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A COMPARISON OF POSITIVE AND NORMATIVE SPATIAL EQUILIBRIUM MODELS OF THE U.S. BEEF INDUSTRY*

J. G. Youde and G. S. Bhagia
Oregon State University

Considerable research has been conducted during the past 20 years on interregional competition and flows in the U.S. beef industry. Most of this analysis has been "normative" in nature. Recently, models with more "positive" implications have been developed and used to analyze this important sector of U.S. agriculture. This paper defines the differences between these two types of models, compares some research results derived from each type, and presents a positive model of the U.S. fed beef industry.

Normative Models

As used in this paper, "normative" refers to those interregional models with an optimizing objective function at their core. A linear programming framework (or one of its variations) is usually employed for this type of analysis, focussing on the maximization of net returns (profits) or the minimization of costs for the entire system analyzed. These models usually assume perfectly competitive product and factor markets [6]. They address themselves to questions about "what ought to be", rather than "what is" [3]. Synonyms for normative as used here are "optimizing" and "prescriptive".

Most of the spatial equilibrium models developed to analyze the U.S. beef industry (and all other agricultural industries) have been normative in nature. Two of the better-known studies using this approach are now described.

Schrader and King [5] studied the regional location of cattle feeding, employing a 20-region linear programming model. Regional supplies of factors (feeder cattle, concentrates, and roughage) are predetermined, with production functions utilized to convert these inputs to carcass beef. The demand for beef, transfer functions, and slaughter costs and location are other activities or constraints in this model. The number of cattle fed in a region is determined simultaneously with the equilibrium flow of factors and products among regions to maximize total returns for cattle feeding.

While this analysis provides a substantial amount of useful information about the cattle feeding industry, it does not accurately predict or describe cattle feeding levels in each region. Large discrepancies exist between actual and estimated regional numbers of cattle fed in 1957-58. Wallace calculated a coefficient of determination of 0.07 between actual and predicted numbers of cattle fed in this study [6. p.16].

Judge, Havlicek, and Rizek [4] conducted a joint spatial analysis of live slaughter cattle and hogs and beef and pork flows for 1955 and 1960. Their model determines regional levels of slaughter and directions and levels of interregional livestock and meat flows necessary to satisfy regional production, consumption, and capacity constraints, while minimizing total costs of live animal and meat transportation. The simultaneous consideration of live slaughter animals and meat is notable, but this study's optimum slaughter and shipment levels do not correspond any closer to actual conditions than the Schrader-King study.

Crom [2] used the Judge-Havlicek-Rizek model to simulate spatial flows of livestock and meat stemming from possible alternative shifts in market organization projected to 1975. This study is significant in that it projects equilibrium solutions ahead in time. However, it must still be considered normative, since it is based on an aggregate cost-minimizing model.

Positive Models

A major limitation of these normative models is that production, consumption, and interregional trade decisions are not normally made for the system as a whole. Rather, they are a composite of actions taken by producers, consumers, and marketers, operating as autonomous (but not necessarily independent) decision-makers. Thus, "positive" models are more concerned with "what is", i.e., they enable us to understand and quantify existing relationships in an economic system. One of the primary tasks of positive models is to provide a system of generalizations that can be used to make correct predictions about the consequences of any change in circumstances [3, p.4]. The accuracy of a positive model is usually judged on the basis of its ability to explain and predict the values of specified dependent variables in the economic system under study.

Simulation, a relatively new research technique, lends itself to modeling the relevant variables and relationships that characterize a real system. Non-linearities, recursive effects, discontinuities, irreversibilities, and time lags can be built into these models. They make it possible to computerize a complex set of relationships and then "operate" on the model by making changes in selected parameters. The specification of an optimizing function is not necessary (nor is it precluded) in a simulation model. Thus, one of the major limitations of the normative models discussed above is avoided.

Given these advantages, it seems surprising that simulation has not been utilized to a greater extent in constructing spatial equilibrium models, even though the technique has been used in several aggregate national studies of the livestock (and other) industries.[1/] The analysis described below actually employs two simulation models. Regional models are constructed to explain and project cattle feeding levels and related variables in each region. Then an interregional trade model links the regions together in predicting movements of live cattle and carcass beef.

The Regional Models

The United States was partitioned into nine regions on the basis of homogeneity of cattle production and placing analytical emphasis on the Western states. The basic economic structure of the cattle feeding industry was hypothesized in terms of functional relationships. The ordinary least squares method of multiple regression analysis was used to estimate the coefficients of the functional relationships. These relationships and three identities were arranged into cause-effect sequence and were incorporated to form a simulation model of the fed beef economy.[2/] The main purpose of the model was to explain and project <u>regional</u> levels of cattle feeding, supplies of feeder cattle, cow inventories, and prices of feeder cattle, fed cattle, and wholesale fed beef as these variables interact in the model.

The validity of the regional models was evaluated at two stages. First, the statistical significance of the individual equations comprising the model and individual variables in the equations was checked. Most t-values of individual variables were significant at the 0.05 level. The R^2-value indicated the extent to which explanatory variables explained the variation in the dependent variable. The R^2-values for most equations were above 0.80.

The second test of validity was the extent of divergence of simulated values from their historical counterparts. The average deviations between the estimated values from the simulation model and historical values of the endogeneous variables were between 1 and 6 percent. The average deviations in the number of cattle fed, the supply of feeder cattle, and cow inventories were about 6, 3, and 1 percent, respectively. The simulated prices in feeder cattle, fed cattle, and wholesale fed beef markets deviated from their historical values by 4, 3, and 1 percent, respectively. These averages were taken over all the regions. Thus, the model portrayed a reasonably accurate picture of the fed beef economy for the 1962-68 period.

One of the important characteristics of the simulation model developed above is that if the values of the exogeneous variables are known for any given period -- past, present, or future -- the values of endogenous variables can be simulated by the model for the comparable period. The model was used to project the values of all endogeneous variables to 1975. The effect of an increase in feed grain prices was also traced through the model.

The Interregional Model

The estimated consumption of fed beef was compared to its production in each region to find deficit-producing and surplus-producing regions. The surplus-producing regions were expected to ship fed beef to deficit-producing regions on the basis of price advantages. Therefore, the differences in wholesale fed beef prices and fed cattle prices between each pair of regions were calculated. The estimated cost of transportation between each pair of regions was subtracted from the corresponding price differential in order to find the net price advantage. The two maximums of these price advantages were selected, one in the wholesale fed beef sector and the other in the live fed cattle sector. Beef in carcass form was shipped if the net price advantage of shipping carcass fed beef was greater than that of shipping fed beef in live form. Live cattle were shipped if the price advantage of shipping live cattle was greater than that of shipping carcass fed beef.

The magnitude of shipment was calculated by multiplying the amount of price advantage by an arbitrary number. The arbitrary number was so selected that it would be large enough to get convergence to a solution in a reasonable number of iterations on the computer, and small enough so that small surplus-producing regions would ship fed beef.

The amount of adjustments needed depends upon the slopes of the demand curves in trading regions. The more elastic the demand curves, the greater the quantity of fed beef which must be shipped to reach equilibrium interregional price levels. With each shipment of fed beef from a surplus-producing to a deficit-producing region, the prices move closer to their equilibrium levels in both regions. In the final equilibrium, the price in the importing region equals price in the exporting region plus the cost of transportation between the two regions. When every pair of trading regions is in equilibrium, the entire system also is in equilibrium.3/

To reach equilibrium prices and quantities under 1968 conditions, 5.9 billion pounds of fed beef were shipped among regions, with virtually all shipments in carcass form. The regional and interregional models were projected to 1975; under the conditions estimated for that year, 9.7 billion pounds entered interregional trade, with 88 percent of this total accounted for by carcass shipments to the Eastern United States from the Great Plains and Midwest regions.

Concluding Remarks

The two models described above utilize simulation techniques to analyze regional and interregional fed beef production, consumption, and trade. They are more "positive" than traditional interregional competition models in that they are not based on the optimization of objective functions. As such, they make a significant step toward "the development of spatial equilibrium models . . . capable of either being accepted or refuted by empirical evidence", a direction advocated by Wallace in 1963 [6, p.17].

FOOTNOTES

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1/ Although Crom [2] called his models simulations, the fact that the projections were based upon a linear programming analysis places his results in the normative category.

2/ For details on model development and results, refer to [1].

3/ For a detailed flow chart and explanation of the interregional model, see [1, p.81 ff.].

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