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# Spatial Equilibrium for Related Commodities

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## INTRODUCTION

Much theoretical work in spatial equilibrium analysis is directed toward development of completely general models that explain spatial patterns of production, consumption, and trade for a number of commodities that are interrelated in demand or supply or both. Commodity groups studied might include all important commodities in the international trade of a country or all commodities produced in an economy or in a subsector such as the agricultural economy of the United States. In addition to the technical problems of achieving simultaneous spatial equilibrium for a number of related commodities, general models of this sort raise questions that either do not arise or are not strongly felt in models of spatial equilibrium of a single good.

New problems arise because general spatial equilibrium analysis seeks a more profound insight into the working of an economic entity, by first intention. But even if it were not more ambitious in conception, a general model would almost surely encounter such fundamental and far-reaching changes in the economy under study as to force reevaluation of the approach taken. The typical multiple-region, single-commodity model is a simple extension of the classical two-region model of international trade. Trade in the commodity between the regions is assumed to be unimportant to the general economy and does not affect wage rates or other input prices, nor does it affect demand and prices of competing consumption goods. In this model, pretrade demand and supply curves have reference in reality, and trade can be legitimately viewed as horizontal and parallel shifts of supply curves. In the more comprehensive, general equilibrium model, trade is so important that it affects the basic structure of the economy. In these circumstances, pretrade conditions become highly fictional and are likely to be irrelevant to the analysis. It is scarcely reasonable to ask what would be the price of corn in a highly industrial state such as New Jersey, or what would be the elasticity of supply of corn in that state, if it had to grow its own livestock feed. A spatial equilibrium model that purports to determine levels of trade in corn as horizontal shifts of supply curves is hence likely to be far from reality. One is hardly any better off considering posttrade supply curves, since it is not clear how these could be shifted to simulate pretrade conditions. Even pretrade demand curves are an absurd fiction, since population—the main determinant of demand—is itself profoundly conditioned in its distribution by the existence of agricultural trade.

A closely related weakness of spatial equilibrium models, but one that is equally damaging to a single-commodity model, is failure to recognize that some parameters of the system are functions of the level of trade. The most obvious example is transfer cost, especially of feedstuffs such as hay and grain, which are geographically dispersed in both production and consumption. Although unit cost of shipment from one central regional marketplace to another may not depend on amount shipped, small amounts would presumably have to be shipped shorter distances. Nonlinear demand and supply schedules also imply changes in parameters of the system as trade occurs, and this is potentially a grave source of error.

All these considerations plead for a spatial equilibrium model that is iterative in the sense that it approaches the final solution by slow degrees, permitting adaptive adjustments of the model parameters as trade proceeds. This paper presents the basic core of such a model and indicates how further elaborations can be accomplished. There appear to be no practical limitations on the number of regions or commodities that can be accommodated, nor on the degree of their economic interrelationship. With suitable modification, nonlinearities of many sorts can be incorporated in the model. The parameters of the system can be altered in response to signals generated by the model, and economic factors other than trade can be introduced into the model. Spatial equilibrium is achieved by effecting trade between regions for each commodity in turn. At frequent intervals the trades that have occurred, and the changes in relative prices that result, are acknowledged by finding a new competitive equilibrium among commodities within each region. Early signals for trade may prove ill-founded in light of subsequent price changes due to trade, reestablishment of equilibrium within a region, or changed parameter values. The trade pattern is periodically tested for such false starts, and unwanted trades are erased or transferred to other regions. This corrective process, plus the basic simplicity of the algorithm, makes the method quite robust. There are very few computational constraints, the model can be made to reflect economic reality, to the extent knowledge permits, and the results of model operation can be essentially devoid of computational artifact.

Because the scope of the method is so wide, a full-scale application has not yet been attempted. The purpose of this present paper is to indicate the scope and limitations of the model as presently developed, to indicate in broad outline the nature of the computer algorithm, and to present an illustrative application to the livestock-feed economy of the United States to further reveal the capabilities of the model. Finally, possible applications are discussed and problems associated with use of the model are considered.

The basic economic model dealt with by the algorithm is best thought of as one of static competitive equilibrium. The model relies heavily on exogenously determined supply and demand schedules and lends itself readily to comparative static analysis, which is the use to which spatial equilibrium models are most frequently put, but is of dubious applicability to dynamic analysis unless extensive modifications or reinterpretations are made. Ordinary supply curves relating decisions on quantity produced to current prices are of doubtful validity in dynamic contexts, and it is this type of supply curve that is used in the model.

The basic structure of the model includes:
regional supply equations,

$$Q_{ij}^P = f(P_{i1}, P_{i2}, \ldots, P_{im}) \qquad \begin{matrix} i = 1, n \\ j = 1, m \end{matrix} \qquad \ldots(1)$$

regional demand equations,

$$Q_{ij}^D = f(P_{i1}, P_{i2} \ldots, P_{im}) \qquad \begin{matrix} i = 1, n \\ j = 1, m \end{matrix} \qquad \ldots(2)$$

and interregional transfer cost functions,

$$T_{ik}^j = F(D_{ik}, X_{ik}^j) \qquad \begin{matrix} i, k = 1, n \\ j = 1, m \end{matrix} \qquad \ldots(3)$$

where

$Q_{ij}^P$ = quantity of commodity $j$ produced in region $i$,

$Q_{ij}^D$ = quantity of commodity $j$ consumed in region $i$,

$P_{ij}$ = price of commodity $j$ in region $i$,

$T_{ik}^j$ = transfer cost from region $i$ to region $k$ (not necessarily equal to $T_{ki}^j$) for commodity $j$,

$X_{ik}^j$ = quantity of commodity $j$ shipped from region $i$ to region $k$,

$D_{ik}$ = distance between shipping points $i$ and $k$,

$m$ = number of commodities, and

$n$ = number of regions.

The quantities available for consumption are then:

$$Q_{ij}^S = Q_{ij}^P + \sum_k^n (X_{ki}^i - X_{ik}^i) \qquad \begin{matrix} i, k = 1, \ldots, n \\ j = 1, \ldots, m \end{matrix} \qquad \ldots(4)$$

and $Q_{ij}^S$ is the quantity of good $j$ available in region $i$. $Q^P$ and $Q^D$ may take any form such that a transformation exists such that equations 1, 2, and 4 become linear in all the transformed arguments.

## THE COMPUTER ALGORITHM

The computer algorithm is iterative. Equilibrium is achieved by effecting trade between regions for each commodity in turn, beginning in an artificial position in which there is either no interregional trade or a predetermined amount. Trades are made across price gradients, from regions of low price to regions of high price. As trade occurs, supply curves, which are the sums of local supply and imports (or local supply minus exports), shift and price gradients are reduced. When no profitable trades remain, the system is in spatial equilibrium.

At equilibrium, the following conditions must hold:

$$\frac{P_{ij} - P_{kj}}{T_{ki}^j} \begin{cases} \leqslant 1 + \tau & \text{for all } X, k, \text{ and } j \\ \geqslant 1 - \tau & \text{for all } X_{ki}^j > 0 \end{cases}$$

$$X_{ki}^j \geqslant 0 \qquad \begin{matrix} i \neq k \\ i, k = 1, \ldots, n \\ j = 1, \ldots, m \end{matrix}$$

which for $\tau = 0$ ($\tau$ is an arbitrary small number used to fix the level of accuracy in the iterative procedure) are the Kuhn-Tucker conditions for the maximum of a nonlinear program that maximizes net social payoff; that is,

$$(P_{ij} - P_{kj} - T_{ki}^j)\, X_{ki}^j = 0$$

$$X_{ki}^j \geqslant 0$$

$$P_{ij} - P_{kj} - T_{ki}^j \leqslant 0$$

The algorithm, however, does not directly maximize an objective function; it acts rather as the market computer suggested by Zusman et al. (*26*) and closely resembles an expanded reactive program (*21*).

Trade in any one commodity not only affects the spatial equilibrium of that commodity but also affects the intercommodity equilibrium within each of the regions among which trade occurs. Equilibrium is maintained within each region by inverting the matrix of coefficients of the set of linear equations relating prices and quantities and multiplying the inverse by the vector of constant terms, which has been altered to reflect the shifts in supply curves resulting from the immediately preceding trades.

The program is designed to acknowledge only *net* trade between two regions, even though a considerable amount of cross-hauling might occur, especially of branded items such as sausages, cheeses, and canned milk. Therefore, each region is treated as an importer or an exporter of a particular commodity, but not both.

In the pseudohistorical process of proceeding from the pretrade to the equilibrium position, some false starts occur. That is, a trade may appear profitable at an intermediate stage of iterative process but not be profitable after all prices have been adjusted to their equilibrium values. The computer algorithm erases such trades.

The computer program has to deal with a number of technical details. The most important of these is the need for special treatment of the situation in which there is no local production of a good in a region and the region depends entirely on imports of that good. In these circumstances, the supply equation becomes inoperative and the matrix must be modified before inversion. Quantity is set equal to imports and price is made to depend on the demand curve only. The demand equation is also "constrained" such that all prices and quantities are nonnegative. The condition of no local production of a commodity can be expected to occur often as equilibrium is approached, especially if demand and supply schedules are linear.

The program also has to eliminate redundant trade routes. In the course of the iterative procedure, two regions might both be exporting to each of two other regions. Transportation costs can be reduced by eliminating one of these sets of trading partners. In the real world, such trade patterns might easily arise and may not really be redundant, but the important economic effects of trade are the result of net trade. It was thought desirable to eliminate the redundant routes in order to emphasize the direct net trade. The redundant routes are eliminated by minimizing transfer cost for a given trade pattern by the simplex algorithm of linear programming applied to the transportation costs.

The model as presently written treats only prices, quantities, and interregional trade of a complex of related commodities as endogenous to the system. All other prices, transportation rates, and other economic factors impinging on the model are treated as exogenous. Actually, in a sufficiently large, inclusive model, such as a model of the entire agricultural economy of the United States, income in some largely agricultural states might be significantly affected by changes in agricultural trade. In such cases, income and perhaps even population might need to be considered endogenous. The iterative nature of the present algorithm appears to facilitate inclusion of various macroscopic factors into the endogenous mechanism, although such has not yet been tried.

The usual mathematical formulation of a general equilibrium model, following Hicks (*9*), considers quantities produced or consumed to be functions of the prices of all commodities. It is quite common in quadratic programming procedures to invert the relationships to obtain prices as functions of quantities (*18*, p. 73). In the present instance, the Hicksian formulation is used, but for computational facility the price of each commodity is expressed as a function of the quantity of that commodity produced or consumed and of all other prices of commodities included in the endogenous model. Because of this formulation, the coefficients of the price–quantity matrix do not have the same relationships to elasticities and to cross-elasticities as they do in the more usual Hicksian formulation, but the Hicksian matrix may be readily obtained by dividing each equation by the quantity coefficient.

## WHY NOT QUADRATIC PROGRAMMING?

A method of determining competitive spatial equilibrium for a number of related commodities exhibiting linear demand and supply curves by quadratic programming methods has been illustrated by Bawden (*1*) using methods developed by Takayama and Judge (*18, 19*). More recently, a modification of quadratic programming applied to a single industry—broiler production—and only three regions, but said to be capable of extension to $n$ regions and $m$ commodities, has been presented by Lee and Seaver (*12*, p. 64). A number of more restrictive methods, including linear programming and transportation methods, have been used to good purpose on spatial problems, but these methods cannot be used on a general equilibrium problem. Quadratic programming would appear to have disadvantages or insurmountable obstacles to its use for the following reasons:

1. Although quadratic programming is iterative (most algorithms employing a modification of the simplex procedure), it does not permit adaptive adjustments of system parameters as the optimal solution is approached. Perhaps parametric programming could be used, but it would be awkward. In particular, the quadratic programming model is restricted to linear demand and supply curves. The alternative algorithm presented here accepts a limited class of nonlinear demand and supply curves and could easily accommodate other nonlinear demand and supply curves by substitution of linear tangent lines at the point of intersection of the supply and demand curves, taking account of all shifts that have occurred due to trade, in a manner similar to that discussed by Edwards (*5*).

Transfer costs between regions can be made to depend on amount of trade and adjusted as trade proceeds, possibly using the approach developed by Beckmann (*3*). Theoretically, interrelationships between commodities vary as relative supplies change, as when trade occurs, so it should be possible to alter them as the model proceeds toward equilibrium. In short, iterative methods, usually disdained by model builders in this field, actually have much to recommend them. Mere mathematical elegance, on the other hand, seems to be irrelevant and not to be sought at the expense of economic content in the model.

2. Results of model operation should depend on the economic theory embodied in the model and should be free of distortion due to computational limitations and restrictions of the model. In view of this, the model should be unrestricted in size, in terms both of number of regions and of number of commodities included. A model should be able to encompass at least 50 regions and 20 commodities. Such a model could have states for regions and could include commodities yielding over 90 percent of agricultural crop and livestock receipts. The Takayama-Judge model of quadratic programming, based on the Wolfe algorithm (*25*), requires $n^2m + 3nm$ rows in the Simplex table. For $n = 50$ regions and $m = 20$ commodities, this would require a matrix of 53,000 rows (and more columns). The Theil–Van de Panne algorithm (*20*) differs somewhat from the Wolfe algorithm and is claimed by the authors to have computational advantages, at least in some circumstances. The

Lee-Seaver algorithm requires a smaller matrix as well (*12*, p. 65). At a very minimum, it would seem that for any modification of quadratic programming, a matrix of the order of magnitude of $m \times n = 1000$ rows at least would be required. The quadratic programming method thus appears to be computationally unwieldy, whatever the capacity of modern computers may be, if for no other reason than because of the housekeeping required.

3. Last, but not least, the quadratic programming method is highly sophisticated, artificial in its economic rationale in at least some formulations, and mathematically uncongenial if not inaccessible to many potential users. Adaptations to spatial problems often involve ingenious modifications that further alienate the casual user and tend to stifle improvisations needed to add economic content to the applications. On the other hand, the alternative algorithm to be presented will be seen to have direct intuitive appeal.

## APPLICATION TO THE LIVESTOCK-FEED ECONOMY OF THE U.S.

The intended purpose of the program developed in this study is to permit simultaneous spatial equilibrium of a complex of commodities related in supply or demand, providing maximum flexibility and scope for economic content. In that spirit, perhaps the best use of the model in agriculture would be to treat that entire agricultural economy as an integrated system, on the grounds that at the very least all agricultural products compete for agricultural inputs, land, labor, and management services. Most agricultural products are foods or fibers, so they are very likely to compete in consumption as well. A model with each state as a region and including feeder cattle, fed cattle, hogs, sheep and lambs, dairy products (perhaps divided into manufactured and fresh fluid milk), eggs, broilers, turkeys, wheat, corn, oats, sorghum, soybeans, pasture, hay, cotton, tobacco, fruits, and vegetables, and possibly a miscellaneous category for crops and livestock, would be a very reasonable undertaking. Quantification of the parameters of such a comprehensive model would obviously be a very difficult task. In order to illustrate the operation of the spatial equilibrium model, we shall employ it in an abbreviated model of the livestock-feed economy of the United States, using four highly aggregated inputs—pasture, hay, low-protein and high-protein feed—and six aggregated outputs—beef, pork, broilers, milk, turkeys, and eggs. There are eight regions in the example: (1) the Pacific Northwest including Alaska and Idaho, (2) the Pacific Southwest including Hawaii and as far inland as Utah, (3) the Northern Plains including Wyoming, (4) the Central Plains including Colorado, (5) the Southern Plains including New Mexico, (6) the Midwest including the Lake States and the Corn Belt, (7) the South from Louisiana to Virginia, and (8) the Northeast including the mid-Atlantic states and New England. Regional assignment of other states should be clear.

The model is constructed at the farm level. Pasture is measured in tons of hay-equivalent rather than in acres and is assumed to be equal to hay in dollar value per ton. Beef, pork, turkeys, and broilers are measured in pounds live-weight, eggs are in dozens, and milk is in hundredweights. High- and low-protein feed are measured in tons. Low-protein feed is a weighted aggregate (weighted by ton) of corn, oats, barley, and sorghum. High-protein feed is assumed to be equal to soybean production. Admittedly, this excludes many sources of high-protein feed, the most important being cottonseed, but the total of the excluded sources is so small relative to soybeans that it was not considered worthwhile to include here at this stage of the analysis.

Demand relations for outputs are based on Brandow's (*4*) estimates and are functions of regional population and regional per capita income. The supply relations are based on estimates of supply elasticities from the literature (*6, 12, 14, 15*), and are at best very shaky. In order to obtain a consistent set of estimates, the sum of supply elasticities from a given commodity was constrained to be equal to zero, with the exception of low- and high-protein feed and pasture. The elasticity of supply of pasture was arbitrarily assumed to be one, as none of the inputs to pasture production are endogenous to the model. The sum of elasticities for both high- and low-protein feed was allowed to be greater than zero because of the importance of exogenous consumption of these commodities.

Regional estimates of supply elasticities were not generally available and were obtained by weighting the national estimates in such a fashion that regions with a large (in value terms) output had relatively more elastic supply schedules than low-output regions.[1]

Demand elasticities for inputs were derived from the estimated regional supply curves, based on the following relations derived from production theory, assuming that the

[1] Estimates of regional supply elasticities were obtained by using the following formula:

$$e_k = \frac{e P_k Q_k Q_T}{\sum_k P_k Q_k^2}$$

where $e_k$ is the regional elasticity of the $k$th region, $e$ is the national elasticity, $P_k$ is the regional price, $Q_T$ is the national production, and $Q_k$ is the regional production. Note that the quantity weighted average of $e_k$ equals $e$:

$$e = \sum_k \frac{e_k Q_k}{\sum_k Q_k}$$

underlying production functions are homogeneous of degree one. For a given output, the elasticities of derived demand are:

$$e_p^D = e_p^s + 1$$

$$e_i^D = e_i^s \quad i \neq k$$

$$e_i^D = e_i^s - 1 \quad i = k$$

where $e^D$ is the derived demand elasticity for the $k$th input, $e^s$ is the supply elasticity, $p$ is output price, and $i$ refers to input prices.

The elasticities of the regional demand equations are then the weighted sum of the derived demand elasticities where the weights are the quantity of the input consumed by each output activity. Estimates of both the regional demand and regional supply elasticity are given in Appendix Tables A-1 and A-2, respectively.

Three forms of supply and demand relations were postulated: linear, hyperbolas based on the estimated elasticities, and hyperbolas based on known resource constraints.

The linear equations were determined such that current production, consumption, and prices corresponded to the estimated regional elasticities. The hyperbolas based on elasticities were estimated in a similar fashion. The general form of hyperbolic supply and demand equations is:

$$Q = a + \sum_k B_k / P_k$$

The third system has the same demand curves as the second, but the supply curves are based on existing resource constraints. The asymptote of the supply curve $a$ is specified to be a function of the available resources. Using the estimated asymptotes and the estimated regional cross-elasticities and current production and prices, the coefficient of the commodity's price is determined for each supply equation. That is, the slope of the hyperbola is determined by the observed price–quantity relations and the known resource constraints, rather than by having the slope be a function of own-price elasticity and by having the intercept determined by known price–quantity relations.

The use of hyperbolas in a comparative static model for agriculture is intuitively appealing for many reasons. As demand for a good increases (decreases), the supply curve becomes more inelastic (elastic). The same is true for linear schedules, but the elasticities change proportionally more when hyperbolas are used. Also, unlike linear relations, hyperbolas put upper "limits" on supply and lower "limits" on demand, and these limits can be determined either exogenously or endogenously. This last property gives hyperbolas the potential of describing or predicting the results of a significant change in demand or supply much more accurately than linear equations. After all, both linear and curvilinear equations are, at best, just approximations of reality, but the concept that supply must be bounded corresponds with reality more than the concept of a possibly infinite increasing supply, even if one were willing to accept the meaningless concept of an infinite price.

In any situation but the short run, the resources within a given region available to a given production activity will depend on what that activity is able to "bid" for the resource. In the case of agriculture, a constraining resource that has to be allocated among different activities is land. As the production of one activity increases, the amount of land available to the other activities must decrease. This can be expressed in terms of the hyperbolic supply schedules as

$$Q_j = d - \sum_{k \neq j}^{m} \frac{G_k}{G_j} Q_k - \sum_{k}^{m} B_k / P_k$$

$$j, k = 1, \ldots, m$$

where

$$L = \sum_k G_k Q_k,$$

$$d = a + \frac{L}{G_j},$$

$L$ = total amount of "suitable" land available in the region,

$G_k$ = a factor that converts the quantity $Q_k$ into equivalent acreage units for commodity $j$, and

$a$ = a factor of the asymptote, perhaps equal to zero, which includes all other factors that may limit production.

Supply equations of the above form can be adapted directly into the iterative procedure being discussed here. The resulting solution would represent the long-run static equilibrium of the postulated system.

The asymptotes for the third system being used as an example here (model 3), were fixed at a certain percentage above the reported production levels for 1972. The same percentages were used for all regions and are reported in Appendix Table A-3. By determining the asymptotes in this fashion, model 3 becomes essentially a short-run model. The approximate time span being allowed for adjustment implicit in locating the asymptotes was approximately one year.

The initial, or pretrade, demand and supply curves, with elasticities shown in Appendix Tables A-1 and A-2, for the first two models, were positioned with reference to prices, quantities consumed, and quantities produced either estimated or reported (*23*) for 1972. For model 3, the curves were positioned relative to 1972 prices, quantities, and production figures, and the fixed asymptotes.

At present, the program is based on the assumption that transfer costs are a linear function of distance and independent of amount shipped. The latitude and longitude of central points were determined and the distances between these points were calculated using spherical geometry. The transfer costs were then based on these distances.

Linear transfer cost functions were adapted from estimates appearing in studies by King and Schrader (*11*), St. Clair and Kelley (*17*), Guedry and Judge (*7*), Schnake and Franzman (*16*), Judge et al. (*10*), Bawden et al. (*2*), USDA-ERS (*24*), and from fragmentary data in other sources.

It was assumed that pasture could not be shipped. However, it is not farfetched to argue that moving feeder calves onto pasture, especially if the movement is against the prevailing pattern of movement of finished beef, is in effect shipment of pasture. This kind of refinement, however, would be difficult to build into the models in a meaningful way.

If one can assume that the specifications of the models are realistic, it should be possible to test the structure of the model by seeing how well the estimated production, consumption, prices, and trade agree with the actual levels. Other measures of internal consistency are possible. For example, one can test whether available supplies of feedstuffs are sufficient to support the estimated level of livestock and livestock product production.

The production estimates of all three models were quite close to the reported production levels. The actual and estimated production levels, along with estimated net trade, are summarized in Table 1. Detailed results for each model are presented in Appendix Tables A-4 to A-6 and the estimated trading patterns in Appendix Table A-7.

Three-quarters of the errors of estimation of the level of production of each commodity in each region are less than plus or minus one-half a unit in absolute value. The errors are uniformly distributed about zero, so there is no persistent bias. In terms of this criterion—prediction of levels of production and consumption for a single year—the model seems to be satisfactory.

The importance of interregional trade in agricultural commodities is well illustrated by all three models. A large percentage of several commodities is shipped between even the large regions used in the example.

Production tends to be slightly underestimated, but the error in any region is generally quite small. Errors of estimation are consistently largest in regions 6 and 7, both of which are the largest producing and exporting regions for the aggregate commodities included in the models.

The allocation of the agricultural inputs, pasture, hay, and feedgrains, is much harder to evaluate. Since pasture varies so in quality, tons of hay-equivalent was used as the unit in place of acres. Pasture so measured was allocated to states according to numbers of roughage-consuming animal units to obtain the estimate of actual production shown in Table 1. The estimates generated by the model differ only in consequence of shifts in demand and supply curves for pasture induced by changes in prices of products and other inputs. It was assumed that relatively more pasture and less hay is used in the Southern region and in the Southern Plains than in other regions. But these features were built into the model and do not provide an independent test of the model estimates.

There are independent reported levels of hay and feedgrain production. Since about 18 percent of the hay produced is sold off the farm, the level of trade in this commodity may be underestimated. On the other hand, perhaps relatively little is shipped far enough to cross regional boundaries of the present model. Estimated supplies of feedgrains, both low- and high-protein, are not quite sufficient to support reported feeding levels in the South. Most surplus grain, for nonfeed use, occurs in the Great Plains and Midwest, as is to be expected.

The ability to simulate actual production patterns is not really a good test of a comparative statics model. The interesting question is whether or not the model can produce useful predictions of the impact of exogenous changes such as crop failure in the Midwest, a change in the world demand for small grains, or a change in transportation costs.

The potential impact on a substantial export of low-protein feed was estimated using all three formulations by shifting the production schedules for low protein to the left in all regions by an amount equivalent to 10 percent of that region's production. This is equivalent to an export of slightly more than 700 million bushels or, alternatively, to a decrease in production of that amount. The percentage change in prices, quantities, and domestic trade is reported in Table 2. The predicted effects of the three models are quite similar, the highest price rise being in low-protein feed, followed by pork, beef, and high-protein feed. Quantities decreased, with the largest decreases associated with the largest price changes. The largest increase in the price of low-protein feed occurred in model 3, the model with the constrained asymptotes and the most inelastic supply schedules. Model 3 also had the smallest changes in average price and total production for the other commodities, a result that initially seems to be counter-intuitive. The effect of the decrease in supplies of low-protein feed in model 3 cannot be compensated for by changes in production due to the inelastic structure of supply, but can only be compensated for by changes in trade, which require either increases in production in exporting regions (or relatively smaller decreases) and the decrease in total quantities being most strongly felt in the production in importing regions. The predicted changes in total interregion trade are by far the most erratic for model 3, with increases for four commodities as compared with decreases for all commodities being predicted by model 1.

Table 3 illustrates the changes in production patterns for two commodities, beef and hay. Regions 1, 3,

**TABLE 1. Comparison of three models with actual**

BEEF

| REGION | ACTUAL | PRODUCTION MODEL1 | PRODUCTION MODEL2 | PRODUCTION MODEL3 | NET IMPORTS MODEL 1 | NET IMPORTS MODEL 2 | NET IMPORTS MODEL 3 |
|---|---|---|---|---|---|---|---|
| | (100 MILLION LBS.) | | | | | | |
| I | 15.8 | 15.9 | 15.9 | 15.9 | -2.6 | -2.6 | -2.6 |
| II | 31.5 | 31.3 | 31.4 | 31.4 | 20.6 | 20.7 | 20.6 |
| III | 42.3 | 41.7 | 42.0 | 42.3 | -37.4 | -37.6 | -38.0 |
| IV | 75.4 | 76.3 | 77.9 | 75.8 | -64.0 | -65.7 | -63.6 |
| V | 73.9 | 74.4 | 74.2 | 74.3 | -45.4 | -45.1 | -45.3 |
| VI | 102.2 | 104.0 | 103.5 | 104.6 | 0.1 | 0.9 | 0.0 |
| VII | 61.7 | 59.0 | 59.0 | 59.0 | 24.2 | 24.5 | 24.3 |
| VIII | 10.5 | 10.5 | 10.5 | 10.3 | 104.5 | 104.7 | 104.6 |
| TOTAL | 413.2 | 413.3 | 414.4 | 413.7 | 149.5 | 151.0 | 149.5 |

BROILERS

| REGION | ACTUAL | PRODUCTION MODEL1 | PRODUCTION MODEL2 | PRODUCTION MODEL3 | NET IMPORTS MODEL 1 | NET IMPORTS MODEL 2 | NET IMPORTS MODEL 3 |
|---|---|---|---|---|---|---|---|
| | (100 MILLION LBS.) | | | | | | |
| I | 1.3 | 1.3 | 1.3 | 1.3 | 2.6 | 2.6 | 2.6 |
| II | 3.7 | 3.7 | 3.7 | 3.7 | 11.0 | 11.0 | 11.1 |
| III | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 | 1.3 | 1.3 |
| IV | 0.1 | 0.0 | 0.0 | 0.0 | 3.4 | 3.4 | 3.4 |
| V | 7.4 | 7.4 | 7.4 | 7.5 | 0.0 | 0.0 | 0.0 |
| VI | 3.2 | 3.2 | 3.2 | 3.2 | 25.3 | 25.3 | 25.4 |
| VII | 81.4 | 80.5 | 80.6 | 81.1 | -57.2 | -57.3 | -57.6 |
| VIII | 17.8 | 17.7 | 17.7 | 17.7 | 13.6 | 13.6 | 13.7 |
| TOTAL | 114.8 | 113.8 | 113.8 | 114.4 | 57.2 | 57.2 | 57.6 |

PORK

| REGION | ACTUAL | PRODUCTION MODEL1 | PRODUCTION MODEL2 | PRODUCTION MODEL3 | NET IMPORTS MODEL1 | NET IMPORTS MODEL2 | NET IMPORTS MODEL3 |
|---|---|---|---|---|---|---|---|
| | (100 MILLION LBS.) | | | | | | |
| I | 1.1 | 1.1 | 1.1 | 1.1 | 5.8 | 5.8 | 5.9 |
| II | 1.0 | 1.0 | 1.0 | 1.0 | 25.8 | 25.8 | 25.8 |
| III | 9.3 | 9.3 | 9.3 | 9.3 | -6.9 | -6.9 | -6.9 |
| IV | 22.2 | 22.2 | 22.2 | 22.2 | -15.8 | -15.8 | -15.8 |
| V | 6.3 | 6.3 | 6.3 | 6.3 | 9.1 | 9.1 | 9.1 |
| VI | 141.3 | 141.6 | 141.5 | 141.7 | -86.4 | -86.4 | -86.6 |
| VII | 31.3 | 31.0 | 31.1 | 31.1 | 12.9 | 12.8 | 12.9 |
| VIII | 3.2 | 3.2 | 3.2 | 3.2 | 55.5 | 55.5 | 55.6 |
| TOTAL | 215.7 | 215.7 | 215.7 | 215.9 | 109.1 | 109.1 | 109.3 |

MILK

| REGION | ACTUAL | PRODUCTION MODEL1 | PRODUCTION MODEL2 | PRODUCTION MODEL3 | NET IMPORTS MODEL1 | NET IMPORTS MODEL2 | NET IMPORTS MODEL3 |
|---|---|---|---|---|---|---|---|
| | (10 MILLION CWT.) | | | | | | |
| I | 5.0 | 4.7 | 4.7 | 4.7 | -0.7 | -0.6 | -0.6 |
| II | 12.2 | 13.9 | 14.0 | 14.1 | 0.7 | 0.6 | 0.6 |
| III | 3.0 | 2.8 | 2.8 | 2.9 | -1.5 | -1.5 | -1.6 |
| IV | 4.2 | 4.0 | 4.0 | 4.0 | -0.3 | -0.3 | -0.3 |
| V | 4.9 | 5.0 | 5.0 | 5.0 | 3.4 | 3.4 | 3.4 |
| VI | 51.4 | 50.2 | 50.2 | 50.5 | -19.2 | -19.2 | -19.4 |
| VII | 15.6 | 15.3 | 15.4 | 15.3 | 8.7 | 8.6 | 8.7 |
| VIII | 23.9 | 24.1 | 24.1 | 24.1 | 8.9 | 9.0 | 9.0 |
| TOTAL | 120.3 | 120.1 | 120.2 | 120.6 | 21.7 | 21.6 | 21.8 |

TABLE 1. (Continued)

EGGS

| REGION | ACTUAL | PRODUCTION MODEL1 | MODEL2 | MODEL3 | NET IMPORTS MODEL1 | MODEL2 | MODEL3 |
|---|---|---|---|---|---|---|---|
| | (10 MILLION DOZ.) | | | | | | |
| I | 14.7 | 14.7 | 14.7 | 14.7 | 3.9 | 3.8 | 3.8 |
| II | 75.9 | 75.5 | 75.6 | 75.2 | -3.9 | -4.2 | -3.8 |
| III | 10.1 | 10.1 | 10.1 | 10.3 | -4.1 | -4.0 | -4.2 |
| IV | 15.2 | 15.3 | 15.3 | 15.6 | 0.5 | 0.8 | 0.5 |
| V | 28.5 | 28.5 | 28.5 | 28.4 | 13.8 | 13.7 | 13.8 |
| VI | 135.7 | 138.7 | 138.4 | 141.4 | 0.0 | 1.0 | -1.3 |
| VII | 212.9 | 208.9 | 209.1 | 209.3 | -83.8 | -84.1 | -83.9 |
| VIII | 86.9 | 84.7 | 84.9 | 83.4 | 73.6 | 73.1 | 75.0 |
| TOTAL | 580.0 | 576.3 | 576.6 | 578.2 | 91.8 | 92.3 | 93.2 |

HAY

| REGION | ACTUAL | PRODUCTION MODEL1 | MODEL2 | MODEL3 | NET IMPORTS MODEL1 | MODEL2 | MODEL3 |
|---|---|---|---|---|---|---|---|
| | (MILLION TONS) | | | | | | |
| I | 8.5 | 7.5 | 7.3 | 7.3 | -0.5 | 0.0 | 0.0 |
| II | 11.9 | 11.4 | 11.5 | 11.5 | 0.5 | 0.0 | 0.0 |
| III | 18.3 | 16.8 | 16.8 | 17.0 | -12.2 | -12.1 | -12.0 |
| IV | 15.5 | 13.1 | 11.6 | 12.8 | -6.7 | -3.9 | -4.6 |
| V | 7.9 | 7.7 | 7.7 | 7.6 | -1.0 | -1.1 | -0.7 |
| VI | 42.2 | 46.4 | 47.0 | 48.4 | 2.5 | 0.8 | 0.5 |
| VII | 13.1 | 13.5 | 13.6 | 14.0 | 4.2 | 3.8 | 4.0 |
| VIII | 10.9 | 11.0 | 11.0 | 11.1 | 13.1 | 12.4 | 12.8 |
| TOTAL | 128.4 | 127.3 | 126.7 | 129.6 | 20.3 | 17.1 | 17.3 |



TURKEYS

| REGION | ACTUAL | PRODUCTION MODEL1 | MODEL2 | MODEL3 | NET IMPORTS MODEL1 | MODEL2 | MODEL3 |
|---|---|---|---|---|---|---|---|
| | (10 MILLION LBS.) | | | | | | |
| I | 4.4 | 4.4 | 4.4 | 4.4 | 2.4 | 2.5 | 2.4 |
| II | 42.4 | 42.5 | 42.5 | 42.4 | -13.3 | -13.4 | -13.3 |
| III | 4.4 | 4.4 | 4.4 | 4.5 | -1.9 | -1.9 | -2.0 |
| IV | 9.8 | 9.8 | 9.8 | 9.8 | -2.4 | -2.4 | -2.3 |
| V | 19.1 | 19.1 | 19.1 | 19.2 | -2.2 | -2.2 | -2.3 |
| VI | 98.6 | 99.1 | 99.1 | 99.3 | -38.4 | -38.4 | -38.6 |
| VII | 56.4 | 56.0 | 56.1 | 56.2 | -6.3 | -6.3 | -6.4 |
| VIII | 7.3 | 7.3 | 7.3 | 7.2 | 62.1 | 62.2 | 62.4 |
| TOTAL | 242.4 | 242.7 | 242.7 | 242.9 | 64.5 | 64.7 | 64.8 |

LOW PROTEIN

| REGION | ACTUAL | PRODUCTION MODEL1 | MODEL2 | MODEL3 | NET IMPORTS MODEL1 | MODEL2 | MODEL3 |
|---|---|---|---|---|---|---|---|
| | (MILLION TONS) | | | | | | |
| I | 1.8 | 1.8 | 1.8 | 1.8 | 4.0 | 4.1 | 4.0 |
| II | 3.0 | 2.9 | 2.9 | 2.9 | 13.5 | 13.7 | 13.7 |
| III | 12.4 | 12.9 | 12.8 | 12.8 | -8.4 | -8.2 | -8.2 |
| IV | 30.1 | 32.2 | 33.3 | 33.2 | -9.1 | -9.6 | -9.5 |
| V | 13.5 | 13.5 | 13.5 | 13.5 | -0.3 | -0.4 | 0.0 |
| VI | 120.1 | 115.1 | 114.4 | 116.8 | -32.4 | -32.4 | -33.4 |
| VII | 13.0 | 13.2 | 13.1 | 13.5 | 16.9 | 17.1 | 17.4 |
| VIII | 4.6 | 4.6 | 4.6 | 4.6 | 15.8 | 15.8 | 16.1 |
| TOTAL | 198.4 | 196.3 | 196.5 | 199.1 | 50.2 | 50.6 | 51.2 |

**TABLE 1. (Continued)**

HIGH PROTEIN

| REGION | ACTUAL | PRODUCTION MODEL1 | PRODUCTION MODEL2 | PRODUCTION MODEL3 | NET IMPORTS MODEL1 | NET IMPORTS MODEL2 | NET IMPORTS MODEL3 |
|---|---|---|---|---|---|---|---|
| | (100,000 TONS) | | | | | | |
| I | 0.0 | 0.0 | 0.0 | 0.0 | 4.4 | 4.4 | 4.5 |
| II | 0.0 | 0.0 | 0.0 | 0.0 | 16.0 | 16.3 | 16.7 |
| III | 3.4 | 3.4 | 3.4 | 3.4 | 0.0 | 0.0 | 0.0 |
| IV | 14.7 | 14.8 | 14.8 | 14.8 | -8.0 | -8.1 | -7.9 |
| V | 2.7 | 2.7 | 2.7 | 2.7 | 21.7 | 21.5 | 22.1 |
| VI | 267.3 | 254.1 | 254.0 | 265.9 | -195.6 | -195.8 | -206.3 |
| VII | 92.8 | 91.9 | 92.1 | 89.0 | 118.2 | 118.0 | 126.1 |
| VIII | 3.9 | 3.9 | 3.9 | 3.9 | 43.6 | 43.9 | 45.1 |
| TOTAL | 384.9 | 370.8 | 370.9 | 379.6 | 203.8 | 204.2 | 214.4 |

PASTURE

| REGION | ACTUAL | PRODUCTION MODEL1 | PRODUCTION MODEL2 | PRODUCTION MODEL3 | NET IMPORTS MODEL1 | NET IMPORTS MODEL2 | NET IMPORTS MODEL3 |
|---|---|---|---|---|---|---|---|
| | (TONS HAY EQUIV.) | | | | | | |
| I | 12.5 | 12.2 | 12.2 | 12.4 | 0.0 | 0.0 | 0.0 |
| II | 19.0 | 19.0 | 19.0 | 19.0 | 0.0 | 0.0 | 0.0 |
| III | 28.5 | 28.4 | 28.3 | 28.5 | 0.0 | 0.0 | 0.0 |
| IV | 33.6 | 33.3 | 33.5 | 33.6 | 0.0 | 0.0 | 0.0 |
| V | 53.5 | 53.6 | 53.4 | 53.6 | 0.0 | 0.0 | 0.0 |
| VI | 82.8 | 84.2 | 83.8 | 83.1 | 0.0 | 0.0 | 0.0 |
| VII | 60.3 | 58.7 | 58.6 | 60.0 | 0.0 | 0.0 | 0.0 |
| VIII | 15.2 | 15.2 | 15.2 | 15.2 | 0.0 | 0.0 | 0.0 |
| TOTAL | 305.4 | 304.7 | 304.1 | 305.4 | 0.0 | 0.0 | 0.0 |

TABLE 2. Percent change in average price, total production, and total interregional trade after "exporting" 10 percent of the low-protein feed, by commodity

| | Percent Change in Average Price | | | Percent Change in Total Estimated Production | | | Percent Change in Total Estimated Interregional Trade | | |
|---|---|---|---|---|---|---|---|---|---|
| Commodity | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 |
| Beef | 1.94 | 1.94 | 1.33 | -1.06 | -1.05 | -.73 | -1.53 | -1.53 | -.26 |
| Pork | 2.21 | 2.25 | 1.31 | -.72 | -.72 | -.40 | -.91 | -.92 | -.45 |
| Broilers | 1.31 | 1.27 | .83 | -.30 | -.23 | -.16 | -.22 | -.15 | .15 |
| Milk | 1.05 | 1.03 | .91 | -.29 | -.28 | -.26 | -.11 | .12 | .29 |
| Eggs | 1.07 | 1.05 | .86 | -.21 | -.19 | -.16 | -.01 | -.08 | .23 |
| Turkeys | 1.06 | 1.04 | .68 | -.30 | -.30 | -.21 | -.20 | -.32 | -.20 |
| Hay | 1.51 | 1.43 | 1.03 | -.30 | -.23 | -.39 | .04 | 2.61 | 3.09 |
| Low Protein | 5.39 | 5.84 | 5.93 | -4.31 | -4.27 | -5.14 | -.90 | -.72 | -2.72 |
| High Protein | 1.68 | 1.70 | 1.48 | -.67 | -.43 | -.82 | -.80 | -.60 | -.29 |
| Pasture | .52 | .53 | .19 | .52 | .51 | .03 | -- | -- | -- |

TABLE 3. Percent change in production of beef and hay in response to "exporting" 10 percent of the low-protein feed, estimates from model 1 and model 3, by region

| | Beef | | Hay | |
|---|---|---|---|---|
| Region | Model 1 | Model 3 | Model 1 | Model 3 |
| I | -.31 | -.27 | -.25 | -.03 |
| II | -.58 | -1.27 | -.25 | -.34 |
| III | -.24 | -.05 | -.27 | .51 |
| IV | -1.80 | -.30 | -.52 | .70 |
| V | -1.36 | -.64 | -.27 | -.08 |
| VI | -.91 | -1.07 | -.32 | -.95 |
| VII | -.49 | -.98 | -.19 | -.49 |
| VIII | -.07 | -1.65 | -.28 | -.97 |

4, and 5 are the major beef-exporting regions and the change in production of beef was relatively less in these regions in the inelastic formulation, model 3, as compared with the linear model. For hay, the difference between the two models is even more obvious. The two principal exporting regions, regions 3 and 4, actually showed an estimated increase in production in the inelastic formulation.

Overall, the effect of exporting 10 percent of the low-protein feed supplies was greatest in the models based on hyperbolas. In all three models, trade in hay increased as hay was substituted for low-protein feed, the largest increase in trade in hay being in the inelastic model. Generally, the more inelastic the postulated structure, the more likely trade was to increase.

Another interesting effect was in the increase in the consumption of pasture in all regions for models 1 and 2 and in all but two regions for model 3, implying that pasture was a strong substitute for low-protein feed and was substituted to an extent that it overrode the production effect of an increase in the price of low-protein feed.

As a summary evaluation, it is clearly possible to achieve a high degree of verisimilitude in model estimates of production, consumption, and trade, but unless supply curves are explicitly constrained by such factors as resource endowments, the validity of the estimates remains in doubt. It would be highly desirable to be able to compare actual and estimated interregional shipments, regional prices, and transfer costs among regions. Estimated trade between regions is reported in Appendix Table A-7. Unfortunately, data on shipments are fragmentary or utterly lacking. Data on regional price levels reflect differences in quality as well as differences in location. For example, the New York prices of hogs in 1972 averaged $21.30 per hundredweight, whereas in Iowa the prices averaged $25.10. Beef cattle showed even greater incomparability, since beef cattle in New York averaged $28.98 while in Iowa the prices averaged about $34.18, clearly reflecting higher quality beef in the Midwest. The problem appears to be less severe for most of the other commodities studied, but, in all cases, published regional prices must be evaluated very carefully for comparability.

It seems to be premature to belabor interregional patterns of prices until the knotty problems of determining transfer costs have been dealt with more adequately. For example, the estimated interregional pattern of broiler prices is similar to the actual pattern in 1972 except that estimated price differences are slightly less than those actually reported. The estimated differential between the South and the Northeast is about 2.5 cents per pound, almost exactly the same as reported. However, the estimated differential between the Pacific Coast and the South is 3.2 cents, about a cent lower than the reported differences in farm prices of 4.1 to 4.3 cents. One needs to determine whether the actual differentials are conditioned more by shipments of frozen or chilled broilers. Similarly, reported price differences in "all milk" may reflect cost of shipment of fluid milk or condensed, powdered, or processed milk.

## PROBLEMS AND OPPORTUNITIES PRESENTED BY THE MODEL

In view of the fairly good fit with observed production and consumption patterns in 1972 afforded by the model, despite the severe limitations of the present development of the model structure, one is naturally led to question the ability of the analysis to discriminate between good and bad, or between realistic and unrealistic, model structures. This is especially so since criteria of evaluation in addition to the patterns of production and consumption either are absent or depend on poor data.

Changes in model structure can take myriad forms, and relatively little can be said generally about the sensitivity of the model to change in structure. However, it should be clear that the model structure, especially the off-diagonal elements of the price–quantity matrix, which embody the interrelationships within the model, cannot be subjected to arbitrary shifts since the model may then become economically meaningless. Seemingly innocuous changes in the coefficient matrix for prices and quantities can lead to erratic changes in the inverse of this matrix. In general, it might be supposed that both matrices should be such that the diagonal elements are dominant; that is, that direct effects are greater than indirect effects (a condition that would always hold if demand and supply curves were realistic and homogeneous of degree zero). If not, a unit shipment of corn into a region might well reduce the price of eggs by a larger amount than it reduces the price of corn in terms of units used. Something akin to the Hawkins-Simon conditions of input-output analysis (*8*) appears to be applicable, but this question has not been pursued far at present.

Changes in structure were made and their effects traced. In one, all off-diagonal elements in the price–quantity matrix were set at zero, while initial levels of price and quantity produced were retained. In the other, off-diagonal elements were increased. Zero elements correspond to the absence of interrelationships among the commodities, which then, in the model, achieved spatial equilibrium separately. With the particular values used in the example, zero off-diagonal elements resulted in more shipments of all commodities except broilers. This is, of course, to be expected, since in the model with related commodities, shipment of grain, for example, substitutes for shipment of livestock or products.

The model with off-diagonal elements increased showed opposite changes. Here the interrelationships are strengthened. Trade is further reduced. As the interrelationships are strengthened, the price changes due to maintaining equilibrium with regions become greater, slowing down the rate of convergence of the model.

The accuracy parameter ($\tau$ tau) of the model was also varied. The results presented were obtained with $\tau$ set to 0.005; that is, given the magnitude of the prices, approximately four significant digits were obtained. By increasing $\tau$ to 0.01, approximately three significant digits were obtained and the fourth digit was accurate within a range of plus or minus 2. Convergence was achieved with about 88 percent of the iterations required for the original setup.

Passing reference has already been made to the fact that most studies of spatial equilibrium have apparently accepted uncritically the notion of pretrade demand and supply curves for each region. When a sufficiently comprehensive model is postulated, however, as in the present instance, the fictional nature of pretrade demand and supply becomes obvious and introduces a serious source of artificiality into the model. The algorithm presented here certainly does not solve the problem automatically. It would appear, however, to provide maximum flexibility in approach to a solution.

The difficulty can probably be dealt with satisfactorily in one of several ways. First of all, one can recognize the artificiality of the pretrade conditions, despair of accurately estimating quantities shipped among regions, and devote primary attention to the posttrade situation. The slopes of demand and supply curves are in this approach made to reflect the posttrade levels of product and input availabilities. Care must be taken to assure that pretrade price and quantity are both nonnegative, but otherwise no serious effort need be made to adduce what price and quantity consumed or produced would be under autarky.

Perhaps a better, but surely more difficult, method would be to postulate a pretrade situation in which many economic factors, including the distribution of population, differ from present reality in response to lack of trade in agricultural products. Then as trade occurs, these factors could be adjusted accordingly. The difficulties in this approach are obvious, but any other approach seems doomed to falsify either pretrade or posttrade economic relationships in the model.

The computer algorithm outlined above appears to be sufficiently comprehensive and flexible so that it can encompass a spatial model of the entire agricultural economy using relatively small regions such as states. There seem to be few sources of error due to limitations of the model that cannot be corrected by straightforward means, usually employing the iterative nature of the algorithm to advantage. The model would thus appear to offer a useful pragmatic test of much econometric work dealing with such things as slope or elasticity of demand or supply of a commodity and cross-elasticities of demand or supply. It also promises a pragmatic test of much of the arcane lore of the marketing specialist. Suppose, for example, that one were to assert that direct purchasing of feeder cattle has worked to the disadvantage (or to the advantage) of the ranchers in the Mountain States. If such an effect cannot be built into the demand and supply specifications of a spatial model, perhaps it has no scientific validity or indeed no reality. Similarly, one might question whether packer feeding really affects prices of beef, whether specification buying has hurt small feedlot operators, or whether the decline of a particular terminal market or of terminal markets in general really matters. If the pragmatic rule is followed that only those marketing factors that can be built into a model and shown to have an effect on price have economic meaning, much marketing knowledge may prove to be a mirage or fantasy. One is led to the familiar conclusion that one cannot safely separate marketing and production in agricultural economic research.

Although the model is essentially a comparative static model, the use of the models based on hyperbolic supply and demand curves shows potential in providing useful predictions of the effect of large exogenous changes on the overall level of production and farm level prices. The impact of a large sale of grains to Russia, for example, could easily be predicted using a model such as model 3.

Malone (*13*) and Brandow (*4*, p. 29) and indeed many empirical researchers have compiled lists of econometric estimates of such economic parameters as the elasticity of demand for pork and beef. Even acknowledging that such parameters undoubtedly change through time and in different theoretical contexts, estimates vary so widely that little confidence can be placed in them. The continuing effort toward better estimates of individual parameters might benefit from a comprehensive model within which the estimates could be evaluated.

One would like eventually to be able to rationalize or predict secular trends that have a spatial aspect. Why did the broiler and egg industries move South? Will the shift continue and for how long? It remains to be seen whether a model of this sort can be made sufficiently sensitive to give definitive answers to such questions, and it would seem that the inherently static nature of the model might limit its usefulness in this area of inquiry.

Is there a livestock-feed economy in the sense that various classes of livestock and feed interact economically? If so, what happens to feed grain production when the hog cycle exhibits a downswing? Do the hog cycle and the cattle cycle interact? Students of livestock production cycles have had little success in adducing relationships of the sort suggested. Here, too, the static nature of the model may limit its applicability. But it would seem that a really comprehensive static model is a necessary precursor to effective dynamic analysis and should contribute significantly to better understanding of the industry or economy being analyzed.

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## APPENDIX

### APPENDIX TABLE A-1. ESTIMATED REGIONAL SUPPLY ELASTICITIES, BY COMMODITY

BEEF

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.158 | -0.009 | 0.0 | 0.0 | 0.0 | 0.0 | -0.016 | -0.073 | -0.029 | -0.032 |
| 2 | 0.331 | -0.018 | 0.0 | 0.0 | 0.0 | 0.0 | -0.033 | -0.152 | -0.061 | -0.067 |
| 3 | 0.397 | -0.022 | 0.0 | 0.0 | 0.0 | 0.0 | -0.040 | -0.182 | -0.074 | -0.080 |
| 4 | 0.735 | -0.040 | 0.0 | 0.0 | 0.0 | 0.0 | -0.074 | -0.337 | -0.136 | -0.148 |
| 5 | 0.723 | -0.039 | 0.0 | 0.0 | 0.0 | 0.0 | -0.073 | -0.332 | -0.134 | -0.145 |
| 6 | [illegible] | -0.055 | 0.0 | 0.0 | 0.0 | 0.0 | -0.103 | -0.468 | -0.189 | -0.205 |
| 7 | 0.634 | -0.034 | 0.0 | 0.0 | 0.0 | 0.0 | -0.064 | -0.291 | -0.117 | -0.128 |
| 8 | 0.110 | -0.006 | 0.0 | 0.0 | 0.0 | 0.0 | -0.011 | -0.051 | -0.020 | -0.022 |

PORK

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -0.001 | 0.005 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.004 | -0.001 | 0.0 |
| 2 | -0.001 | 0.005 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.004 | -0.001 | 0.0 |
| 3 | -0.005 | 0.042 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.032 | -0.005 | 0.0 |
| 4 | -0.012 | 0.098 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.074 | -0.012 | 0.0 |
| 5 | -0.004 | 0.029 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.022 | -0.004 | 0.0 |
| 6 | -0.076 | 0.605 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.455 | -0.074 | 0.0 |
| 7 | -0.018 | 0.141 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.106 | -0.017 | 0.0 |
| 8 | -0.002 | 0.015 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.011 | -0.002 | 0.0 |

BROILERS

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.003 | 0.0 | -0.001 | 0.0 | 0.0 | -0.002 | -0.000 | 0.0 |
| 2 | 0.0 | 0.0 | 0.009 | 0.0 | -0.002 | 0.0 | 0.0 | -0.006 | -0.001 | 0.0 |
| 3 | 0.0 | 0.0 | 0.000 | 0.0 | -0.000 | 0.0 | 0.0 | -0.000 | -0.000 | 0.0 |
| 4 | 0.0 | 0.0 | 0.000 | 0.0 | -0.000 | 0.0 | 0.0 | -0.000 | -0.000 | 0.0 |
| 5 | 0.0 | 0.0 | 0.014 | 0.0 | -0.003 | 0.0 | 0.0 | -0.010 | -0.002 | 0.0 |
| 6 | 0.0 | 0.0 | 0.007 | 0.0 | -0.001 | 0.0 | 0.0 | -0.005 | -0.001 | 0.0 |
| 7 | 0.0 | 0.0 | 0.120 | 0.0 | 0.0 | 0.0 | 0.0 | -0.104 | -0.017 | 0.0 |
| 8 | 0.0 | 0.0 | 0.230 | 0.0 | 0.0 | 0.0 | 0.0 | -0.198 | -0.032 | 0.0 |

MILK

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.430 | 0.0 | 0.0 | -0.050 | -0.065 | -0.065 | -0.249 |
| 2 | 0.0 | 0.0 | 0.0 | 1.500 | 0.0 | 0.0 | -0.174 | -0.228 | -0.228 | -0.869 |
| 3 | 0.0 | 0.0 | 0.0 | 0.420 | 0.0 | 0.0 | -0.049 | -0.064 | -0.064 | -0.243 |
| 4 | 0.0 | 0.0 | 0.0 | 0.420 | 0.0 | 0.0 | -0.049 | -0.064 | -0.064 | -0.243 |
| 5 | 0.0 | 0.0 | 0.0 | 1.020 | 0.0 | 0.0 | -0.118 | -0.155 | -0.155 | -0.591 |
| 6 | 0.0 | 0.0 | 0.0 | 0.530 | 0.0 | 0.0 | -0.061 | -0.081 | -0.081 | -0.307 |
| 7 | 0.0 | 0.0 | 0.0 | 0.850 | 0.0 | 0.0 | -0.099 | -0.129 | -0.129 | -0.493 |
| 8 | 0.0 | 0.0 | 0.0 | 0.290 | 0.0 | 0.0 | -0.034 | -0.044 | -0.044 | -0.168 |

**APPENDIX TABLE A-1. (Continued)**

EGGS

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | -0.002 | 0.0 | 0.011 | 0.0 | 0.0 | -0.005 | -0.005 | 0.0 |
| 2 | 0.0 | 0.0 | -0.011 | 0.0 | 0.056 | 0.0 | 0.0 | -0.023 | -0.023 | 0.0 |
| 3 | 0.0 | 0.0 | -0.001 | 0.0 | 0.006 | 0.0 | 0.0 | -0.002 | -0.002 | 0.0 |
| 4 | 0.0 | 0.0 | -0.002 | 0.0 | 0.009 | 0.0 | 0.0 | -0.004 | -0.004 | 0.0 |
| 5 | 0.0 | 0.0 | -0.005 | 0.0 | 0.025 | 0.0 | 0.0 | -0.010 | -0.010 | 0.0 |
| 6 | 0.0 | 0.0 | -0.017 | 0.0 | 0.088 | 0.0 | 0.0 | -0.036 | -0.036 | 0.0 |
| 7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.120 | 0.0 | 0.0 | -0.060 | -0.060 | 0.0 |
| 8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.230 | 0.0 | 0.0 | -0.115 | -0.115 | 0.0 |

TURKEYS

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | -0.001 | 0.0 | 0.0 | 0.007 | 0.0 | -0.005 | -0.001 | 0.0 |
| 2 | 0.0 | 0.0 | -0.007 | 0.0 | 0.0 | 0.067 | 0.0 | -0.051 | -0.006 | 0.0 |
| 3 | 0.0 | 0.0 | -0.001 | 0.0 | 0.0 | 0.007 | 0.0 | -0.005 | -0.001 | 0.0 |
| 4 | 0.0 | 0.0 | -0.002 | 0.0 | 0.0 | 0.017 | 0.0 | -0.013 | -0.002 | 0.0 |
| 5 | 0.0 | 0.0 | -0.003 | 0.0 | 0.0 | 0.029 | 0.0 | -0.022 | -0.004 | 0.0 |
| 6 | 0.0 | 0.0 | -0.016 | 0.0 | 0.0 | 0.156 | 0.0 | -0.121 | -0.020 | 0.0 |
| 7 | 0.0 | 0.0 | -0.009 | 0.0 | 0.0 | 0.091 | 0.0 | -0.070 | -0.011 | 0.0 |
| 8 | 0.0 | 0.0 | -0.001 | 0.0 | 0.0 | 0.014 | 0.0 | -0.011 | -0.002 | 0.0 |

HAY

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.203 | -0.061 | -0.020 | -0.122 |
| 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.308 | -0.092 | -0.031 | -0.185 |
| 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.262 | -0.079 | -0.026 | -0.157 |
| 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.340 | -0.102 | -0.034 | -0.204 |
| 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.196 | -0.059 | -0.020 | -0.118 |
| 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.923 | -0.277 | -0.092 | -0.554 |
| 7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.329 | -0.099 | -0.033 | -0.197 |
| 8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.354 | -0.106 | -0.035 | -0.212 |

LOW PROTEIN

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.012 | 0.044 | -0.017 | -0.007 |
| 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.021 | 0.077 | -0.031 | -0.013 |
| 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.057 | 0.213 | -0.085 | -0.036 |
| 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.157 | 0.587 | -0.235 | -0.098 |
| 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.071 | 0.266 | -0.106 | -0.044 |
| 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.599 | 2.245 | -0.898 | -0.374 |
| 7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.069 | 0.260 | -0.104 | -0.043 |
| 8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.027 | 0.101 | -0.040 | -0.017 |

## APPENDIX TABLE A-1. (Continued)

HIGH PROTEIN

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.000 | 0.000 | 0.0 |
| 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.000 | 0.000 | 0.0 |
| 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.008 | 0.016 | 0.0 |
| 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.034 | 0.069 | 0.0 |
| 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.006 | 0.013 | 0.0 |
| 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.640 | 1.280 | 0.0 |
| 7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.223 | 0.446 | 0.0 |
| 8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.009 | 0.018 | 0.0 |

PASTURE

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.000 |
| 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.000 |
| 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.000 |
| 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.000 |
| 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.000 |
| 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.000 |
| 7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.000 |
| 8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.000 |

## APPENDIX TABLE A-2.
## ESTIMATED REGIONAL DEMAND ELASTICITIES, BY COMMODITY

BEEF

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -0.663 | 0.065 | 0.052 | 0.003 | 0.003 | 0.006 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | -0.663 | 0.065 | 0.052 | 0.003 | 0.003 | 0.006 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | -0.663 | 0.065 | 0.052 | 0.003 | 0.003 | 0.006 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | -0.663 | 0.065 | 0.052 | 0.003 | 0.003 | 0.006 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | -0.663 | 0.065 | 0.052 | 0.003 | 0.003 | 0.006 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | -0.663 | 0.065 | 0.052 | 0.003 | 0.003 | 0.006 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | -0.663 | 0.065 | 0.052 | 0.003 | 0.003 | 0.006 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | -0.663 | 0.065 | 0.052 | 0.003 | 0.003 | 0.006 | 0.0 | 0.0 | 0.0 | 0.0 |

PORK

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.116 | -0.458 | 0.042 | 0.003 | 0.003 | 0.005 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.116 | -0.458 | 0.042 | 0.003 | 0.003 | 0.005 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0.116 | -0.458 | 0.042 | 0.003 | 0.003 | 0.005 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 0.116 | -0.458 | 0.042 | 0.003 | 0.003 | 0.005 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 0.116 | -0.458 | 0.042 | 0.003 | 0.003 | 0.005 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 0.116 | -0.458 | 0.042 | 0.003 | 0.003 | 0.005 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | 0.116 | -0.458 | 0.042 | 0.003 | 0.003 | 0.005 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | 0.116 | -0.458 | 0.042 | 0.003 | 0.003 | 0.005 | 0.0 | 0.0 | 0.0 | 0.0 |

**APPENDIX TABLE A-2. (Continued)**

BROILERS

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.200 | 0.092 | -0.737 | 0.003 | 0.003 | 0.081 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.200 | 0.092 | -0.737 | 0.003 | 0.003 | 0.081 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0.200 | 0.092 | -0.737 | 0.003 | 0.003 | 0.081 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 0.200 | 0.092 | -0.737 | 0.003 | 0.003 | 0.081 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 0.200 | 0.092 | -0.737 | 0.003 | 0.003 | 0.081 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 0.200 | 0.092 | -0.737 | 0.003 | 0.003 | 0.081 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | 0.200 | 0.092 | -0.737 | 0.003 | 0.003 | 0.081 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | 0.200 | 0.092 | -0.737 | 0.003 | 0.003 | 0.081 | 0.0 | 0.0 | 0.0 | 0.0 |

MILK

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.010 | 0.004 | 0.002 | -0.309 | 0.002 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.010 | 0.004 | 0.002 | -0.309 | 0.002 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0.010 | 0.004 | 0.002 | -0.309 | 0.002 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 0.010 | 0.004 | 0.002 | -0.309 | 0.002 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 0.010 | 0.004 | 0.002 | -0.309 | 0.002 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 0.010 | 0.004 | 0.002 | -0.309 | 0.002 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | 0.010 | 0.004 | 0.002 | -0.309 | 0.002 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | 0.010 | 0.004 | 0.002 | -0.309 | 0.002 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |

EGGS

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.013 | 0.005 | 0.003 | 0.005 | -0.233 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.013 | 0.005 | 0.003 | 0.005 | -0.233 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0.013 | 0.005 | 0.003 | 0.005 | -0.233 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 0.013 | 0.005 | 0.003 | 0.005 | -0.233 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 0.013 | 0.005 | 0.003 | 0.005 | -0.233 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 0.013 | 0.005 | 0.003 | 0.005 | -0.233 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | 0.013 | 0.005 | 0.003 | 0.005 | -0.233 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | 0.013 | 0.005 | 0.003 | 0.005 | -0.233 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |

TURKEYS

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.084 | 0.039 | 0.317 | 0.003 | 0.003 | -0.924 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.084 | 0.039 | 0.317 | 0.003 | 0.003 | -0.924 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0.084 | 0.039 | 0.317 | 0.003 | 0.003 | -0.924 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 0.084 | 0.039 | 0.317 | 0.003 | 0.003 | -0.924 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 0.084 | 0.039 | 0.317 | 0.003 | 0.003 | -0.924 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 0.084 | 0.039 | 0.317 | 0.003 | 0.003 | -0.924 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | 0.084 | 0.039 | 0.317 | 0.003 | 0.003 | -0.924 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | 0.084 | 0.039 | 0.317 | 0.003 | 0.003 | -0.924 | 0.0 | 0.0 | 0.0 | 0.0 |

## APPENDIX TABLE A-2. (Continued)

### HAY

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.836 | -0.006 | 0.0 | 0.397 | 0.0 | 0.0 | -1.025 | -0.071 | -0.039 | -0.092 |
| 2 | 0.961 | -0.013 | 0.0 | 0.695 | 0.0 | 0.0 | -1.072 | -0.173 | -0.108 | -0.290 |
| 3 | 1.009 | -0.016 | 0.0 | 0.395 | 0.0 | 0.0 | -1.042 | -0.149 | -0.071 | -0.125 |
| 4 | 1.253 | -0.029 | 0.0 | 0.395 | 0.0 | 0.0 | -1.067 | -0.261 | -0.116 | -0.174 |
| 5 | 1.244 | -0.028 | 0.0 | 0.561 | 0.0 | 0.0 | -1.085 | -0.283 | -0.140 | -0.269 |
| 6 | 1.459 | -0.040 | 0.0 | 0.425 | 0.0 | 0.0 | -1.091 | -0.360 | -0.159 | -0.234 |
| 7 | 1.180 | -0.025 | 0.0 | 0.514 | 0.0 | 0.0 | -1.073 | -0.246 | -0.121 | -0.229 |
| 8 | 0.802 | -0.004 | 0.0 | 0.358 | 0.0 | 0.0 | -1.017 | -0.049 | -0.027 | -0.063 |

### LOW PROTEIN

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.799 | 0.185 | 0.043 | 0.003 | 0.057 | 0.019 | -0.011 | -1.051 | -0.021 | -0.022 |
| 2 | 0.925 | 0.177 | 0.042 | 0.005 | 0.057 | 0.020 | -0.023 | -1.109 | -0.045 | -0.048 |
| 3 | 0.957 | 0.186 | 0.043 | 0.003 | 0.058 | 0.019 | -0.027 | -1.131 | -0.052 | -0.055 |
| 4 | 1.197 | 0.181 | 0.042 | 0.003 | 0.056 | 0.019 | -0.051 | -1.248 | -0.097 | -0.103 |
| 5 | 1.182 | 0.171 | 0.043 | 0.004 | 0.059 | 0.020 | -0.050 | -1.234 | -0.094 | -0.101 |
| 6 | 1.384 | 0.266 | 0.042 | 0.003 | 0.060 | 0.021 | -0.071 | -1.415 | -0.147 | -0.143 |
| 7 | 1.115 | 0.197 | 0.048 | 0.004 | 0.065 | 0.021 | -0.044 | -1.229 | -0.088 | -0.088 |
| 8 | 0.772 | 0.186 | 0.052 | 0.003 | 0.067 | 0.019 | -0.008 | -1.052 | -0.022 | -0.016 |

### HIGH PROTEIN

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.018 | 0.089 | 0.697 | 0.012 | 0.156 | 0.037 | -0.001 | -0.004 | -1.002 | -0.003 |
| 2 | 0.021 | 0.089 | 0.702 | 0.022 | 0.159 | 0.039 | -0.002 | -0.014 | -1.007 | -0.009 |
| 3 | 0.021 | 0.093 | 0.691 | 0.012 | 0.159 | 0.038 | -0.001 | -0.007 | -1.003 | -0.003 |
| 4 | 0.026 | 0.097 | 0.695 | 0.012 | 0.155 | 0.038 | -0.002 | -0.014 | -1.004 | -0.004 |
| 5 | 0.026 | 0.091 | 0.701 | 0.017 | 0.159 | 0.038 | -0.002 | -0.018 | -1.007 | -0.007 |
| 6 | 0.025 | 0.142 | 0.698 | 0.013 | 0.166 | 0.043 | -0.002 | -0.062 | -1.017 | -0.006 |
| 7 | 0.023 | 0.101 | 0.774 | 0.016 | 0.178 | 0.041 | -0.002 | -0.099 | -1.026 | -0.006 |
| 8 | 0.017 | 0.090 | 0.859 | 0.011 | 0.186 | 0.037 | -0.000 | -0.159 | -1.041 | -0.002 |

### PASTURE

| REGION | BEEF | PORK | BRLRS | MILK | EGGS | TURKEY | HAY | LOW P | HIGH P | PAST |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.042 | -0.008 | 0.0 | 0.143 | 0.0 | 0.0 | -0.019 | -0.072 | -0.033 | -1.054 |
| 2 | 1.198 | -0.016 | 0.0 | 0.250 | 0.0 | 0.0 | -0.047 | -0.159 | -0.078 | -1.147 |
| 3 | 1.257 | -0.019 | 0.0 | 0.142 | 0.0 | 0.0 | -0.041 | -0.170 | -0.073 | -1.096 |
| 4 | 1.562 | -0.036 | 0.0 | 0.142 | 0.0 | 0.0 | -0.071 | -0.310 | -0.129 | -1.157 |
| 5 | 1.551 | -0.035 | 0.0 | 0.202 | 0.0 | 0.0 | -0.077 | -0.314 | -0.136 | -1.190 |
| 6 | 1.818 | -0.050 | 0.0 | 0.153 | 0.0 | 0.0 | -0.099 | -0.429 | -0.178 | -1.215 |
| 7 | 1.471 | -0.031 | 0.0 | 0.185 | 0.0 | 0.0 | -0.067 | -0.275 | -0.119 | -1.164 |
| 8 | 0.999 | -0.005 | 0.0 | 0.129 | 0.0 | 0.0 | -0.013 | -0.050 | -0.023 | -1.037 |

## APPENDIX TABLE A-3.

The asymptotes in model 3 were fixed by multiplying reported production in each region by these factors for each commodity:

| | |
|---|---|
| Beef | 1.05 |
| Pork | 1.075 |
| Broilers | 1.10 |
| Milk | 1.025 |
| Eggs | 1.075 |
| Turkeys | 1.075 |
| Hay | 1.10 |
| Low Protein Feed | 1.10 |
| High Protein Feed | 1.10 |
| Pasture | 1.15 |

## APPENDIX A-4.

### MODEL 1. LINEAR SUPPLY AND DEMAND EQUATIONS, REPORTED PRODUCTION, ESTIMATED PRODUCTION, IMPORTS AND EXPORTS, AND ESTIMATED TOTAL SUPPLIES AVAILABLE FOR CONSUMPTION, BY COMMODITY AND REGION

BEEF

| REGION | LOCAL PRODUCTION | | TRADE | | CONSUMPTION |
|---|---|---|---|---|---|
| | ACTUAL | ESTIMATED | IMPORTS | EXPORTS | SUPPLIES |
| | (100 MILLION LBS.) | | | | |
| I | 15.8 | 15.9 | 0.0 | 2.6 | 13.3 |
| II | 31.5 | 31.3 | 20.6 | 0.0 | 52.0 |
| III | 42.3 | 41.7 | 0.0 | 37.4 | 4.3 |
| IV | 75.4 | 76.3 | 0.0 | 64.0 | 12.3 |
| V | 73.9 | 74.4 | 0.0 | 45.4 | 29.1 |
| VI | 102.2 | 104.0 | 0.1 | 0.0 | 104.2 |
| VII | 61.7 | 59.0 | 24.2 | 0.0 | 83.3 |
| VIII | 10.5 | 10.5 | 104.5 | 0.0 | 115.0 |
| TOTALS | 413.2 | 413.3 | 149.5 | 149.4 | 413.3 |

PORK

| REGION | LOCAL PRODUCTION | | TRADE | | CONSUMPTION |
|---|---|---|---|---|---|
| | ACTUAL | ESTIMATED | IMPORTS | EXPORTS | SUPPLIES |
| | (100 MILLION LBS.) | | | | |
| I | 1.1 | 1.1 | 5.8 | 0.0 | 6.9 |
| II | 1.0 | 1.0 | 25.8 | 0.0 | 26.8 |
| III | 9.3 | 9.3 | 0.0 | 6.9 | 2.4 |
| IV | 22.2 | 22.2 | 0.0 | 15.8 | 6.4 |
| V | 6.3 | 6.3 | 9.1 | 0.0 | 15.5 |
| VI | 141.3 | 141.6 | 0.0 | 86.4 | 55.1 |
| VII | 31.3 | 31.0 | 12.9 | 0.0 | 43.9 |
| VIII | 3.2 | 3.2 | 55.5 | 0.0 | 58.7 |
| TOTALS | 215.7 | 215.7 | 109.1 | 109.1 | 215.7 |

**APPENDIX TABLE A-4. (Continued)**

BROILERS

| REGION | LOCAL ACTUAL | PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | | (100 MILLION LBS.) | | | |
| I | 1.3 | 1.3 | 2.6 | 0.0 | 3.8 |
| II | 3.7 | 3.7 | 11.0 | 0.0 | 14.7 |
| III | 0.0 | 0.0 | 1.3 | 0.0 | 1.3 |
| IV | 0.1 | 0.0 | 3.4 | 0.0 | 3.5 |
| V | 7.4 | 7.4 | 0.0 | 0.0 | 7.4 |
| VI | 3.2 | 3.2 | 25.3 | 0.0 | 28.5 |
| VII | 81.4 | 80.5 | 0.0 | 57.2 | 23.4 |
| VIII | 17.8 | 17.7 | 13.6 | 0.0 | 31.3 |
| TOTALS | 114.8 | 113.8 | 57.2 | 57.2 | 113.8 |

EGGS

| REGION | LOCAL ACTUAL | PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | | (10 MILLION DOZ.) | | | |
| I | 14.7 | 14.7 | 3.9 | 0.0 | 18.6 |
| II | 75.9 | 75.5 | 0.0 | 3.9 | 71.5 |
| III | 10.1 | 10.1 | 0.0 | 4.1 | 6.1 |
| IV | 15.2 | 15.3 | 0.5 | 0.0 | 15.7 |
| V | 28.5 | 28.5 | 13.8 | 0.0 | 42.3 |
| VI | 135.7 | 138.7 | 0.0 | 0.0 | 138.6 |
| VII | 212.9 | 208.9 | 0.0 | 83.8 | 125.2 |
| VIII | 86.9 | 84.7 | 73.6 | 0.0 | 158.3 |
| TOTALS | 580.0 | 576.3 | 91.8 | 91.8 | 576.3 |

MILK

| REGION | LOCAL ACTUAL | PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | | (10 MILLION CWT.) | | | |
| I | 5.0 | 4.7 | 0.0 | 0.7 | 4.0 |
| II | 12.2 | 13.9 | 0.7 | 0.0 | 14.6 |
| III | 3.0 | 2.8 | 0.0 | 1.5 | 1.3 |
| IV | 4.2 | 4.0 | 0.0 | 0.3 | 3.7 |
| V | 4.9 | 5.0 | 3.4 | 0.0 | 8.4 |
| VI | 51.4 | 50.2 | 0.0 | 19.2 | 31.0 |
| VII | 15.6 | 15.3 | 8.7 | 0.0 | 24.0 |
| VIII | 23.9 | 24.1 | 8.9 | 0.0 | 33.0 |
| TOTALS | 120.3 | 120.1 | 21.7 | 21.7 | 120.1 |

TURKEYS

| REGION | LOCAL ACTUAL | PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | | (10 MILLION LBS.) | | | |
| I | 4.4 | 4.4 | 2.4 | 0.0 | 6.8 |
| II | 42.4 | 42.5 | 0.0 | 13.3 | 29.2 |
| III | 4.4 | 4.4 | 0.0 | 1.9 | 2.5 |
| IV | 9.8 | 9.8 | 0.0 | 2.4 | 7.4 |
| V | 19.1 | 19.1 | 0.0 | 2.2 | 16.9 |
| VI | 98.6 | 99.1 | 0.0 | 38.4 | 60.7 |
| VII | 56.4 | 56.0 | 0.0 | 6.3 | 49.7 |
| VIII | 7.3 | 7.3 | 62.1 | 0.0 | 69.4 |
| TOTALS | 242.4 | 242.7 | 64.5 | 64.5 | 242.7 |

## APPENDIX TABLE A-4. (Continued)

### HAY

| REGION | LOCAL PRODUCTION ACTUAL | ESTIMATED | TRADE IMPORTS | EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (MILLION TONS) | | | | |
| I | 8.5 | 7.5 | 0.0 | 0.5 | 6.9 |
| II | 11.9 | 11.4 | 0.5 | 0.0 | 11.9 |
| III | 18.3 | 16.8 | 0.0 | 12.2 | 4.7 |
| IV | 15.5 | 13.1 | 0.0 | 6.7 | 6.4 |
| V | 7.9 | 7.7 | 0.0 | 1.0 | 6.7 |
| VI | 42.2 | 46.4 | 2.5 | 0.0 | 48.9 |
| VII | 13.1 | 13.5 | 4.2 | 0.0 | 17.8 |
| VIII | 10.9 | 11.0 | 13.1 | 0.0 | 24.0 |
| TOTALS | 128.4 | 127.3 | 20.3 | 20.3 | 127.3 |

### HIGH PROTEIN

| REGION | LOCAL PRODUCTION ACTUAL | ESTIMATED | TRADE IMPORTS | EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (100,000 TONS) | | | | |
| I | 0.0 | 0.0 | 4.4 | 0.0 | 4.4 |
| II | 0.0 | 0.0 | 16.0 | 0.0 | 16.0 |
| III | 3.4 | 3.4 | 0.0 | 0.0 | 3.2 |
| IV | 14.7 | 14.8 | 0.0 | 8.0 | 6.8 |
| V | 2.7 | 2.7 | 21.7 | 0.0 | 24.4 |
| VI | 267.3 | 254.1 | 0.0 | 195.6 | 58.5 |
| VII | 92.8 | 91.9 | 118.2 | 0.0 | 210.1 |
| VIII | 3.9 | 3.9 | 43.6 | 0.0 | 47.5 |
| TOTALS | 384.9 | 370.8 | 203.8 | 203.6 | 370.8 |

### LOW PROTEIN

| REGION | LOCAL PRODUCTION ACTUAL | ESTIMATED | TRADE IMPORTS | EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (MILLION TONS) | | | | |
| I | 1.8 | 1.8 | 4.0 | 0.0 | 5.8 |
| II | 3.0 | 2.9 | 13.5 | 0.0 | 16.4 |
| III | 12.4 | 12.9 | 0.0 | 8.4 | 4.5 |
| IV | 30.1 | 32.2 | 0.0 | 9.1 | 23.2 |
| V | 13.5 | 13.5 | 0.0 | 0.3 | 13.2 |
| VI | 120.1 | 115.1 | 0.0 | 32.4 | 82.7 |
| VII | 13.0 | 13.2 | 16.9 | 0.0 | 30.0 |
| VIII | 4.6 | 4.6 | 15.8 | 0.0 | 20.4 |
| TOTALS | 198.4 | 196.3 | 50.2 | 50.2 | 196.3 |

### PASTURE

| REGION | LOCAL PRODUCTION ACTUAL | ESTIMATED | TRADE IMPORTS | EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (TONS HAY EQUIV.) | | | | |
| I | 12.5 | 12.2 | 0.0 | 0.0 | 12.2 |
| II | 19.0 | 19.0 | 0.0 | 0.0 | 19.0 |
| III | 28.5 | 28.4 | 0.0 | 0.0 | 28.4 |
| IV | 33.6 | 33.3 | 0.0 | 0.0 | 33.3 |
| V | 53.5 | 53.6 | 0.0 | 0.0 | 53.6 |
| VI | 82.8 | 84.2 | 0.0 | 0.0 | 84.2 |
| VII | 60.3 | 58.7 | 0.0 | 0.0 | 58.7 |
| VIII | 15.2 | 15.2 | 0.0 | 0.0 | 15.2 |
| TOTALS | 305.4 | 304.7 | 0.0 | 0.0 | 304.7 |

## APPENDIX A-5.
## MODEL 2. HYPERBOLAS WITH ASYMPTOTES AS FUNCTIONS OF ELASTICITIES, REPORTED PRODUCTION, ESTIMATED PRODUCTION, IMPORTS AND EXPORTS, AND ESTIMATED TOTAL SUPPLIES AVAILABLE FOR CONSUMPTION, BY COMMODITY AND REGION

BEEF

| REGION | LOCAL PRODUCTION ACTUAL | ESTIMATED | TRADE IMPORTS | EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (100 MILLION LBS.) | | | | |
| I | 15.8 | 15.9 | 0.0 | 2.6 | 13.3 |
| II | 31.5 | 31.4 | 20.7 | 0.0 | 52.1 |
| III | 42.3 | 42.0 | 0.0 | 37.6 | 4.3 |
| IV | 75.4 | 77.9 | 0.0 | 65.7 | 12.3 |
| V | 73.9 | 74.2 | 0.0 | 45.1 | 29.1 |
| VI | 102.2 | 103.5 | 0.9 | 0.0 | 104.5 |
| VII | 61.7 | 59.0 | 24.5 | 0.0 | 83.5 |
| VIII | 10.5 | 10.5 | 104.7 | 0.0 | 115.2 |
| TOTALS | 413.2 | 414.4 | 151.0 | 151.0 | 414.4 |

BROILERS

| REGION | LOCAL PRODUCTION ACTUAL | ESTIMATED | TRADE IMPORTS | EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (100 MILLION LBS.) | | | | |
| I | 1.3 | 1.3 | 2.6 | 0.0 | 3.9 |
| II | 3.7 | 3.7 | 11.0 | 0.0 | 14.7 |
| III | 0.0 | 0.0 | 1.3 | 0.0 | 1.3 |
| IV | 0.1 | 0.0 | 3.4 | 0.0 | 3.5 |
| V | 7.4 | 7.4 | 0.0 | 0.0 | 7.5 |
| VI | 3.2 | 3.2 | 25.3 | 0.0 | 28.5 |
| VII | 81.4 | 80.6 | 0.0 | 57.3 | 23.3 |
| VIII | 17.8 | 17.7 | 13.6 | 0.0 | 31.3 |
| TOTALS | 114.8 | 113.8 | 57.2 | 57.3 | 113.9 |

PORK

| REGION | LOCAL PRODUCTION ACTUAL | ESTIMATED | TRADE IMPORTS | EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (100 MILLION LBS.) | | | | |
| I | 1.1 | 1.1 | 5.8 | 0.0 | 6.9 |
| II | 1.0 | 1.0 | 25.8 | 0.0 | 26.8 |
| III | 9.3 | 9.3 | 0.0 | 6.9 | 2.4 |
| IV | 22.2 | 22.2 | 0.0 | 15.8 | 6.4 |
| V | 6.3 | 6.3 | 9.1 | 0.0 | 15.5 |
| VI | 141.3 | 141.5 | 0.0 | 86.4 | 55.1 |
| VII | 31.3 | 31.1 | 12.8 | 0.0 | 43.9 |
| VIII | 3.2 | 3.2 | 55.5 | 0.0 | 58.7 |
| TOTALS | 215.7 | 215.7 | 109.1 | 109.1 | 215.7 |

MILK

| REGION | LOCAL PRODUCTION ACTUAL | ESTIMATED | TRADE IMPORTS | EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (10 MILLION CWT.) | | | | |
| I | 5.0 | 4.7 | 0.0 | 0.6 | 4.1 |
| II | 12.2 | 14.0 | 0.6 | 0.0 | 14.6 |
| III | 3.0 | 2.8 | 0.0 | 1.5 | 1.3 |
| IV | 4.2 | 4.0 | 0.0 | 0.3 | 3.7 |
| V | 4.9 | 5.0 | 3.4 | 0.0 | 8.4 |
| VI | 51.4 | 50.2 | 0.0 | 19.2 | 31.0 |
| VII | 15.6 | 15.4 | 8.6 | 0.0 | 24.0 |
| VIII | 23.9 | 24.1 | 9.0 | 0.0 | 33.0 |
| TOTALS | 120.3 | 120.2 | 21.6 | 21.6 | 120.2 |

**APPENDIX TABLE A-5. (Continued)**

EGGS

| REGION | LOCAL PRODUCTION ACTUAL | LOCAL PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (10 MILLION DOZ.) | | | | |
| I | 14.7 | 14.7 | 3.8 | 0.0 | 18.5 |
| II | 75.9 | 75.6 | 0.0 | 4.2 | 71.4 |
| III | 10.1 | 10.1 | 0.0 | 4.0 | 6.1 |
| IV | 15.2 | 15.3 | 0.8 | 0.0 | 16.0 |
| V | 28.5 | 28.5 | 13.7 | 0.0 | 42.1 |
| VI | 135.7 | 138.4 | 1.0 | 0.0 | 139.4 |
| VII | 212.9 | 209.1 | 0.0 | 84.1 | 125.0 |
| VIII | 86.9 | 84.9 | 73.1 | 0.0 | 157.9 |
| TOTALS | 580.0 | 576.6 | 92.3 | 92.3 | 576.6 |

HAY

| REGION | LOCAL PRODUCTION ACTUAL | LOCAL PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (MILLION TONS) | | | | |
| I | 8.5 | 7.3 | 0.0 | 0.0 | 7.3 |
| II | 11.9 | 11.5 | 0.0 | 0.0 | 11.5 |
| III | 18.3 | 16.8 | 0.0 | 12.1 | 4.7 |
| IV | 15.5 | 11.6 | 0.0 | 3.9 | 7.8 |
| V | 7.9 | 7.7 | 0.0 | 1.1 | 6.6 |
| VI | 42.2 | 47.0 | 0.8 | 0.0 | 47.8 |
| VII | 13.1 | 13.6 | 3.8 | 0.0 | 17.4 |
| VIII | 10.9 | 11.0 | 12.4 | 0.0 | 23.5 |
| TOTALS | 128.4 | 126.7 | 17.1 | 17.1 | 126.7 |

TURKEYS

| REGION | LOCAL PRODUCTION ACTUAL | LOCAL PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (10 MILLION LBS.) | | | | |
| I | 4.4 | 4.4 | 2.5 | 0.0 | 6.8 |
| II | 42.4 | 42.5 | 0.0 | 13.4 | 29.1 |
| III | 4.4 | 4.4 | 0.0 | 1.9 | 2.5 |
| IV | 9.8 | 9.8 | 0.0 | 2.4 | 7.5 |
| V | 19.1 | 19.1 | 0.0 | 2.2 | 16.9 |
| VI | 98.6 | 99.1 | 0.0 | 38.4 | 60.7 |
| VII | 56.4 | 56.1 | 0.0 | 6.3 | 49.7 |
| VIII | 7.3 | 7.3 | 62.2 | 0.0 | 69.5 |
| TOTALS | 242.4 | 242.7 | 64.7 | 64.7 | 242.7 |

LOW PROTEIN

| REGION | LOCAL PRODUCTION ACTUAL | LOCAL PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (MILLION TONS) | | | | |
| I | 1.8 | 1.8 | 4.1 | 0.0 | 5.9 |
| II | 3.0 | 2.9 | 13.7 | 0.0 | 16.6 |
| III | 12.4 | 12.8 | 0.0 | 8.2 | 4.6 |
| IV | 30.1 | 33.3 | 0.0 | 9.6 | 23.7 |
| V | 13.5 | 13.5 | 0.0 | 0.4 | 13.1 |
| VI | 120.1 | 114.4 | 0.0 | 32.4 | 82.0 |
| VII | 13.0 | 13.1 | 17.1 | 0.0 | 30.2 |
| VIII | 4.6 | 4.6 | 15.8 | 0.0 | 20.4 |
| TOTALS | 198.4 | 196.5 | 50.6 | 50.6 | 196.5 |

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### APPENDIX TABLE A-5. (Continued)

HIGH PROTEIN

| REGION | LOCAL PRODUCTION ACTUAL | ESTIMATED | TRADE IMPORTS | EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (100,000 TONS) | | | | |
| I | 0.0 | 0.0 | 4.4 | 0.0 | 4.4 |
| II | 0.0 | 0.0 | 16.3 | 0.0 | 16.3 |
| III | 3.4 | 3.4 | 0.0 | 0.0 | 3.1 |
| IV | 14.7 | 14.8 | 0.0 | 8.1 | 6.7 |
| V | 2.7 | 2.7 | 21.5 | 0.0 | 24.2 |
| VI | 267.3 | 254.0 | 0.0 | 195.8 | 58.2 |
| VII | 92.8 | 92.1 | 118.0 | 0.0 | 210.1 |
| VIII | 3.9 | 3.9 | 43.9 | 0.0 | 47.8 |
| TOTALS | 384.9 | 370.9 | 204.2 | 203.9 | 370.9 |

PASTURE

| REGION | LOCAL PRODUCTION ACTUAL | ESTIMATED | TRADE IMPORTS | EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (TONS HAY EQUIV.) | | | | |
| I | 12.5 | 12.2 | 0.0 | 0.0 | 12.2 |
| II | 19.0 | 19.0 | 0.0 | 0.0 | 19.0 |
| III | 28.5 | 28.3 | 0.0 | 0.0 | 28.3 |
| IV | 33.6 | 33.5 | 0.0 | 0.0 | 33.5 |
| V | 53.5 | 53.4 | 0.0 | 0.0 | 53.4 |
| VI | 82.8 | 83.8 | 0.0 | 0.0 | 83.8 |
| VII | 60.3 | 58.6 | 0.0 | 0.0 | 58.6 |
| VIII | 15.2 | 15.2 | 0.0 | 0.0 | 15.2 |
| TOTALS | 305.4 | 304.1 | 0.0 | 0.0 | 304.1 |

### APPENDIX TABLE A-6.
### MODEL 3. HYPERBOLAS WITH CONSTRAINED ASYMPTOTES, REPORTED PRODUCTION, ESTIMATED PRODUCTION, IMPORTS AND EXPORTS, AND ESTIMATED TOTAL SUPPLIES AVAILABLE FOR CONSUMPTION, BY COMMODITY AND REGION

BEEF

| REGION | LOCAL PRODUCTION ACTUAL | ESTIMATED | TRADE IMPORTS | EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (100 MILLION LBS.) | | | | |
| I | 15.8 | 15.9 | 0.0 | 2.6 | 13.3 |
| II | 31.5 | 31.4 | 20.6 | 0.0 | 52.0 |
| III | 42.3 | 42.3 | 0.0 | 38.0 | 4.3 |
| IV | 75.4 | 75.8 | 0.0 | 63.6 | 12.2 |
| V | 73.9 | 74.3 | 0.0 | 45.3 | 29.0 |
| VI | 102.2 | 104.6 | 0.0 | 0.0 | 104.6 |
| VII | 61.7 | 59.0 | 24.3 | 0.0 | 83.3 |
| VIII | 10.5 | 10.3 | 104.6 | 0.0 | 114.9 |
| TOTALS | 413.2 | 413.7 | 149.5 | 149.5 | 413.6 |

PORK

| REGION | LOCAL PRODUCTION ACTUAL | ESTIMATED | TRADE IMPORTS | EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (100 MILLION LBS.) | | | | |
| I | 1.1 | 1.1 | 5.9 | 0.0 | 6.9 |
| II | 1.0 | 1.0 | 25.8 | 0.0 | 26.8 |
| III | 9.3 | 9.3 | 0.0 | 6.9 | 2.4 |
| IV | 22.2 | 22.2 | 0.0 | 15.8 | 6.4 |
| V | 6.3 | 6.3 | 9.1 | 0.0 | 15.5 |
| VI | 141.3 | 141.7 | 0.0 | 86.6 | 55.1 |
| VII | 31.3 | 31.1 | 12.9 | 0.0 | 43.9 |
| VIII | 3.2 | 3.2 | 55.6 | 0.0 | 58.8 |
| TOTALS | 215.7 | 215.9 | 109.3 | 109.3 | 215.9 |

**APPENDIX TABLE A-6. (Continued)**

BROILERS

| REGION | LOCAL PRODUCTION ACTUAL | LOCAL PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (100 MILLION LBS.) | | | | |
| I | 1.3 | 1.3 | 2.6 | 0.0 | 3.9 |
| II | 3.7 | 3.7 | 11.1 | 0.0 | 14.8 |
| III | 0.0 | 0.0 | 1.3 | 0.0 | 1.3 |
| IV | 0.1 | 0.0 | 3.4 | 0.0 | 3.5 |
| V | 7.4 | 7.5 | 0.0 | 0.0 | 7.5 |
| VI | 3.2 | 3.2 | 25.4 | 0.0 | 28.6 |
| VII | 81.4 | 81.1 | 0.0 | 57.6 | 23.5 |
| VIII | 17.8 | 17.7 | 13.7 | 0.0 | 31.4 |
| TOTALS | 114.8 | 114.4 | 57.6 | 57.6 | 114.5 |

EGGS

| REGION | LOCAL PRODUCTION ACTUAL | LOCAL PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (10 MILLION DOZ.) | | | | |
| I | 14.7 | 14.7 | 3.8 | 0.0 | 18.5 |
| II | 75.9 | 75.2 | 0.0 | 3.8 | 71.4 |
| III | 10.1 | 10.3 | 0.0 | 4.2 | 6.1 |
| IV | 15.2 | 15.6 | 0.5 | 0.0 | 16.1 |
| V | 28.5 | 28.4 | 13.8 | 0.0 | 42.2 |
| VI | 135.7 | 141.4 | 0.0 | 1.3 | 140.1 |
| VII | 212.9 | 209.3 | 0.0 | 83.9 | 125.4 |
| VIII | 86.9 | 83.4 | 75.0 | 0.0 | 158.4 |
| TOTALS | 580.0 | 578.2 | 93.2 | 93.2 | 578.2 |

MILK

| REGION | LOCAL PRODUCTION ACTUAL | LOCAL PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (10 MILLION CWT.) | | | | |
| I | 5.0 | 4.7 | 0.0 | 0.6 | 4.1 |
| II | 12.2 | 14.1 | 0.6 | 0.0 | 14.7 |
| III | 3.0 | 2.9 | 0.0 | 1.6 | 1.3 |
| IV | 4.2 | 4.0 | 0.0 | 0.3 | 3.7 |
| V | 4.9 | 5.0 | 3.4 | 0.0 | 8.4 |
| VI | 51.4 | 50.5 | 0.0 | 19.4 | 31.1 |
| VII | 15.6 | 15.3 | 8.7 | 0.0 | 24.1 |
| VIII | 23.9 | 24.1 | 9.0 | 0.0 | 33.1 |
| TOTALS | 120.3 | 120.6 | 21.8 | 21.8 | 120.6 |

TURKEYS

| REGION | LOCAL PRODUCTION ACTUAL | LOCAL PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (10 MILLION LBS.) | | | | |
| I | 4.4 | 4.4 | 2.4 | 0.0 | 6.8 |
| II | 42.4 | 42.4 | 0.0 | 13.3 | 29.1 |
| III | 4.4 | 4.5 | 0.0 | 2.0 | 2.5 |
| IV | 9.8 | 9.8 | 0.0 | 2.3 | 7.5 |
| V | 19.1 | 19.2 | 0.0 | 2.3 | 16.9 |
| VI | 98.6 | 99.3 | 0.0 | 38.6 | 60.7 |
| VII | 56.4 | 56.2 | 0.0 | 6.4 | 49.8 |
| VIII | 7.3 | 7.2 | 62.4 | 0.0 | 69.6 |
| TOTALS | 242.4 | 242.9 | 64.8 | 64.8 | 242.9 |

APPENDIX TABLE A-6. (Continued)

HAY

| REGION | LOCAL ACTUAL | PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (MILLION TONS) | | | | |
| I | 8.5 | 7.3 | 0.0 | 0.0 | 7.3 |
| II | 11.9 | 11.5 | 0.0 | 0.0 | 11.5 |
| III | 18.3 | 17.0 | 0.0 | 12.0 | 5.0 |
| IV | 15.5 | 12.8 | 0.0 | 4.6 | 8.2 |
| V | 7.9 | 7.6 | 0.0 | 0.7 | 6.9 |
| VI | 42.2 | 48.4 | 0.5 | 0.0 | 48.9 |
| VII | 13.1 | 14.0 | 4.0 | 0.0 | 18.0 |
| VIII | 10.9 | 11.1 | 12.8 | 0.0 | 23.9 |
| TOTALS | 128.4 | 129.6 | 17.3 | 17.3 | 129.6 |

HIGH PROTEIN

| REGION | LOCAL ACTUAL | PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (100,000 TONS) | | | | |
| I | 0.0 | 0.0 | 4.5 | 0.0 | 4.5 |
| II | 0.0 | 0.0 | 16.7 | 0.0 | 16.7 |
| III | 3.4 | 3.4 | 0.0 | 0.0 | 3.2 |
| IV | 14.7 | 14.8 | 0.0 | 7.9 | 6.8 |
| V | 2.7 | 2.7 | 22.1 | 0.0 | 24.8 |
| VI | 267.3 | 265.9 | 0.0 | 206.3 | 59.6 |
| VII | 92.8 | 89.0 | 126.1 | 0.0 | 215.1 |
| VIII | 3.9 | 3.9 | 45.1 | 0.0 | 49.0 |
| TOTALS | 384.9 | 379.6 | 214.4 | 214.3 | 379.6 |

LOW PROTEIN

| REGION | LOCAL ACTUAL | PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (MILLION TONS) | | | | |
| I | 1.8 | 1.8 | 4.0 | 0.0 | 5.9 |
| II | 3.0 | 2.9 | 13.7 | 0.0 | 16.6 |
| III | 12.4 | 12.8 | 0.0 | 8.2 | 4.6 |
| IV | 30.1 | 33.2 | 0.0 | 9.5 | 23.7 |
| V | 13.5 | 13.5 | 0.0 | 0.0 | 13.4 |
| VI | 120.1 | 116.8 | 0.0 | 33.4 | 83.4 |
| VII | 13.0 | 13.5 | 17.4 | 0.0 | 30.9 |
| VIII | 4.6 | 4.6 | 16.1 | 0.0 | 20.7 |
| TOTALS | 198.4 | 199.1 | 51.2 | 51.1 | 199.1 |

PASTURE

| REGION | LOCAL ACTUAL | PRODUCTION ESTIMATED | TRADE IMPORTS | TRADE EXPORTS | CONSUMPTION SUPPLIES |
|---|---|---|---|---|---|
| | (TONS HAY EQUIV.) | | | | |
| I | 12.5 | 12.4 | 0.0 | 0.0 | 12.4 |
| II | 19.0 | 19.0 | 0.0 | 0.0 | 19.0 |
| III | 28.5 | 28.5 | 0.0 | 0.0 | 28.5 |
| IV | 33.6 | 33.6 | 0.0 | 0.0 | 33.6 |
| V | 53.5 | 53.6 | 0.0 | 0.0 | 53.6 |
| VI | 82.8 | 83.1 | 0.0 | 0.0 | 83.1 |
| VII | 60.3 | 60.0 | 0.0 | 0.0 | 60.0 |
| VIII | 15.2 | 15.2 | 0.0 | 0.0 | 15.2 |
| TOTALS | 305.4 | 305.4 | 0.0 | 0.0 | 305.4 |

## APPENDIX TABLE A-7.
## TRADING PARTNERS, BY MODEL AND COMMODITY

### BEEF

| FROM REGION | TO REGION | MODEL1 | MODEL2 | MODEL3 |
|---|---|---|---|---|
| | | (100 MILLION LBS.) | | |
| 1 | 2 | 2.624 | 2.623 | 2.634 |
| 3 | 2 | 18.005 | 18.124 | 17.973 |
| 3 | 8 | 19.426 | 19.505 | 20.006 |
| 4 | 6 | 0.129 | 0.931 | 0.0 |
| 4 | 8 | 63.894 | 64.730 | 63.608 |
| 5 | 7 | 24.234 | 24.550 | 24.293 |
| 5 | 8 | 21.138 | 20.502 | 21.011 |
| TOTALS | | 149.449 | 150.966 | 149.525 |

### BROILERS

| FROM REGION | TO REGION | MODEL1 | MODEL2 | MODEL3 |
|---|---|---|---|---|
| | | (100 MILLION LBS.) | | |
| 7 | 1 | 2.579 | 2.586 | 2.614 |
| 7 | 2 | 11.013 | 11.036 | 11.133 |
| 7 | 3 | 1.325 | 1.331 | 1.337 |
| 7 | 4 | 3.392 | 3.391 | 3.411 |
| 7 | 5 | 0.007 | 0.082 | 0.040 |
| 7 | 6 | 25.260 | 25.274 | 25.357 |
| 7 | 8 | 13.605 | 13.559 | 13.746 |
| TOTALS | | 57.181 | 57.259 | 57.637 |

### EGGS

| FROM REGION | TO REGION | MODEL1 | MODEL2 | MODEL3 |
|---|---|---|---|---|
| | | (10 MILLION DOZ.) | | |
| 2 | 1 | 3.917 | 3.847 | 3.838 |
| 2 | 5 | 0.0 | 0.355 | 0.0 |
| 3 | 4 | 0.462 | 0.762 | 0.483 |
| 3 | 5 | 3.619 | 2.250 | 3.678 |
| 3 | 6 | 0.0 | 0.999 | 0.0 |
| 6 | 8 | 0.053 | 0.0 | 1.294 |
| 7 | 5 | 10.172 | 11.054 | 10.158 |
| 7 | 8 | 73.580 | 73.066 | 73.707 |
| TOTALS | | 91.803 | 92.333 | 93.157 |

### PORK

| FROM REGION | TO REGION | MODEL1 | MODEL2 | MODEL3 |
|---|---|---|---|---|
| | | (100 MILLION LBS.) | | |
| 3 | 1 | 5.842 | 5.841 | 5.853 |
| 3 | 2 | 1.042 | 1.052 | 1.047 |
| 4 | 2 | 15.807 | 15.834 | 15.821 |
| 6 | 2 | 8.917 | 8.889 | 8.944 |
| 6 | 5 | 9.123 | 9.111 | 9.133 |
| 6 | 7 | 12.851 | 12.834 | 12.871 |
| 6 | 8 | 55.546 | 55.549 | 55.619 |
| TOTALS | | 109.127 | 109.110 | 109.288 |

### MILK

| FROM REGION | TO REGION | MODEL1 | MODEL2 | MODEL3 |
|---|---|---|---|---|
| | | (10 MILLION CWT.) | | |
| 1 | 2 | 0.679 | 0.628 | 0.579 |
| 3 | 5 | 1.507 | 1.483 | 1.556 |
| 4 | 5 | 0.302 | 0.297 | 0.274 |
| 6 | 5 | 1.601 | 1.626 | 1.591 |
| 6 | 7 | 8.666 | 8.638 | 8.740 |
| 6 | 8 | 8.934 | 8.957 | 9.026 |
| TOTALS | | 21.690 | 21.629 | 21.767 |

### TURKEYS

| FROM REGION | TO REGION | MODEL1 | MODEL2 | MODEL3 |
|---|---|---|---|---|
| | | (10 MILLION LBS.) | | |
| 2 | 1 | 2.416 | 2.465 | 2.433 |
| 2 | 8 | 10.853 | 10.924 | 10.863 |
| 3 | 8 | 1.943 | 1.950 | 1.961 |
| 4 | 8 | 2.380 | 2.364 | 2.312 |
| 5 | 8 | 2.192 | 2.209 | 2.278 |
| 6 | 8 | 38.421 | 38.443 | 38.556 |
| 7 | 8 | 6.297 | 6.337 | 6.405 |
| TOTALS | | 64.502 | 64.692 | 64.810 |

APPENDIX TABLE A-7. (Continued)

HAY

| FROM REGION | TO REGION | MODEL 1 | MODEL 2 | MODEL 3 |
|---|---|---|---|---|
| | | (MILLION TONS) | | |
| 1 | 2 | 0.547 | 0.0 | 0.0 |
| 3 | 8 | 12.166 | 12.147 | 12.026 |
| 4 | 6 | 2.516 | 0.821 | 0.492 |
| 4 | 7 | 3.262 | 2.737 | 3.280 |
| 4 | 8 | 0.886 | 0.302 | 0.817 |
| 5 | 7 | 0.969 | 1.058 | 0.712 |
| TOTALS | | 20.345 | 17.065 | 17.327 |

LOW PROTEIN

| FROM REGION | TO REGION | MODEL 1 | MODEL 2 | MODEL 3 |
|---|---|---|---|---|
| | | (MILLION TONS) | | |
| 3 | 1 | 4.028 | 4.093 | 4.029 |
| 3 | 2 | 4.420 | 4.135 | 4.185 |
| 4 | 2 | 9.078 | 9.566 | 9.483 |
| 5 | 7 | 0.321 | 0.405 | 0.074 |
| 6 | 7 | 16.547 | 16.649 | 17.312 |
| 6 | 8 | 15.843 | 15.780 | 16.109 |
| TOTALS | | 50.237 | 50.627 | 51.193 |

HIGH PROTEIN

| FROM REGION | TO REGION | MODEL 1 | MODEL 2 | MODEL 3 |
|---|---|---|---|---|
| | | (100,000 TONS) | | |
| 3 | 1 | 0.190 | 0.225 | 0.157 |
| 4 | 2 | 8.022 | 8.103 | 7.924 |
| 6 | 1 | 4.161 | 4.181 | 4.353 |
| 6 | 2 | 7.946 | 8.169 | 8.728 |
| 6 | 5 | 21.712 | 21.536 | 22.052 |
| 6 | 7 | 118.200 | 118.050 | 126.140 |
| 6 | 8 | 43.600 | 43.902 | 45.073 |
| TOTALS | | 203.831 | 204.166 | 214.428 |

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**College of Tropical Agriculture and Human Resources**
**University of Hawaii**
**Noel P. Kefford, Dean of the College and Director of the Institute**

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