohibition of usury has resulted in the rich receiving a disporportionate share of subsidized institutional credit; that minimum wage laws induced a shift away from labor-intensive to labor-extensive crops; and that rent control resulted in the eviction of tenants to establish landlords' direct management. These examples suggest that it is important not to rely on superficial economic reasoning. This viewpoint is entirely consistent with the spirit of the entitlement approach.

Macroeconomic, sector, and target interventions provide a variety of ways for policymakers to alter market outcomes. It is important, therefore, to gain a better understanding of the consequences of proposed actions to avoid simple policy prescriptions that lead to unintended and undesirable ramifications.

In his paper on exchange rates and trade policy, Valdes looks at linkages between macro and sector policies that decisionmakers often ignore. He sensitizes us to the importance of recognizing, for instance, that import barriers lower the value of the exchange rate, implicitly taxing domestically produced exports. An implication is that developing countries that promote industrialization by erecting tariffs or by establishing quantitative import restrictions are, in effect, reducing incentives to their producers of agricultural exports and raising domestic consumer incentives to purchase agricultural imports.

Rausser and others examine the issue of instability in agricultural markets. They note that prices of nontraded commodities are "sticky" compared with traded commodities, which are subject to global competitive forces. The implication of this fixed, flexed price dichotomy is that changes in macroeconomic policies can induce externalities. If, for example, the monetary authorities increase the money supply or lower interest rates, the exchange rate depreciates, raising (lowering) the domestic price of exportables (importables) relative to other goods produced in the economy. Therefore, price swings for food, in developing countries reliant on international agricultural trade, may be wider than price swings for nontraded commodities.

The proceedings issue of the 1985 International Association of Agriculture Economists meetings held at Malaga, Spain, contains a wealth of information about the often subtle, but significant, consequences of proposed action. Review of a small sampling of articles suggests that contemporary economists are not only acutely aware of food, hunger, and economic problems confronting world agriculture, but they are gaining an increasingly better understanding of the important forces that shape them. I hope this volume will receive a reception among decisionmakers, as it contains valuable source material needed to formulate sound policy.

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