1982

U.S. agricultural policy and the demand for imported beef

William John Martin
Iowa State University

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Martin, William John

U.S. AGRICULTURAL POLICY AND THE DEMAND FOR IMPORTED BEEF

Iowa State University

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U.S. agricultural policy and the demand for imported beef

by

William John Martin

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of the Requirements for the Degree of DOCTOR OF PHILOSOPHY

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For the Major Department

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For the Graduate College

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Ames, Iowa

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CHAPTER I. INTRODUCTION

The U.S. livestock-feed grain subsector is a massive system, both in relation to U.S. and world agriculture. This subsector is strongly influenced by a number of policy measures which affect the supplies and prices of meats and feed grains. The size of the subsector, its structural complexities and the extent of government policy involvement in it make continuing research into the behavior of this system an important priority.

In their excellent survey of systems analysis and simulation, Johnson and Hausser [1977, p. 158] pointed out that research in an applied discipline such as agricultural economics is "usually designed to bring available information to bear on particular types of problems which arise in public and private sectors." The informational problems of policymakers are extreme in the case of this subsector since it contains complex interactions on both the supply and the demand side. Lagged responses and inventories in the system also contribute to complex intertemporal responses. Policy measures designed for one part of the subsector may have substantial and unintended effects upon other, closely interrelated, parts [see e.g., Breimyer and Rhodes, 1975].

The primary purpose of this study is to develop a model to examine the impacts of major policy measures upon the U.S. livestock-feed subsector and upon the demand for imported beef. Although the major emphasis of the study is on the livestock subsector, the feed subsector has been included because of the strong interdependence of these two
systems. Particular attention has been given to providing a framework for the analysis of the Meat Import Act of 1979 [Conable, 1980].

In addition to its primary objective of developing a model for policy analysis, this study had some secondary objectives of a more technical nature. Several such issues were investigated in this study, including (1) the effects of using fed/nonfed versus table/processing quality categorizations of total beef supply, (2) the effects of government inventory changes upon total corn inventory, and (3) the use of the symmetry restrictions from economic theory in estimating retail meat demand equations. Finally, it was hoped that the model developed for the analysis might have some practical, predictive value as a forecasting model.

A great deal of research has been undertaken on various aspects of the livestock-feed subsector. Some of this work has been undertaken as part of studies dealing with the entire agricultural sector [e.g., Ray and Heady, 1974]. Other studies have focused only upon the livestock subsector [e.g., Freebairn and Rausser, 1975] or the feed grains subsector [e.g., Subotnik and Houck, 1979]. This study concentrates primarily on the livestock subsector but, like the Arzac and Wilkinson study [1979a] also includes a small feed grain market model. In this way, it was hoped that the most important interactions could be captured without broadening the scope of the model to the point where it became unmanageable.

Johnson and Rausser [1977] have emphasized that study of the underlying system of interest should precede consideration of model
construction. They suggested a three-stage process for investigation of the system: (1) systems analysis, (2) systems synthesis, and (3) systems design. Using this approach, the structure of the sub-subsector was first analyzed as a basis for decisions about model scope and the necessary structure of the component subsystems. In the systems synthesis stage, attention focused on the interrelations between the components of the subsector and the modeling issues which these interrelations raised. The systems design phase included consideration of the maintained hypotheses to be incorporated in the model and its broad structure. This last step clearly overlapped and led into the first stage of model construction, the specification of the initial form of the model.

The model construction stage included the five well-known steps of (1) specification, (2) parameter estimation, (3) verification of these estimates, (4) model validation, and (5) model revision. After a final version of the model had been obtained, its properties were investigated using simulation and by calculation of the eigenvalues which characterize its dynamic properties. Finally, multipliers were calculated for the effects of policy variables and some other key exogenous variables on the endogenous variables of the system.

The organization of this study reflects the research procedure suggested by Johnson and Rausser. In Chapter II, the approximate boundaries of the system to be analyzed have been delineated and the system then broken down into components for subsequent analysis. This
chapter provides a description of the physical and economic components of the system, as well as the major policy measures influencing the subsector.

Previous studies of the subsector have raised a number of modeling issues relevant to the specification of a model for the system under study. A review of some of these modeling issues is contained in Chapter III.

Since 1965, the Meat Import Acts have provided for a quota limiting the quantity of meat imported into the United States. These quotas have been a binding constraint in some years but not in others, and the limited-dependent nature of these quotas raises some serious problems for estimation in this market. The nature of this problem and some approaches to dealing with it are discussed in Chapter IV.

The overall system to be modeled and the interaction between its components are discussed in Chapter V. Following an explanation of the estimation procedure used, the specification and estimation of the individual equations of the model has been discussed in some detail.

In Chapter VI, the focus of concern is upon the characteristics and performance of the model as a whole. The equations of the final model and brief definitions of the variables have been presented in Tables 6.1 and 6.2, respectively. The approaches used to validate the model and the dynamic properties of the model have then been discussed in the remainder of this chapter.

Dynamic multipliers for the model are presented in Chapter VII, both for the effects of exogenous variables on the U.S. livestock-
feed subsector, and on beef import demand. In Chapter VIII, we have dealt with the effects of two alternative approaches to disaggregating total beef consumption: the production approach of disaggregating into fed and nonfed beef and the end-use approach of disaggregating into table and processing beef.

Chapter IX contains a summary and the main conclusions of the study. Complete definitions and sources of all variables used in the model are given in Appendix A. The procedures used to derive the model data set are also detailed in this appendix. A description of the method used to calculate the eigenvalues of the model is presented in Appendix B.
CHAPTER II. THE STRUCTURE OF THE U.S.

LIVESTOCK-FEED SUBSECTOR

A first stage in the construction of a subsector model is the careful delineation of the system to be investigated. Delineation of the system under investigation involves a trade-off between the marginal gains of system expansion and the marginal costs of this activity. Given the objectives of a modeling exercise, some gains can almost always be made by increasing the size of the system to include more endogenous interactions. On the other hand, such expansion of the system usually involves considerable cost in acquiring the necessary institutional and structural knowledge and in developing the model.

In order to ascertain the appropriate scope of the system for this study, the livestock-feed grain subsector was first considered in relation to U.S. agriculture as a whole. After the approximate boundaries of the system had been delineated, the basic structure of the system was considered as a basis for model construction. This chapter deals with these two parts of the process of systems analysis.

The Livestock-Feed Subsector in Relation to the U.S. Agricultural Sector

To provide some indication of the relative importance of individual commodities within U.S. agriculture, estimates of total cash receipts from some major crop and livestock commodities are presented in Table 2.1. From the table, it appears that crops and livestock, in aggregate, each contributed a similar amount to total farm receipts.
Table 2.1. Cash receipts from major crop and livestock commodities, 1978-1980

<table>
<thead>
<tr>
<th></th>
<th>1978</th>
<th>1979</th>
<th>1980</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>($'000 million)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle and calves</td>
<td>28.2</td>
<td>34.4</td>
<td>31.2</td>
</tr>
<tr>
<td>Dairy products</td>
<td>12.7</td>
<td>14.6</td>
<td>16.6</td>
</tr>
<tr>
<td>Hogs</td>
<td>8.7</td>
<td>9.0</td>
<td>8.9</td>
</tr>
<tr>
<td>Broilers</td>
<td>3.7</td>
<td>4.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Eggs</td>
<td>2.9</td>
<td>3.3</td>
<td>3.2</td>
</tr>
<tr>
<td>Turkeys</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Total livestock products</td>
<td>59.2</td>
<td>68.5</td>
<td>67.4</td>
</tr>
<tr>
<td>Corn</td>
<td>8.2</td>
<td>10.3</td>
<td>12.8</td>
</tr>
<tr>
<td>Soybeans</td>
<td>11.8</td>
<td>13.0</td>
<td>13.4</td>
</tr>
<tr>
<td>Wheat</td>
<td>4.7</td>
<td>7.8</td>
<td>9.0</td>
</tr>
<tr>
<td>Cotton</td>
<td>3.4</td>
<td>4.2</td>
<td>4.5</td>
</tr>
<tr>
<td>Sorghum</td>
<td>0.9</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Barley</td>
<td>0.6</td>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Oats</td>
<td>0.3</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Total crops</td>
<td>53.7</td>
<td>63.4</td>
<td>69.0</td>
</tr>
<tr>
<td>All commodities</td>
<td>112.9</td>
<td>131.9</td>
<td>136.4</td>
</tr>
</tbody>
</table>

*Source: [USDA, 1981a, p. 18].

The sale of cattle and calves for meat was by far the largest single component of returns with dairy products, hogs, broilers, corn, soybeans, and wheat being other major components of the total. These figures understate the relative importance of the feed grains which are intermediate products within the agricultural sector. A great deal of the total value of livestock products is clearly value added within the livestock subsector by grain feeding. The estimated total value of corn produced in 1979 was $18,600 million [USDA, 1980a, p. 30] or around one and three-quarter times the direct cash receipts from this source.
Similarly, the total value of production for sorghum, at $1,900 million [USDA, 1980a, p. 50] was roughly one and three-quarter times the corresponding total cash receipts item in Table 2.1.

Despite their deficiencies, the figures presented in Table 2.1 are useful in identifying the major components of the system. Even after allowing for the contribution of feed grains to output value from cattle and calves, the meat production included in this item is probably the most important component of the subsector in terms of value added. Beef cattle compete with hogs and broilers for feed, and the meat from all of these animals is linked through interdependence in consumer demand. Clearly, at the very least, the beef, pork, and broiler industries should be included in the system to be studied. The turkey industry also has strong links with these industries but the total value of turkey production is relatively small and so its exclusion might be justifiable in the interests of keeping the size of the model manageable.

Dairy production also competes with the remainder of the livestock subsector for feed grains, and particularly with beef production for livestock and grazing land. However, there does not appear to be a great deal of interdependence between meats and dairy products in consumer demand [Brandow, 1961, p. 17]. In addition, dairy production is heavily influenced by an array of federal policy measures specific to the dairy industry [Manchester, 1978, p. 2]. While the dairy industry influences beef production, it appears that in the presence of the
dairy program, conditions in the beef industry have only a secondary effect on the dairy industry. In addition, Bain [1977] reported difficulty in attempts to model the dairy industry. For these reasons, and to keep the problem manageable, the dairy industry was excluded from the system under study.

Egg production is another important source of output value and obviously a major competitor for feed grains. However, it was excluded from the system because of its rather complex structure [Chavas, 1978] and its very limited interaction with retail meat demand [Brandow, 1961, p. 17].

On the crops side, corn is clearly by far the most important of the feed grains, accounting for around 80 percent of total feed grain value in recent years. Even in 1965, when production of oats was nearly twice its 1979 level [USDA, 1980a, p. 38], and sorghum was relatively more important than in 1979, corn production made up some 75 percent of the value of total feed grain production [USDA, 1980a].

It was felt that oats and barley could be excluded from the model because of their relatively small value of output. Grain sorghum has had a considerably greater value of output than either oats or barley and has been roughly as important as oats and barley combined as a source of livestock feed [USDA, 1980a, p. 56]. However, Houck and Ryan [1972, p. 190] found that substitution of land between corn and sorghum has been relatively limited since 1961. Arzac and Wilkinson [1979a, p. 302] used the very high observed correlation between corn, sorghum,
and barley prices to justify the exclusion of the other feed grains from their model. Given the high correlation observed between feed grain yields [Morton, 1982], as well as between the prices, it was felt that concentration on corn production alone could be justified even though inclusion of sorghum supply would undoubtedly be desirable.

From Table 2.1, it appears that soybeans have had the largest cash receipts of any individual crop. In addition, Houck and Ryan [1972] suggested that the loan rate for soybeans may have had a substantial effect on corn plantings. While inclusion of the soybean market would seem desirable, this would involve modeling of a subsystem in which a volatile export market and the industrial demand for oil are important components. Given the objectives of this study, it was felt that it would not be possible to devote sufficient resources to the estimation of such a model.

The wheat industry is another major agricultural industry which needs to be considered. While some wheat is fed to livestock, the quantity fed amounted to less than 4 percent of the quantity of corn fed during the period 1975-1979 [USDA, 1980a, p. 56]. Because wheat also does not compete strongly with corn for land, it was felt that wheat could be excluded from the system with very little loss of information about the variables of interest.

The system to be analyzed has now been reduced to the beef industry, the pork industry, the broiler industry, and the corn industry. In the remainder of this chapter we will consider the structure of the components of this system.
Analysis of the Structure of the System Under Investigation

The major components of the system under investigation are:
(1) beef production, (2) hog production, (3) broiler production,
(4) meat processing, retailing, and foreign trade, (5) feed grain production, (6) feed grain marketing and trade distribution, and
(7) government policy instruments. The characteristics of each of these components of the system will be briefly reviewed in the remainder of this section. The structure of the system is obviously important for any modeling effort. Since econometric modeling based on time series data was thought most likely to be appropriate for this study, some attention was also given to the likely extent of structural change over the past twenty years.

Beef production

Beef production in the United States can usefully be divided into two specialized stages: (1) feeder calf production and (2) cattle feeding.

Feeder calf production

Cow-calf herds are maintained primarily to produce feeder steers and heifers which can then be finished for slaughter. Cow-calf herds are usually most economically maintained on pasture or relatively low-quality feeds such as crop residues. While steers and heifers can be prepared for slaughter under these conditions, the rate of weight gain is lower and the meat generally does not receive as high a per unit price [Rhodes and Davis, 1976]. Since the 1950s, the vast majority of slaughter steers and heifers has been fed
on concentrates prior to slaughter, although high feed prices and low profitability in cattle feeding during the 1974-1976 period led to an increase in the production of beef from nonfed steers and heifers.

Beef cow herds are maintained in all 50 U.S. states, but the majority of the cow herd is located in the Western Rangelands, the Corn Belt, and the Southeastern States [USITC, 1977a, p. 16]. The Western Range States accounted for 45 percent of the total cow herd in 1977. In these states, cow herds are generally relatively large with a 300 cow herd being viewed as reasonably typical. The proportion of the cow herd in the Southeastern States increased from about one-fifth to one-fourth of the total between the early 1960s and 1977 [USITC, 1977a, p. 18]. This increase has been attributed at least partially to improvements in pasture varieties. The proportion of the cow herd maintained in the Corn Belt was 28 percent in 1977, slightly less than in the early 1960s. Cow herds are generally relatively small in both the Corn Belt and the Southeast, with herds of 50 cows being regarded as typical. In the Corn Belt, cow herds are frequently maintained as one part of a diversified farm enterprise. The total enterprise also frequently includes crops such as corn and soybeans, and intensive livestock activities such as cattle feeding or hog raising.

The dairy cow herd declined dramatically during the 1960s, falling by 34 percent between 1960 and 1970 [USDA, 1973, p. 5]. The decline in this industry continued in the 1970s, but at a much slower rate, falling by 8.7 percent between 1971 and 1981 [USDA, 1981b, p. 19]. By 1981, dairy cows made up 21.8 percent of the total cow herd, compared
to 42.6 percent in 1960. This decline in the size of the dairy herd made available some additional pasture resources for the beef industry. On the other hand, it reduced the supply of dairy-type calves available for feeding. It probably also contributed to a marked reduction in the proportion of calves slaughtered instead of being grown to maturity. Calf slaughter declined from 33 percent of total adult cattle slaughter in 1960 to only 7.7 percent in 1980 [USDA, 1973, p. 95; USDA, 1981b, p. 63].

Overall, however, rapid structural change does not appear to have been a dominant feature of calf production in the past 20 years. The overall calving ratio, a key structural parameter, has not risen greatly above its 1965 level of 90 percent, and actually fell a little below this level during the 1975-1979 period [USDA, 1981b, p. 19].

**Cattle feeding** Like feeder calf production, cattle feeding is widely distributed geographically. In 1980, there were 113,326 feedlots in the 23 major cattle feeding states. Ninety-eight percent (111,178) of these were relatively small feedlots with a capacity of under 1,000 head and most of these feedlots were located in the Corn Belt and adjacent states [USDA, 1982i, p. 12]. However, the 2 percent of feedlots with a capacity of more than 1,000 head accounted for 72 percent of total cattle marketings. Most of these larger feedlots were located in the western and southwestern states.

A tendency towards larger feedlots and an increase in the relative importance of feedlots outside the Corn Belt have caused considerable
structural change in cattle feeding during the past two decades [Nicol
and Heady, 1971; USITC, 1977a]. One key structural parameter does not
appear to have changed significantly, feed consumption per pound of meat
produced does not appear to have declined and may, in fact, have in-
creased slightly [USDA, 1980a, p. 57].

The rations fed to cattle on feed usually include feed grains
(especially corn), a protein supplement and some roughage in the form
of hay or silage. The most important cost components in cattle feeding
are the cost of the feeder steer and the feed grain component of the
ration. Based on prices for July of 1981 to January of 1982, the cost
of the feeder steer was estimated to be 53 percent of the total cost of
feeding a 600 pound steer to 1,100 pounds in the Corn Belt [USDA, 1982e,
p. 18]. Feed grains contributed an additional 20 percent, while the
protein supplement (e.g., soybean meal) made up only 5 percent of total
costs. These cost proportions seem to have been fairly stable through
time and suggest that the key price variables in modeling cattle feeding
are likely to be feeder steer and feed grain prices.

The U.S. is a net importer of feeder cattle with almost all of
these imports obtained from Canada and Mexico [USITC, 1977b, p. A-26].
The number of cattle imported has fluctuated considerably from year to
year, but has always been small in relation to the domestic supply of
feeders. In 1978, when imports of feeder calves were at their highest
level since 1972, they made up only 3 percent of total placements on
feed [USDA, 1981b, pp. 152 and 44].
The timing of placements of cattle on feed varies, depending upon relative prices, seasonal conditions, and pasture availability. Industry specialists suggest that most cattle are placed on feed between 7 and 18 months of age and that the average length of time spent on feed is in the 120-180 day range. The length on feed is generally inversely related to the age at placement. Variations in this age, the length of feeding, and the number of cattle fed, allow producers to adjust the quantity of grain fed and the output of beef in response to market signals.

Inspection of the quarterly data for placements on feed reveals a marked peak in placements during the fourth quarter of the calendar year. Larsen [1972] suggests that this peak is due to placements on feed in October-November when grazing of crop residues has been completed and pasture quality has undergone a seasonal deterioration. The seasonal peak appears to be particularly marked in the Corn Belt where Larsen notes that feeding generally takes 7-9 months instead of the 4-5 months which is common in other areas. Many of the animals placed on feed in this fall peak are likely to be younger, smaller calves born in the calving peak of the previous spring. Despite the peak in placements, Larsen notes that marketings of fed cattle are relatively evenly distributed throughout the year.

Steer and heifer calves can be viewed as capital goods which can be sold at any time, or alternatively, retained for further investment through additional feeding [Jarvis, 1974]. Heifer calves may, in addition, be retained for the breeding herd. These alternative
sources of demand, interacting with the total supply of potential feeder calves, determine the closely related prices of feeder steers and heifers. A marked change in the inventory of breeding cows is a well-known feature of the cattle cycle and it appears that a large proportion of this change is achieved by changing the level of calf retention [Breimyer, 1955, p. 8]. However, the importance of this source of demand for calves should possibly not be exaggerated. From Table 2.2, it appears that the change in the beef cow inventory did not rise above 4.5 percent nor fall below -5.7 percent of the previous year's calf crop during the period from 1965 to 1982.

Hog production

The structural features of hog production have been discussed in detail in a recent report by Van Arsdall [1978] and only a few key aspects will be summarized here.

Hogs are produced on a large number of farms: A total of 581,060 operations had hogs during 1981 [USDA, 1981d, p. 20]. Hog production is strongly concentrated in the North Central Region of the United States, with 67 percent of the 1981 hog inventory being located in eight states in this region: Illinois, Indiana, Iowa, Minnesota, Nebraska, Ohio, South Dakota, and Wisconsin [USDA, 1981d, p. 8].

Farms producing hogs were usually diversified into at least one other activity. Two-thirds or more of farms producing hogs in 1975 had other livestock or poultry activities and 90 percent of these farms with other livestock had beef cows or cattle feeding activities.
### Table 2.2. The change in beef cow numbers in relation to the total calf crop of the previous year

<table>
<thead>
<tr>
<th>Year</th>
<th>Beef cow inventory(^a) January 1</th>
<th>Change in beef cow numbers during year</th>
<th>Calf crop previous year(^a)</th>
<th>Beef cow inventory change as a percentage of calf crop (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>33,400</td>
<td>100</td>
<td>43,809</td>
<td>0.2</td>
</tr>
<tr>
<td>1966</td>
<td>33,500</td>
<td>270</td>
<td>43,922</td>
<td>0.6</td>
</tr>
<tr>
<td>1967</td>
<td>33,770</td>
<td>800</td>
<td>43,537</td>
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</tr>
<tr>
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<td>34,570</td>
<td>920</td>
<td>43,803</td>
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</tr>
<tr>
<td>1969</td>
<td>35,490</td>
<td>1,199</td>
<td>44,315</td>
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<td>1970</td>
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<td>1,189</td>
<td>45,177</td>
<td>2.6</td>
</tr>
<tr>
<td>1971</td>
<td>37,878</td>
<td>932</td>
<td>45,871</td>
<td>2.0</td>
</tr>
<tr>
<td>1972</td>
<td>38,810</td>
<td>2,122</td>
<td>46,738</td>
<td>4.5</td>
</tr>
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<td>1973</td>
<td>40,932</td>
<td>2,250</td>
<td>47,682</td>
<td>4.7</td>
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<td>1974</td>
<td>43,182</td>
<td>2,530</td>
<td>49,194</td>
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</tr>
<tr>
<td>1975</td>
<td>45,712</td>
<td>-1,811</td>
<td>50,873</td>
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</tr>
<tr>
<td>1976</td>
<td>43,901</td>
<td>-2,458</td>
<td>50,183</td>
<td>-4.9</td>
</tr>
<tr>
<td>1977</td>
<td>41,443</td>
<td>-2,705</td>
<td>47,384</td>
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</tr>
<tr>
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<td>38,738</td>
<td>-1,676</td>
<td>45,931</td>
<td>-3.6</td>
</tr>
<tr>
<td>1979</td>
<td>37,062</td>
<td>24</td>
<td>43,818</td>
<td>0.1</td>
</tr>
<tr>
<td>1980</td>
<td>37,086</td>
<td>1,901</td>
<td>42,603</td>
<td>4.5</td>
</tr>
<tr>
<td>1981</td>
<td>38,987(^b)</td>
<td>390</td>
<td>45,354</td>
<td>0.9</td>
</tr>
<tr>
<td>1982</td>
<td>39,377(^b)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

\(^a\)Source: [USDA, 1981b, pp. 4 and 19; USDA, 1973, pp. 5 and 18].

\(^b\)Source: [USDA, 1982e, p. 6].

Pig production can be divided into two activities: (1) feeder pig production and (2) feeder pig finishing. Some enterprises specialize in only one activity, while others integrate the two in "farrow-to-finish" operations. Van Arsdall [1978, p. VI] reports that feeder pigs were sold by approximately one-fourth of all farms selling hogs in 1974. He estimates that feeder pigs were usually marketed between 8 and 9 weeks after farrowing. Feeder pig finishing takes approximately 19 weeks while integrated farrow-to-finish raising takes around 6 months.
Based on USDA budgets, the two largest expenses in hog feeding appear to be the cost of the feeder pig and of the feed grain used for feeding [USDA, 1982e]. During July to November of 1981, these two expenses would have accounted for 29.1 percent and 30.8 percent, respectively, of the total feeding cost. Protein supplement costs were considerably more important than in cattle feeding but still made up only 18.1 percent of total costs.

Hog producers appear to have made substantial investments in improved facilities. The USDA [1980a, p. 443] reports a dramatic reduction in the hours of labor required per hundred pounds liveweight of output in this industry -- from 1.4 in 1965-1969 to 0.5 in 1975-1979. However, no long-term improvement in the feed conversion ratio appears to have occurred between 1965 and 1978 [USDA, 1980a, p. 57]. The number of pigs per litter, a key technological parameter, also does not appear to have improved greatly over the past 15 years.

**Broiler production**

Broilers are young chickens of heavy breeds raised specifically for their meat [Shepherd and Futrell, 1969, p. 408]. This product has very different marketing characteristics from the meat of mature chickens which are a by-product of egg laying flocks -- both commercial egg producers and breeding hens.

Time lags in the broiler industry are shorter than in other livestock industries, but still of some importance. Rausser and Cargill [1970] note that there is a lag of 26 days between shipment of eggs to
the hatchery and the placement of the resulting chicks in the flock. From placement, it takes an additional eight weeks to produce a typical 3.8 pound liveweight broiler [Chavas, 1978, p. 65]. At any time, the supply of hatching eggs available is larger than is likely to be needed. If demand for baby chicks increases, it can usually be accommodated by hatching some of the smaller eggs which would otherwise have been sold to breakers [K. Blase, USDA, Washington, D.C., personal communication].

The minimum time span between a decision to increase or decrease output and the output of finished broilers should, thus, be approximately the three months needed to convert eggs to finished broilers.

Chavas [1978, p. 65] notes that a typical broiler ration includes corn and soybean meal in a ratio of 70 to 30. This compares with an 80/20 ratio in hog feeding [USDA, 1982e, p. 25]. At the prices prevailing during July-November 1981, the corn and soybean components of the broiler ration would be approximately equal in cost.

Vertical coordination procedures are used very extensively in broiler production. In 1977, 99 percent of broiler output was produced either under a contract or in vertically integrated firms [Rogers, et. al., 1977, p. 39]. Rausser and Cargill [1970, p. 120] suggest that price stabilization through vertical coordination may have destabilized quantities to some extent. They also concluded that there was little evidence of sustained price and quantity cycles in the industry.

Rapid technological change has been a key feature of this industry. The USDA estimates that the quantity of feed required per 100 pounds
of broilers fell by 23 percent between 1965 and 1979 — from 302 pounds to 231 pounds [USDA,1980a, p. 57]. The index of farm production per hour of labor rose rapidly, from 87 to 265, during the same period [USDA,1980a, p. 442]. Chavas [1978, p. 60] attributes these gains to a combination of improvements in poultry breeding, nutrition, disease control, and management.

**Meat processing, retailing and foreign trade**

Beef and pork generally move through similar marketing channels involving firms with very little involvement in the production stage. Broilers, by contrast, are almost all processed by firms which are vertically integrated into the production stage. Except at the retail level, there is little overlap of firms in meat and poultry marketing. It will be worthwhile to discuss the marketing of beef and pork together, with some reference to poultry marketing.

The process of transforming the live animal into retail products involves a number of specific activities and, usually, at least two distinct groups of firms. Packing firms generally handle the purchase and slaughter of the live animal, and the transportation and wholesaling of the carcass. The packing industry is also increasingly involved in fabrication\(^1\) activities. Retail firms purchase carcasses or boneless cuts for transformation into retail portions and final sale.

In contrast to the broiler industry, there is relatively little integration of beef packing or retailing with beef production. McCoy

\(^1\)Fabrication refers to the transformation of carcasses into wholesale or retail cuts of meat to be sold in boxed-beef form.
[1979, p. 190] presents a table showing that the percentage of total fed cattle marketings originating from packer controlled feedlots varied between 6 and 8 percent for the period 1960 to 1976. Over the same period, cattle feeding by retailers was insignificant. Only 20 thousand head were fed in retailer-owned feedlots during 1976, as against a total of 25,168 thousand head of fed cattle marketed [McCoy, 1979, pp. 188 and 190].

Many older plants were designed to slaughter a number of different types of livestock, e.g., cattle, calves, hogs, and sheep. The trend in the construction of more modern plants has been to specialize in only one species. Poultry are generally slaughtered in entirely separate establishments at which wage rates have been much lower than in meat packing. In 1980, hourly earnings in meat packing plants, at $8.49, were almost double those in poultry dressing plants, at $4.47 [Bureau of Labor Statistics, 1981, pp. 160 and 162].

Wages, salaries, and benefits have ranged between 51 and 55 percent of meat packers operating expenses during the 1960-1979 period [American Meat Institute, 1980a, p. 12]. Other major operating expenses included supplies and containers, and depreciation, but these items were individually very much smaller.

In addition to meat products, packers produce by-products such as tallow, offal, and hides. The farm by-product allowance has accounted for about 10 percent of gross farm value since 1970 [USDA, 1981b] and has been found to have a significant impact on cattle prices [Blake and Clevenger,
1980]. By contrast, the value of by-products is virtually insignificant in poultry packing.

Meat is traded at the wholesale level, both by independent wholesalers and through direct sales between packers and retailers, especially the larger chains. Formula pricing is used for about 70 percent of beef carcass sales and 10-20 percent of boxed beef sales with the remainder of the sales conducted by negotiation [Hayenga and Schrader, 1980, p. 753]. These approaches reduce transactions costs but may have presented some problems for price discovery.

Retail sales of meat can be divided into: (1) sales through retail outlets and (2) sales through hotel, restaurant, and institutional outlets (HRI). Sales through HRI outlets, and particularly through fast-food outlets, have been increasing and McCoy [1979, p. 223] estimates that they now account for approximately 40 percent of final meat sales. While no price for the meat component alone is observable in HRI sales, its opportunity cost is clearly the retail meat price and, under competition, this should equal its share of per unit output value.

Supermarket chains controlled 46.9 percent of total grocery sales in 1977 [McCoy, 1979, p. 233] and frequently control a higher percentage in particular market areas. These chains face extensive competition from affiliated supermarkets (48.6 percent) and convenience stores (4.5 percent) and it seems unlikely that retailers are able to greatly affect the average price of meat through the exercise of market power.
While McCoy [1979, p. 426] refers to a long-term decline in the farmers' share of retail meat prices, this rate of decline has been very slow in recent years. For meat products as a group, the farm value of retail cost stayed in the 52 to 57 percent range between 1968 and 1979 [USDA, 1980a, p. 446], suggesting that the rate of technological advance was not greatly different between the farm and marketing stages. For poultry and eggs, the farm share ranged from 51 to 63 percent and may have increased slightly during the period -- suggesting even more rapid productivity growth in poultry marketing than in production. McCoy [1979, p. 418] also notes a tendency for the farm-retail margin to be more stable than farm prices.

Some stocks of meats are held during the year. These stocks are small in relation to total quarterly production and consumption and are probably held primarily for convenience or "pipeline" purposes. Beef stocks are likely to be of processing quality beef since the quality of table beef deteriorates in storage. USDA data obtained for this study, and defined in Appendix A, were used to investigate the size of stocks in relation to consumption during the period 1962-1979. End of quarter beef stocks averaged 12.6 percent of quarterly processing beef consumption, with a standard deviation just over 20 percent of that for consumption. Pork end of quarter inventories averaged 260.3 million pounds or 7.6 percent of average per quarter consumption of pork, with a standard deviation which was 19 percent of that for consumption. Young chicken stocks were only 1.7 percent of average production, with a standard deviation 2.3 percent of that for consumption.
While beef and pork inventory behavior may have a slight impact on quarterly prices, it seems likely that broiler inventory behavior has an insignificant impact on quarterly prices.

Foreign trade in meats is small in relation to total U.S. production and consumption. The United States is the world's largest producer of beef, pork, and poultry, and also the largest importer of beef and veal [USDA, 1982h, pp. 18, 19, 23, and 25]. The U.S. has been a net importer of pork in recent years, but net pork imports have been less than 2 percent of total U.S. production [USDA, 1982h, pp. 19, 26]. U.S. exports of young chicken have increased from around 2 percent of production in the early 1970s to over 6 percent of production in 1982 [USDA, 1982h, pp. 22 and 29]. Chicken exports were the cause of a fascinating dispute between the United States and the EEC in the early 1960s [Talbot, 1978] but have generally been unimportant for the purpose of analyzing the behavior of the subsector. Only beef imports and exports will be considered further in this study.

From Table 2.3, it is evident that beef imports have been relatively small in relation to U.S. beef production during the 1960-1980 period. Imports ranged from a low of 5 percent of commercial production in 1965 to a high of 11.3 percent in 1979. However, beef is not a homogeneous commodity, and it is generally believed that beef imports are more comparable with low quality manufacturing or processing beef than with the higher grade beef obtained from fed steer and heifer carcasses [American Meat Institute, 1980b, p. 1]. Imports made up a
Table 2.3. Beef imports and exports in relation to U.S. total commercial beef production and processing quality beef supply, 1961-1980

<table>
<thead>
<tr>
<th>Year</th>
<th>Beef imports&lt;sup&gt;a&lt;/sup&gt; carcass weight (million pounds)</th>
<th>Beef exports&lt;sup&gt;b&lt;/sup&gt; carcass weight</th>
<th>Commercial beef&lt;sup&gt;b&lt;/sup&gt; production carcass weight</th>
<th>Processing beef supply&lt;sup&gt;c&lt;/sup&gt; carcass weight</th>
<th>Imports as a percentage of commercial beef production carcass weight</th>
<th>Imports as a percentage of processing beef supply carcass weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961</td>
<td>1,021</td>
<td>56</td>
<td>14,930</td>
<td>6,441</td>
<td>6.8</td>
<td>15.8</td>
</tr>
<tr>
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<td>51</td>
<td>14,931</td>
<td>7,121</td>
<td>9.5</td>
<td>19.8</td>
</tr>
<tr>
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<td>1,651</td>
<td>52</td>
<td>16,049</td>
<td>7,433</td>
<td>10.3</td>
<td>22.2</td>
</tr>
<tr>
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<td>1,068</td>
<td>91</td>
<td>18,037</td>
<td>7,873</td>
<td>5.9</td>
<td>13.6</td>
</tr>
<tr>
<td>1965</td>
<td>923</td>
<td>91</td>
<td>18,325</td>
<td>8,446</td>
<td>5.0</td>
<td>10.9</td>
</tr>
<tr>
<td>1966</td>
<td>1,182</td>
<td>83</td>
<td>19,493</td>
<td>8,748</td>
<td>6.1</td>
<td>13.5</td>
</tr>
<tr>
<td>1967</td>
<td>1,313</td>
<td>88</td>
<td>19,991</td>
<td>8,822</td>
<td>6.6</td>
<td>14.9</td>
</tr>
<tr>
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<td>1,500</td>
<td>88</td>
<td>20,662</td>
<td>9,173</td>
<td>7.3</td>
<td>16.4</td>
</tr>
<tr>
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<td>20,960</td>
<td>9,410</td>
<td>7.7</td>
<td>17.2</td>
</tr>
<tr>
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<td>1,792</td>
<td>101</td>
<td>21,472</td>
<td>9,500</td>
<td>8.3</td>
<td>18.9</td>
</tr>
<tr>
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<td>1,734</td>
<td>117</td>
<td>21,697</td>
<td>9,579</td>
<td>8.0</td>
<td>18.1</td>
</tr>
<tr>
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<td>1,960</td>
<td>113</td>
<td>22,218</td>
<td>9,862</td>
<td>8.8</td>
<td>19.9</td>
</tr>
<tr>
<td>1973</td>
<td>1,990</td>
<td>144</td>
<td>21,088</td>
<td>9,661</td>
<td>9.4</td>
<td>20.6</td>
</tr>
<tr>
<td>1974</td>
<td>1,615</td>
<td>115</td>
<td>22,844</td>
<td>10,233</td>
<td>7.1</td>
<td>15.8</td>
</tr>
<tr>
<td>1975</td>
<td>1,758</td>
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</tr>
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<td>12,423</td>
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</tr>
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<td>24,010</td>
<td>11,403</td>
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<td>20.1</td>
</tr>
<tr>
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<td>215</td>
<td>21,261</td>
<td>10,112</td>
<td>11.3</td>
<td>23.8</td>
</tr>
<tr>
<td>1980</td>
<td>2,064</td>
<td>220</td>
<td>21,464</td>
<td>9,975</td>
<td>9.6</td>
<td>20.7</td>
</tr>
</tbody>
</table>

<sup>a</sup>Sources: The variable BM as defined in Appendix A.

<sup>b</sup>[USDA, 1982e and earlier issues].

<sup>c</sup>XPF as defined in Appendix A.
far more significant proportion of the estimated total supply of processing beef in Table 2.3, with the percentage ranging from 10.9 to 23.8 during the period covered.

Beef exports were only approximately one-third of 1 percent of production in 1961 but have increased to around 1 percent in 1980 [USDA, 1981b]. The export figures cited include shipments to U.S. territories and Crom [1970, p. 14] suggests that a high proportion of this beef is likely to be of high-quality beef. In the absence of trade barriers, it is quite possible that the United States could become a substantial exporter of high quality beef, while still importing low quality beef [Simpson, 1981].

A large number of countries supply beef to the U.S. market (Table 2.4). However, most of these are only very minor suppliers and the two largest suppliers, Australia and New Zealand, have generally supplied between 50 and 70 percent of total imports. The presence of hoof and mouth disease in Argentina greatly reduces trade in beef between the United States and Argentina. Because of quarantine restrictions, only cooked meat can be exported from Argentina to the North American market [Bureau of Agricultural Economics, 1979a, p. 25]. Canada is a substantial net importer and so is unlikely to become a major source of U.S. beef imports. Both Mexico and Ireland have decreased in importance as suppliers of beef imports in recent years because of increasing domestic demand and policy changes. All of the major import suppliers have market oriented economies but the level of imports is affected by
Table 2.4. Percentage of U.S. beef and veal imports supplied by six supplying countries, 1961-1980\(^a\)

<table>
<thead>
<tr>
<th>Year</th>
<th>Australia</th>
<th>New Zealand</th>
<th>Ireland</th>
<th>Canada</th>
<th>Argentina</th>
<th>Mexico</th>
<th>Percentage of total imports supplied by these countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961</td>
<td>33.9</td>
<td>22.4</td>
<td>9.4</td>
<td>4.7</td>
<td>9.5</td>
<td>7.8</td>
<td>87.7</td>
</tr>
<tr>
<td>1962</td>
<td>45.6</td>
<td>22.1</td>
<td>7.3</td>
<td>2.0</td>
<td>5.8</td>
<td>6.1</td>
<td>88.9</td>
</tr>
<tr>
<td>1963</td>
<td>46.2</td>
<td>21.1</td>
<td>6.5</td>
<td>1.5</td>
<td>7.8</td>
<td>6.5</td>
<td>89.6</td>
</tr>
<tr>
<td>1964</td>
<td>47.1</td>
<td>21.0</td>
<td>2.5</td>
<td>3.6</td>
<td>6.8</td>
<td>6.1</td>
<td>87.1</td>
</tr>
<tr>
<td>1965</td>
<td>43.9</td>
<td>14.8</td>
<td>1.0</td>
<td>10.2</td>
<td>7.8</td>
<td>6.6</td>
<td>84.3</td>
</tr>
<tr>
<td>1966</td>
<td>45.2</td>
<td>16.2</td>
<td>4.3</td>
<td>6.4</td>
<td>9.0</td>
<td>6.4</td>
<td>87.5</td>
</tr>
<tr>
<td>1967</td>
<td>43.5</td>
<td>17.5</td>
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</tr>
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<td>18.0</td>
<td>5.0</td>
<td>4.1</td>
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<td>5.8</td>
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<td>10.7</td>
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<td>84.0</td>
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<td>39.7</td>
<td>17.9</td>
<td>5.1</td>
<td>6.0</td>
<td>10.5</td>
<td>5.8</td>
<td>85.0</td>
</tr>
<tr>
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<td>38.6</td>
<td>18.4</td>
<td>4.9</td>
<td>6.1</td>
<td>6.7</td>
<td>6.0</td>
<td>80.7</td>
</tr>
<tr>
<td>1972</td>
<td>45.6</td>
<td>18.0</td>
<td>2.1</td>
<td>4.0</td>
<td>6.4</td>
<td>5.5</td>
<td>81.6</td>
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<tr>
<td>1973</td>
<td>46.6</td>
<td>19.5</td>
<td>1.5</td>
<td>3.8</td>
<td>5.4</td>
<td>4.5</td>
<td>81.3</td>
</tr>
<tr>
<td>1974</td>
<td>42.2</td>
<td>21.3</td>
<td>3.6</td>
<td>3.0</td>
<td>7.3</td>
<td>3.2</td>
<td>80.6</td>
</tr>
<tr>
<td>1975</td>
<td>51.8</td>
<td>21.0</td>
<td>0.5</td>
<td>1.6</td>
<td>4.3</td>
<td>2.3</td>
<td>81.5</td>
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<tr>
<td>1976</td>
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<td>0.3</td>
<td>5.7</td>
<td>6.4</td>
<td>3.5</td>
<td>79.7</td>
</tr>
<tr>
<td>1977</td>
<td>46.3</td>
<td>19.5</td>
<td>-</td>
<td>5.5</td>
<td>5.7</td>
<td>4.3</td>
<td>81.3</td>
</tr>
<tr>
<td>1978</td>
<td>49.0</td>
<td>20.5</td>
<td>-</td>
<td>4.6</td>
<td>6.4</td>
<td>3.8</td>
<td>84.3</td>
</tr>
<tr>
<td>1979</td>
<td>50.4</td>
<td>20.5</td>
<td>-</td>
<td>4.5</td>
<td>6.5</td>
<td>0.3</td>
<td>82.2</td>
</tr>
<tr>
<td>1980</td>
<td>51.7</td>
<td>21.3</td>
<td>-</td>
<td>6.1</td>
<td>4.8</td>
<td>-</td>
<td>83.9</td>
</tr>
</tbody>
</table>

\(^a\)Source: [USDA, 1973, p. 294; USDA, 1981b, p. 154].
import restraints in the United States and, potentially, by the policies of the countries which supply U.S. beef imports.

**Feed grain production**

The major U.S. feed grains are corn, sorghum, barley, and oats. Of these, corn is by far the most important, accounting for over 80 percent of the total value of receipts from feed grain in recent years [USDA, 1981a, p. 15]. Given the predominant position of corn in the national feed grain market, and the fact that its price is very highly correlated with that of the other feed grains, only corn production will be considered in detail.

Leath, Meyer and Hill [1982, p. IV] note that the United States annually produces about half of the world's corn and accounts for about 80 percent of total world corn exports. The regional distribution of corn production appears to have been relatively stable since 1960 with around half of total production derived from the five Corn Belt states\(^1\) and another 30 percent produced in the adjacent Lake States\(^2\) and Northern Plains regions\(^3\) [Leath, et al., 1982, p. 13].

In these major corn producing regions, corn is frequently produced in a rotation with soybeans and there are some substitution possibilities

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\(^1\) The Corn Belt was defined as Iowa, Illinois, Indiana, Ohio, and Missouri.

\(^2\) The Lake States were Wisconsin, Michigan, and Minnesota.

\(^3\) The Northern Plains were defined as North Dakota, South Dakota, and Nebraska.
between corn, soybeans, and, to a lesser extent, sorghum. Substitution possibilities also exist between crops and pastures in these regions.

Corn acreage planted has varied considerably during the period since 1950. Leath et al. [1982, p. 6] attribute this variability primarily to the operation of government programs. No long-term trend is evident in the total corn acreage planted, with average plantings being 82.44 million acres in the period 1950-1954 and 81.6 million in the 1978 and 1979 crop years [Leath et al., 1982, p. 7]. However, under the influence of policy restraints, corn area planted fell as low as 65.0 million acres in 1962.

Corn yields, by contrast, have increased dramatically with per acre yields in the late 1970s being almost three times as large as in the early 1950s. The most rapid increases in yields came during the 1950s and 1960s when the development and adoption of new technology and production practices had its greatest effect. Leath et al. [1982, p. 9] attribute these increases to a combination of high yielding hybrids, increased rates of fertilization, higher seeding rates and improved control methods for weeds and diseases. Yield increases during the 1970s were less rapid than in the 1950s and 1960s and variability in yields, primarily due to weather conditions, was considerably greater.

The regional location and total land area available for corn appear to have been fairly stable since 1960. However, yields have been highly variable and attention obviously needs to be given to both yield increases and variability in any modeling effort.
Corn marketing

U.S. domestic corn demand can be divided into four components: (1) food, (2) alcoholic beverages, (3) seed, and (4) animal feed. Of these uses, feed demand is by far the most important, accounting for 85 percent of total domestic use in 1980-1981 [Leath et al., 1982, p. 19]. The seed and alcoholic beverages uses are extremely small components while food uses accounted for 13.4 percent of total U.S usage in 1980-1981. With the development of new products such as corn syrup, food use has exhibited rapid growth, increasing by 200 percent between 1960-1961 and 1980-1981, while feed demand rose by 34 percent. Export demand for corn has shown the most dramatic growth of any component, increasing by a factor of ten between 1959-1960 and 1980-1981. In 1980-1981, exports accounted for 32.5 percent of the total disappearance of corn.

A sizeable proportion of cattle and hog feeding takes place on grain producing farms. Leath et al., [1982, p. 18] note that about 60 percent of the corn used as animal feed is fed on the farm where it was produced. The remainder, two-thirds of total corn production, is sold off-farm. Approximately 80 percent of total corn is handled initially by country elevators which are one element of a highly competitive and efficient grain marketing system. The homogeneity of feed grains, and the large number of traders participating in the market, allow efficient price formation across both space and time.

Stockholding behavior is extremely important in the corn industry. Almost all harvesting of corn for grain occurs in the fourth quarter of
the crop year (first quarter of the marketing year) and so the supply of corn in the other three quarters is derived solely from stocks. Some corn is also carried over from year to year, either to provide continuity of supplies (convenience motive) or to take advantage of different prices between years (speculative motive). The very well-developed corn futures market allows corn stockholders to hedge against price risk and nonstockholders to indirectly purchase storage [Subotnik and Houck, 1979]. Stockholding behavior is heavily influenced by government policy, as will be discussed in the next section.

**Government policy instruments**

The U.S. livestock feed subsector is influenced by a number of government policy measures. Brunk et al. [1979] have delineated 12 different sets of policy measures affecting the beef industry alone: (1) anti-trust and trade, (2) weights and measures, (3) price reporting and market information, (4) product quality and safety, (5) international trade, (6) environmental quality, (7) labor and occupational safety, (8) land and range use controls, (9) finance and taxes, (10) transportation productivity, (11) feed additive controls, and (12) animal health controls. This list, with the addition of the major feed grain programs [Fulton, 1981], agricultural research and extension, and food policy includes most of the policy measures affecting the entire livestock feed subsector.

Of these many types of government intervention, the great majority are intended, at least in principle, to improve the efficiency of the
market in allocating resources within the subsector. Anti-trust measures should do this by promoting competition, weights and measures regulations by ensuring accurate product definition, reporting and marketing information services by providing improved information to market participants. Environmental policies are intended to deal specifically with externality problems, as are land and range use controls. Controls on product quality, feed additives and animal health are clearly a reaction to deficiencies of information which would otherwise inhibit efficient functioning of the market.

Some policy measures, however, are not designed primarily to make the market function more efficiently but rather to alter the resulting distribution of income or to affect the stability of market outcomes. Beef import policies would appear to fall into this category.

Policy measures can also be categorized by the location of their primary objectives. Policies such as labor and occupational safety rules, and federal tax policies are economy-wide in orientation. By contrast, the meat import law and the feed grain programs are aimed primarily at the agricultural sector and administered by the U.S. Department of Agriculture.

This study deals primarily with the meat import law and the feed grain programs. These two policy measures both have an impact on the livestock subsector and have been primarily the responsibility of one set of policymakers who need to consider the interactions between the livestock and feed grain subsectors [Breimyer and Rhodes, 1975]. Food
export control policies have also been of some importance in recent years and will be considered in this study.

Both the meat import law and the feed grain programs are rather complex and a reasonably detailed knowledge of the nature of these policy instruments is essential for their specification. A description of these policy measures is, accordingly, given below.

**Meat Import policy**  From 1965 to 1979, the major policy instrument affecting beef imports was a quantitative restraint on the quantity imported. The level of imports of beef, veal, mutton, and goat meats permitted was determined by the provisions of the Meat Import Act of 1964 [see USITC, 1977a, p. C-2]. In addition to this quota restriction, imports were subject to an import tariff at a rate of 3 cents per pound. This tariff has been a relatively minor factor, being equivalent to an ad valorem tariff of 5 percent in 1976 [USITC, 1977a, p. 93].

Since the beginning of 1980, meat imports have been restricted under the Meat Import Act of 1979 [Simpson, 1981, p. 57]. This Act modified the Meat Import Act of 1964 to incorporate a "counter-cyclical" element in the calculation of the import quota.

Allowable beef imports under the 1964 Act were determined on the basis of an Adjusted Base Quota, calculated on an annual basis [Sheales and Weekes, 1979, p. 63]. The Adjusted Base Quota under the 1964 Act was calculated as:

$$ABQ_t = BQM \times \frac{MP_t}{BP}$$  \hspace{1cm} (2.1)
Where:

\[ \text{ABQ}_t = \text{Adjusted Base Quota for the quota year } t \text{ under the 1964 Act}, \]
\[ \text{BQM} = \text{Base Quota of 725.4 million pounds (product weight), equal to the average annual import level for 1959-1963}, \]
\[ \text{MP3}_t = \text{three year moving average of U.S. meat production. Uses a forecast of production in the quota year and observed production in the previous two years, and} \]
\[ \text{BP} = \text{Base average production during 1959-1963 (= 15703 million pounds)}. \]

The 1964 Act provided that imports could not exceed a "trigger" level given by 110 percent of the Adjusted Base Quota. The quota itself was applied in only one case, 1976 [Conable, 1980, p. 5]. In all other years in which restrictions were effective, the quantity imported was controlled by Voluntary Restraint Agreements negotiated with the supplying countries. These Voluntary Restraint Agreements allocated a total level of imports among the supplying countries on the basis of factors such as their past levels of supply. Import supplying countries had a strong incentive to comply with the voluntary restraints because they were based on the trigger level rather than the lower quota level.

Under the 1964 Act, the President had considerable discretion to suspend or increase the import quota. In 1972, 1973, 1975, 1978, and 1979, this discretion was used to increase the quantity of meat imported into the United States substantially above the trigger level [AMLC, 1980, p. 39].
The 1964 Act essentially provided importers with a specified share of the market for quota meats. This long-term share of the market was set by the quota formula [Simpson, 1981, p. 13] at:

Long-term share of imports = \( E \left[ \frac{\Delta Q}{MP3} \right] = \frac{BOM}{BP} = \frac{725.4 \times CE}{15703} = 6.35\% \) (2.2)

Where:

- \( CE \) is a carcass weight equivalent of 1.375 for product weight imports derived as the average of the 1.35 and 1.40 factors used by USDA [1981b, p. 154], and
- \( E \) is the expectation operator, and all other terms are defined for Equation (2.1).

Since the trigger value, rather than the quota, has been used to determine imports in practice [Conable, 1980, p. 2], the actual market share allowed was just under 7 percent.

A reasonably regular cycle in inventories and prices of livestock has long been evident in the U.S. beef industry. Simpson [1981, p. 3] notes that these cycles have generally been of roughly ten years duration since World War II. During a cycle, the level of the adjusted base quota under the 1964 Act increased during periods of high domestic production and decreased during periods of low domestic production. Although the use of a three-year average of domestic production obviously dampened the cyclical pattern of imports relative to domestic production, this aspect of the 1964 Act was the major rationale for the introduction of the "countercyclical" Meat Import Act of 1979 [Simpson, 1981].
The Meat Import Act of 1979 modified the Meat Import Act of 1964 in three main respects:

(1) introduction of a "countercyclical" quota formula,
(2) introduction of a guaranteed minimum level of imports, and
(3) limitation of the discretion of the U.S. president to increase the quota.

Under this act, the import quota is determined by the following formula [see Simpson, 1981, p. 17]:

\[ Q_t = BQM \times \frac{MP3}{RBP} \times \frac{CB5}{CB2} \]  \hspace{1cm} (2.3)

Where:

- \( Q_t \) = the annual import quota under the 1979 Act,
- \( BQM \) = average annual imports, 1968-1977 (= 1204.6 million pounds product weight),
- \( MP3 \) = a three-year moving average of domestic commercial production of beef, veal, mutton, and goat (carcass weight), less total carcass weight of live cattle imports. This average is calculated using a forecast for the quota year and actual data for the two preceding years,
- \( RBP \) = a ten-year average base-period production value of production (for the years 1968-1977) calculated using the same product definitions as for \( MP3 \) (= 23184 million pounds carcass weight),
- \( CB5 \) = a five-year moving average of domestic per capita federally
inspected cow beef supply (the quota year forecast and four preceding years), and

\[ CB2 = \text{a two-year moving average of domestic per capita cow beef supply as defined above (uses a quota year forecast and the preceding year's figure).} \]

The first two terms of the 1979 quota formula correspond closely to an updated version of the 1964 Act. Only slight changes have been made in the definitions of meat production, e.g., the exclusion of beef produced from slaughter of live cattle imports. The third term in the quota expression is, however, entirely new and it is this term which is intended to give the act its countercyclical properties.

When the U.S. cattle industry is in the liquidation phase of its cycle, the denominator of the countercyclical factor (CB2) is likely to be larger than the numerator (CB5), and so the countercyclical term should reduce imports. Conversely, during the expansion phase of the cycle, allowable imports are likely to be increased. In this way, it was expected that the import quota would vary inversely with domestic production and so act as a countercyclical influence [Conable, 1980, p. 2]. In a recent study, Simpson [1982, p. 248] found that the quota formula is, however, rather insensitive to assumptions about the rate of change in cattle inventories and that, under quite plausible assumptions, the import quota may still be positively correlated with changes in domestic production.

The 1979 Act provided a guaranteed minimum level of market access of 1,250 million pounds (product weight), irrespective of the value of
the quota formula in Equation 2.3. This figure was the result of a compromise between the House of Representatives, which proposed a minimum of 1200 million pounds, and the President, who had requested a minimum of 1,300 million pounds [House of Representatives, 1979, p. 20].

The incorporation of the guaranteed minimum access level in the 1979 Act can only increase the expected market share allowed for imports. However, even without this provision, the 1979 Act allows a slightly higher market share for imports because of the use of the 1968-1977 base period, rather than the 1959-1963 base period used in the 1964 Act. Taking expectations, the long-run market share corresponding to that given by Equation (2.2) becomes 7.1 percent under the 1979 Act, as compared to 6.4 percent under the 1964 Act. However, this increase in market share may be offset by the additional restrictions on presidential discretion included in the 1979 Act.

Under the 1964 Act, the President had discretion to suspend or increase the quota if "the supply ... will be inadequate to meet domestic demand at reasonable prices" [U.S. Congress, 1964]. Under the 1979 Act, this discretion is only available to the President if the countercyclical factor $\frac{CB5}{CB2}$ has a value of less than one. When this factor is greater than one, the President may not increase the level of allowable imports except in the event of a national emergency or major national market disruption [U.S. Congress, 1979]. This reduction in presidential discretion may have a substantial effect on average import levels in some years. In 1972, 1973, 1978, and 1979, use of

\footnote{Using a carcass/product equivalent at 1.375 [USDA, 1981b, p. 154].}
presidential discretion allowed imports to be increased above the trigger level by 18.2 percent, 17.8 percent, 14 percent, and 23 percent, respectively [Conable, 1980, p. 5].

The import quota, under both the 1964 Act and the 1979 Act, has been expressed on an annual basis. This distribution of imports within a year is left to the discretion of those firms which obtain allocations to supply imported beef. Thus, the supply of beef imports is likely to be price-responsive for any subperiod within a year, even in those years when it is subject to a quota limit for the year as a whole.

While U.S. policy sets maximum levels for beef imports, it must be remembered that the level of imports can fall, and frequently has fallen, below this level. In this situation, the actual level of imports is determined by the interaction of U.S. import demand and the foreign excess supply curves. The policies used by exporting countries to influence their exports then become relevant to the determination of the import level. The policies of the two major supplying countries will be briefly reviewed to assess what effect, if any, they have on the import supply function.

Australia does not control exports to the United States during periods when the U.S. import restraints are not binding [AMLC, 1981, p. 36]. Similarly, New Zealand does not control exports under these circumstances [L. Bryant, New Zealand Meat Producers' Board, Wellington, N.Z., personal communication]. Since there is a reasonably large number of exporting firms in each country, a supply function can be derived
under the assumption of profit maximization, unless this function is affected by conditions in those years when imports are restrained.

Under the Meat Import Acts, the responsibility for controlling the volume of imports has been given to the exporting governments. Since, in the presence of a binding quantitative restraint, the U.S. price will exceed the world price, this responsibility becomes one of allocating valuable property rights to exporting firms — the right to receive a premium price on each unit imported. Some methods of allocating these property rights would have no effect on the allocation of supplies, e.g., the system of auctioning export rights proposed by Freebairn and Gruen [1977, p. 34]. Other possible systems, such as basing export allocations on the volume of exports to the United States by a firm during unrestricted years, could markedly influence the supply function for imports during nonrestricted years.

The Australian government controls exports to the United States during quota-restricted years by allocating shares of total exports to individual exporting firms [AMLC, 1980, p. 36]. Since 1977, these entitlements to export have been allocated to individual firms on the basis of their share of exports to all destinations in the previous year. In a year of unrestricted exports, exporters, therefore, have an incentive to increase their exports to all destinations if they feel that U.S. import restraints will be binding during the following year. Since 1977, there have not been any cases in which a year of unrestricted imports was followed by a year of restricted imports [see AMLC, 1981, p. 38] and so this effect has probably not been
significant. Prior to 1977, Australian exports were allocated on the basis of current year exports to markets other than the United States [Freebairn and Gruen, 1977], and so the export diversification scheme used would not have had any effect on U.S. import supplies during unrestricted years.

The New Zealand export control scheme is based upon exports in the current year. Total export supplies to all destinations are first estimated and U.S. market access expressed as a ratio of this quantity. Individual exporters are then able to allocate this percentage of their total exports to the U.S. market. This system is essentially equivalent to the system used by Australia prior to 1977 and should have no impact upon the supply function in nonrestricted years.

**Feed grain programs** The current U.S. feed grain programs have evolved from the Agricultural Adjustment Act of 1933 [Fulton, 1981, p. 12]. Three major objectives can be distinguished for the feed grain program: (1) to increase farm grain prices, (2) to stabilize prices, and (3) to support farm income. Through the years, the program has had three major policy instruments to apply to these objectives: (1) market price/storage policy, (2) acreage reduction payments, and (3) income support direct payments. Two additional policy instruments were introduced during the 1970s: (1) disaster payments in the 1973 Act and (2) long-term, farmer-owned storage contracts under the Farmer Owned Reserve introduced in the 1977 Act.

The basic policy parameters are set out in the "farm bills" which have been passed approximately every four years since 1965. In recent
years, the Secretary of Agriculture has acquired considerable dis-
cretion in setting the size of program features to be used [Tweeten,
1979, p. 479]. Although different prices are set for each feed grain,
these must be set in relation to the corn price [Fulton, 1981, p. 13]
and so a single feed grain program can usefully be considered. A
brief description of the operation of the feed grain program is given
below on a policy instrument by policy instrument basis.

**Market price/storage policy**

Market price/storage policy has generally been used to maintain a minimum level of prices for each feed grain. After harvest, any farmer participating in the program is eligible to obtain a loan for up to nine months from the Commodity Credit Corporation at the loan rate specified for the particular crop year. These nonrecourse loans can be repaid by surrendering the grain used as collateral, or by repayment in cash [Tweeten, 1979, p. 458]. If the market price is at or below the loan rate, then participating farmers have a strong incentive to accept the loan rate by surrendering the grain. Given a substantial rate of participation, the existence of the loan provides a floor to the market price, since no participant is likely to sell grain at a price below the loan rate.

From the data presented in Table 2.5, it is clear that the loan rate has generally provided an effective floor to the market price. Only in three years between 1960-1961 and 1981-1982 has the loan rate been above the season average farm price, and then only by a relatively small amount.
Table 2.5. Corn loan rate and season average farm price, 1960-1980a

<table>
<thead>
<tr>
<th>Year</th>
<th>Loan rate</th>
<th>Farm price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-1961</td>
<td>1.06</td>
<td>1.00</td>
</tr>
<tr>
<td>1961-1962</td>
<td>1.20</td>
<td>1.10</td>
</tr>
<tr>
<td>1962-1963</td>
<td>1.20</td>
<td>1.12</td>
</tr>
<tr>
<td>1963-1964</td>
<td>1.07</td>
<td>1.11</td>
</tr>
<tr>
<td>1964-1965</td>
<td>1.10</td>
<td>1.17</td>
</tr>
<tr>
<td>1965-1966</td>
<td>1.05</td>
<td>1.16</td>
</tr>
<tr>
<td>1966-1967</td>
<td>1.00</td>
<td>1.24</td>
</tr>
<tr>
<td>1967-1968</td>
<td>1.05</td>
<td>1.03</td>
</tr>
<tr>
<td>1968-1969</td>
<td>1.05</td>
<td>1.08</td>
</tr>
<tr>
<td>1969-1970</td>
<td>1.05</td>
<td>1.16</td>
</tr>
<tr>
<td>1970-1971</td>
<td>1.05</td>
<td>1.33</td>
</tr>
<tr>
<td>1971-1972</td>
<td>1.03</td>
<td>1.08</td>
</tr>
<tr>
<td>1972-1973</td>
<td>1.01</td>
<td>1.57</td>
</tr>
<tr>
<td>1973-1974</td>
<td>1.32</td>
<td>2.55</td>
</tr>
<tr>
<td>1974-1975</td>
<td>1.10</td>
<td>3.03</td>
</tr>
<tr>
<td>1975-1976</td>
<td>1.10</td>
<td>2.54</td>
</tr>
<tr>
<td>1976-1977</td>
<td>1.50</td>
<td>2.15</td>
</tr>
<tr>
<td>1977-1978</td>
<td>2.00</td>
<td>2.02</td>
</tr>
<tr>
<td>1978-1979</td>
<td>2.00</td>
<td>2.25</td>
</tr>
<tr>
<td>1979-1980</td>
<td>2.10</td>
<td>2.52</td>
</tr>
<tr>
<td>1980-1981</td>
<td>2.25</td>
<td>3.11</td>
</tr>
<tr>
<td>1981-1982</td>
<td>2.40</td>
<td></td>
</tr>
</tbody>
</table>

aSource: [Leath et al., 1982, pp. 103 and 79].

The use of the loan rate as a policy variable makes government corn stocks an endogenous variable. Only during those periods when the market price is above the loan rate can the government treat the level of its stocks as a policy variable.

Clearly, the loan rate/storage policy option has primarily been used to stabilize grain prices, or at least to remove an element of downside risk from these prices. In the short-run, this policy measure can be used to increase prices, but continued use in this way will
inevitably lead to accumulation of excessive stocks, as occurred during the 1950s. The major policy measure used to improve farm prices has been supply reductions brought about by reductions in the area planted.

**Acreage reduction policy** Recent farm programs have included two voluntary acreage reduction measures. The first of these, the Acreage Set-Aside Program, is required of all farmers choosing to participate in the farm program of that particular year. The second, the Paid Acreage Diversion Program, provides for program participants to be paid for land diverted from production. If a set-aside requirement is in effect, the diverted area must be in addition to the area set aside.

Details of the operation of the current acreage reduction program are given in Appendix A, where set-aside and diversion payments have been incorporated into a single effective support price variable. No direct, per acre, payment is made for set-aside acres, and so the payment made for such acreage reductions is provided by the other program benefits, especially the target price protection, but also provisions such as the disaster payment program. Since the implementation of the Food and Agriculture Act of 1977, areas set aside or diverted have been expressed as a percentage of the area actually planted [Penn, 1979; USDA, 1979d]. Thus, if a 10 percent set-aside is in effect, a farmer must set aside one acre for each ten which he actually plants. A 10 percent set-aside therefore results in slightly less than a 10 percent reduction in the area planted.
Support price—target price payments

Income support payments separate from the loan rate were introduced in 1963 [Cochrane and Ryan, 1976, p. 199]. This device allowed the government to maintain a market price in line with the world price while achieving a politically determined total price to participating farmers. In the 1973 Act, the system of offering a specified price support payment to participants was replaced by the target price system. Price support payments were replaced by deficiency payments which are payable only if the market price falls below the target price. The maximum deficiency payment is given by the difference between the target price and the loan rate, e.g., $2.10 - $2.00 = $0.10 for corn in 1978-1979 [Fulton, 1981, p. 22].

While the target price is officially referred to as an income support payment [Penn, 1979, p. 3], it clearly also has an effect on the incentive to set aside land from production. When a set-aside requirement is in effect for farm program participation, the size of the support price or potential deficiency payment becomes crucial in deciding whether to participate and, hence, to set aside land from production. In a number of studies [e.g., Gallagher, 1978], the deficiency payment has been classified as part of the incentive to divert land.

Disaster payments

A disaster payment program was introduced in the 1973 Act [Tweeten, 1979, p. 472]. This program provides for eligible producers to receive payments if they are prevented from planting any part of their allotment because of a natural disaster or
conditions beyond their control. This program is essentially a free insurance program available to program participants [Penn, 1979, p. 5]. Like the target price system, this feature of the program influences the decision to participate. When a set-aside is in effect, this additional incentive to participate should increase the total area set aside and, hence, help to raise prices.

**Farmer owned reserve** The 1977 Act introduced the farmer-owned reserve (FOR) grain program with the explicit objective of providing additional grain price stabilization [Penn, 1979, p. 6]. The FOR provides an incentive for participating producers to store grain under an extended price support loan with a contract of 3 to 5 years duration.

To encourage participation in the Farmer-Owned Reserve, producers receive a higher loan rate for grain entering the reserve. In 1981, for example, the loan rate for corn entering the reserve was $2.55, compared to a national loan rate of $2.40 [USDA, 1981e]. In addition, the government makes advance annual storage payments for grain held and can, under some circumstances, provide a waiver of interest on the loan. The benefits available under the FOR may provide some additional incentive for producers to participate in the overall program.

Grain in the FOR cannot be sold unless the average market price exceeds one of two particular levels. The first level, the release level, is set at 125 percent of the loan rate. When the market price exceeds this level, producers are allowed to sell feed grains out of the reserve [Fulton, 1981, p. 19]. The second level, the call level, is set at 140 percent or 150 percent of the loan rate (depending upon
the particular reserve program). Once the call trigger level has been reached, the reserve loans are called and producers must pay their reserve loans within 90 days of notification. Failure to pay the loan results in forfeiture of the loan to the government. While producers are not required to sell their grain, it is likely that the calling of FOR loans would result in an increase of supplies onto the market.

Gardner [1981, p. 1] concluded that the FOR had increased carry-over stocks and stabilized the price of grain to some degree. To date, the provisions of the program have been changed frequently and Gardner has also argued [1981, p. 79] that these changes have tended to reduce the effectiveness of the program. Clearly, the stabilizing performance of the FOR depends to a large degree upon the use which is made of the discretion allowed to the administrators of the program.
CHAPTER III. A SURVEY OF SOME MODELING ISSUES

As a result of the importance of the U.S. livestock-feed subsector, a great deal of research has been undertaken to investigate the structure of the subsector, to forecast outcomes and to analyze policy impacts within the subsector. A great deal of information has been gained as a result of these studies and much information can be obtained from a careful review of previous studies. The purpose of this survey is to condense some of the findings of previous work and the relevant theoretical literature as a basis for model specification in Chapter V.

Since the objective of this study is to explore the dynamic impacts of policies in the livestock-feed subsector, some form of quantitative model of the subsector was believed to be necessary. In this survey, we examine a number of previous models, considering firstly the choice of modeling approaches, and then some features of econometric models of the livestock-feed subsector. Only the broad characteristics of the models will be considered here. The specification of particular model components will be discussed in Chapter V, together with the components of the model used in this study.

Modeling Methods

The selection of an approach to modeling a particular system involves a number of choices. The broad type of model to be used must be selected and then decisions need to be made about the complexity and size of the model, the time interval to be used, and the specific method of obtaining estimates of its structural parameters.
Most economic models of systems are either programming models or econometric models. In a programming model, some objective such as profit maximization is posited and becomes an explicit part of the specification of the model. Econometric models, by contrast depend upon the solution of a system of equations.

The conceptual difference between behavioral models based on programming approaches and econometric approaches may be more apparent than real. An econometric model based upon microeconomic theory incorporates the hypothesis of maximization in the specification of its behavioral functions [Samuelson, 1947]. An advantage of the econometric approach is that it allows for testing of the hypotheses about behavior which are generated by the postulated maximizing process. In a programming model, by contrast, the maximization hypothesis is a maintained hypothesis not subject to testing except through an evaluation of the performance of the model in replicating observed behavior.

Programming models have proven extremely useful in modeling normative supply response, and the structure of input demand where the objective function is relatively well-defined. They have not, however, been widely used to model consumer demand because of a lack of information about the structure of the objective function. In addition, the methods for dealing with dynamic responses in programming models are not fully satisfactory. If one is particularly interested in the structure of supply, then one option is to combine econometric and programming models into a single "hybrid" model [Huang, Weisz, and Heady, 1980; Schatzer and Heady, 1982].
Since the dynamic responses of the system were of particular interest, and most attention focused upon endogenous variables in the output rather than the input markets, an econometric model was chosen for this analysis.

Econometric Models of the Livestock-Feed Subsector

Given the choice of an econometric model, this survey will focus primarily upon aspects of previously estimated econometric models of the livestock-feed subsector. Important aspects of modeling methods on which models have differed substantially are: (1) model purposes, (2) delineation of model boundaries, (3) data periodicity, (4) estimation technique, (5) level of aggregation, (6) complexity of model structure, and (7) formation of expectations. Each of these aspects will be reviewed in relation to previous models.

Model purposes

The purposes(s) for which the model is being constructed should be the most important single factor in determining its characteristics. Econometric modeling work is usually oriented towards one of three broad purposes: (1) forecasting, (2) structural analysis, or (3) policy analysis.

Forecasting models are likely to differ from the other types of models for several reasons. Firstly, a useful forecasting model requires that its endogenous variables be chosen from variables which are more readily predicted than the variables to be forecast. Since knowledge of the reduced-form coefficients, but not the structural
coefficients, is required, there is no absolute necessity to obtain estimates of the structural parameters. In fact, time series models using no theoretical structure seem to perform almost as well in many forecasting applications as structural models [Granger, 1978, p. 126].

Models constructed for structural analysis and for policy analysis tend to be more closely related. However, the construction of a model is usually only the first stage in policy analysis. The effects of policy can be analyzed by simulation techniques [e.g., Bain, 1977], multiplier analysis [e.g., Arzac and Wilkinson, 1979a] or by applying optimal control procedures to the model [e.g., Freebairn, 1972]. Some of these applications impose constraints upon the structure of the model. For example, the model must be linear, or at least amenable to linearization, to allow the calculation of multipliers.

Table 3.1 provides a list of some previous econometric models of the livestock-feed subsector or its component parts. The primary objectives for which each model was constructed are given in Table 3.1, together with data periodicity and the extent of industry coverage. The models presented in this table include a great deal of diversity in the modeling aspects considered in the following subsections.

**Delineation of model boundaries**

While the objectives of the analyst define the system of interest, the boundaries of an econometric model must be delineated by defining particular variables as exogenous to the system. Unless the variables defining the boundary of the model are at least predetermined, their
Table 3.1. Some econometric models of the livestock-feed grain subsector

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Industry coverage</th>
<th>Periodicity</th>
<th>Primary objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hildreth and Jarrett</td>
<td>1959</td>
<td>Livestock-feed</td>
<td>Annual</td>
<td>Policy and forecasting</td>
</tr>
<tr>
<td>Cromarty</td>
<td>1959</td>
<td>Agricultural sector</td>
<td>Annual</td>
<td>Macro forecasting</td>
</tr>
<tr>
<td>Egbert and Reutlinger</td>
<td>1965</td>
<td>Livestock-feed</td>
<td>Annual</td>
<td>Long-run projections</td>
</tr>
<tr>
<td>Craddock</td>
<td>1966</td>
<td>Livestock-feed</td>
<td>Quarterly</td>
<td>Feed grain policy</td>
</tr>
<tr>
<td>Langemeier and Thompson</td>
<td>1967</td>
<td>Beef</td>
<td>Annual</td>
<td>Structural analysis</td>
</tr>
<tr>
<td>Gruber and Heady</td>
<td>1968</td>
<td>Beef</td>
<td>Annual</td>
<td>Structural analysis</td>
</tr>
<tr>
<td>Hayenga and Hacklander</td>
<td>1970</td>
<td>Beef and pork</td>
<td>Monthly</td>
<td>Forecasting</td>
</tr>
<tr>
<td>Crom</td>
<td>1970</td>
<td>Beef and pork</td>
<td>Quarterly</td>
<td>Forecasting/policy</td>
</tr>
<tr>
<td>Ray</td>
<td>1971</td>
<td>Agricultural sector</td>
<td>Annual</td>
<td>Policy analysis</td>
</tr>
<tr>
<td>Freebairn</td>
<td>1972</td>
<td>Livestock</td>
<td>Annual</td>
<td>Beef import policy</td>
</tr>
<tr>
<td>Kamal-Abdou</td>
<td>1975</td>
<td>Livestock</td>
<td>Quarterly</td>
<td>Structural Analysis</td>
</tr>
<tr>
<td>Freebairn and Rausser</td>
<td>1975</td>
<td>Livestock</td>
<td>Annual</td>
<td>Policy</td>
</tr>
<tr>
<td>Paulsen, et al.</td>
<td>1976</td>
<td>Livestock</td>
<td>Quarterly</td>
<td>Forecasting</td>
</tr>
<tr>
<td>Bain</td>
<td>1977</td>
<td>Livestock</td>
<td>Quarterly</td>
<td>Forecasting/policy</td>
</tr>
<tr>
<td>Folwell and Shapouri</td>
<td>1977</td>
<td>Beef</td>
<td>Annual</td>
<td>Policy</td>
</tr>
<tr>
<td>Chen</td>
<td>1977</td>
<td>Agriculture</td>
<td>Quarterly</td>
<td>Macroeconomic linkage</td>
</tr>
<tr>
<td>Arzac and Wilkinson</td>
<td>1979a</td>
<td>Livestock-feed</td>
<td>Quarterly and annual</td>
<td>Forecasting/policy</td>
</tr>
<tr>
<td>Reeves</td>
<td>1979</td>
<td>Livestock</td>
<td>Annual</td>
<td>Stabilization policy</td>
</tr>
<tr>
<td>Ryan</td>
<td>1978</td>
<td>Beef</td>
<td>Monthly</td>
<td>Marketing margins</td>
</tr>
</tbody>
</table>
Table 3.1 (continued)

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Industry coverage</th>
<th>Periodicity</th>
<th>Primary objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shonkwiler</td>
<td>1979</td>
<td>Livestock-feed</td>
<td>Semi-annual</td>
<td>Forecasting</td>
</tr>
<tr>
<td>Roberts and Heady</td>
<td>1980</td>
<td>Livestock-feed</td>
<td>Annual</td>
<td>Policy</td>
</tr>
<tr>
<td>Ospina and Shumway</td>
<td>1980</td>
<td>Livestock</td>
<td>Annual</td>
<td>Structural analysis</td>
</tr>
<tr>
<td>Just</td>
<td>1981</td>
<td>Livestock-feed</td>
<td>Quarterly</td>
<td>Policy analysis</td>
</tr>
<tr>
<td>Ziemer and White</td>
<td>1982</td>
<td>Fed beef</td>
<td>Quarterly</td>
<td>Disequilibrium analysis</td>
</tr>
<tr>
<td>Morton</td>
<td>1982</td>
<td>Feed-livestock</td>
<td>Annual</td>
<td>Policy analysis</td>
</tr>
</tbody>
</table>
specification as exogenous may result in specification biased parameter estimates.

Egbert and Reutlinger [1965] pointed out two crucial points at which boundaries for a livestock-feed model could be drawn to minimize this specification bias. The very low cross elasticities of demand between livestock products and other commodities [Brandow, 1961], provided one such opportunity. Since feed grain prices were primarily determined by government policy during the 1950s and 1960s, Freebairn [1972, p. 181], as well as Egbert and Reutlinger, argued that the price of feed grain could be viewed as exogenous. During the 1970s, the price of feed grain deviated considerably from the loan rate and Arzac and Wilkinson [1979a] have included feed grain production and price as endogenous.

Most models have included both the beef and pork subsectors because of the strong interactions between them, both in production and in consumption. Some models, e.g., Ray [1971] have included other agricultural industries, such as tobacco, which have little interaction with the feed-livestock subsector. This clearly reflects model purposes which include an interest in these other industries per se.

Foreign trade has been viewed as exogenously determined in most livestock-feed models. In some years, this has clearly been the case for beef imports, but in the majority of years, the import quota has not been a binding constraint and so imports have been endogenous. Freebairn and Rauser [1975, p. 677] treated meat imports as predetermined in an annual model only to keep their model manageable.
Meat generally takes from four to six weeks to travel from the major supplying countries to the United States and the assumption of predetermined imports seems reasonable for a quarterly model when ordering and shipping lags are considered. Chambers et al. [1981, p. 129] assumed imports to be price-responsive within the current month and attempted to use disequilibrium analysis to take into account the effects of the import restraints. A detailed discussion of their approach and some of the issues which arise in modeling a limited-dependent variable situation such as the Meat Import Law is contained in Chapter IV.

Where the behavior of the feed grain market has been considered, exports of feed grain have generally been treated as exogenous since they are clearly subject to political control [Paarlberg, 1982] and because they were a relatively minor source of demand prior to the 1970s. The combination of increasing exports and of exchange rate flexibility [Chambers and Just, 1981] made the determination of export demand an increasingly important issue and some models [e.g., Just, 1981; Morton, 1982] have included excess demand functions for feed grains. However, delays in arranging export sales probably allow grain exports to be viewed as approximately predetermined for estimation of a quarterly model.

**Data periodicity**

Real economic systems operate in continuous time and dynamic economic theory is primarily formulated in continuous time, but time
series estimation requires the use of discrete data. Periodicities chosen have ranged from monthly [Hayenga and Hacklander, 1970] through quarterly [Paulsen et al., 1976; Bain, 1977] to annual [Roberts and Heady, 1980].

The data intervals used depend partly upon the purposes of the model and partly upon data availability. Freebairn [1972] used annual data because he was analyzing beef import policy and the level of the import quota was determined only annually. Similarly, Roberts and Heady [1980] used an annual model to examine feed grain and beef import policies. By contrast, models intended for forecasting have tended to use shorter intervals such as months [Hayenga and Hacklander, 1970] or quarters [Paulsen et al., 1976]. Shonkwiler [1979, p. 8] was primarily interested in forecasting but chose a semi-annual model because this provides some information about intra-year variations while avoiding some of the disadvantages associated with incomplete quarterly data series.

Most of the data series needed to represent the behavior of the system are available on a quarterly, as well as an annual, basis. While the use of quarterly data obviously does not provide four times as much information as using annual data, it can be expected to provide some additional information about responses in the livestock subsector. In this way, it may allow the use of a shorter time period for estimation and so reduce the problems of structural change. In addition, the shorter the time period, the more likely it is that the model can be viewed as recursive, with causality proceeding in a linear chain without
feedback. Johnston [1972, p. 380] points out that enforced aggregation of data can turn a truly recursive model into a fully simultaneous one with the consequent estimation difficulties.

As noted in the previous section, the existence of lags in foreign trade may allow beef imports to be viewed as predetermined in a quarterly model, rather than as a simultaneous limited-dependent variable relationship. This advantage could be considerable for a model where the effects of imports are of particular interest.

**Estimation technique**

The most important distinction between the various estimation procedures used is that between the various simultaneous equation estimators and Ordinary Least Squares (OLS).

Ordinary Least Squares is far simpler and less expensive than any of the explicitly simultaneous methods of analysis. The use of OLS can be theoretically justified under two sets of circumstances: (1) obtaining estimates of the unrestricted reduced form coefficients for forecasting purposes or (2) where the assumptions necessary for a recursive model are satisfied, i.e., the matrix of coefficients on the endogenous variables is triangular and the contemporaneous error variance-covariance matrix is diagonal [Johnston, 1972, p. 377].

Bain [1977, p. 84] estimated some unrestricted reduced form equations (by OLS) for forecasting and policy analysis. This approach has the advantage of being computationally very simple and of automatically providing estimates of the variances of the coefficient
estimates. Unfortunately, it does not make use of the prior information available from economic theory. Despite this, Shonkwiler [1979, pp. 140-151] concluded that the reduced form coefficients which he obtained by OLS corresponded closely with the restricted estimates obtained from the structural form. Howrey, Klein, McCarthy, and Schink [1981] note that OLS is still extensively used by applied model builders, despite the availability of consistent simultaneous equation estimators.

Where the stringent conditions applying to a recursive model are not satisfied, it is still quite likely that a large econometric model will be block recursive, i.e., the coefficient matrix will be block triangular and the error variance-covariance matrix will be block diagonal. As Dhrymes [1970, p. 308] demonstrates, this can greatly reduce the problems associated with simultaneous estimation since current endogenous variables from outside the block of interest can be treated as predetermined when estimating the coefficients for a particular block. Roberts and Heady [1980] made use of the block-recursive properties of their model to facilitate its estimation.

Some details on the size, periodicity and estimation technique of some recent models are given in Table 3.2.

From Table 3.2, it is evident that there has been considerable variation in the approaches taken by modelers. Although Hayenga and Hacklander used the shortest time period of any of the models considered, they chose to use a simultaneous framework. Of the three primarily quarterly models, the Bain [1977] and the Paulsen et al. [1976] models were primarily recursive, while the Arzac and Wilkinson
Table 3.2. Size, periodicity and estimation technique for some recent models

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Number of Stochastic equations</th>
<th>Periodicity</th>
<th>Estimation Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chambers et al.</td>
<td>1981</td>
<td>2</td>
<td>Monthly</td>
<td>MLE (disequilibrium)</td>
</tr>
<tr>
<td>Just</td>
<td>1981</td>
<td>22</td>
<td>Quarterly</td>
<td>Nonlinear 2SLS</td>
</tr>
<tr>
<td>Roberts and Heady</td>
<td>1980</td>
<td>44</td>
<td>Annual</td>
<td>Livestock: block recursive. Crops: recursive</td>
</tr>
<tr>
<td>Arzac and Wilkinson</td>
<td>1979a</td>
<td>23</td>
<td>Quarterly</td>
<td>Primarily simultaneous</td>
</tr>
<tr>
<td>Shonkwiler</td>
<td>1979</td>
<td>48</td>
<td>Semi-annual</td>
<td>Simultaneous</td>
</tr>
<tr>
<td>Chen (Wharton)</td>
<td>1977</td>
<td>Large</td>
<td>Quarterly</td>
<td>Mainly OLS</td>
</tr>
<tr>
<td>Bain</td>
<td>1977</td>
<td>17</td>
<td>Primarily quarterly</td>
<td>Primarily recursive</td>
</tr>
<tr>
<td>Paulsen et al.</td>
<td>1976</td>
<td>38</td>
<td>Quarterly</td>
<td>Primarily recursive</td>
</tr>
<tr>
<td>Freebairn</td>
<td>1972</td>
<td>20</td>
<td>Annual</td>
<td>Simultaneous</td>
</tr>
<tr>
<td>Hayenga and Hacklander</td>
<td>1970</td>
<td>5</td>
<td>Monthly</td>
<td>Simultaneous</td>
</tr>
</tbody>
</table>
[1979a] model was primarily simultaneous. The Shonkwiler [1979] model was the largest of those considered to have been estimated by a simultaneous method. The Roberts and Heady [1980] model was also quite large and used primarily a recursive framework. Since all the models gave "reasonable" results, it will be necessary to look at the models more closely to provide a basis for choosing between modeling approaches. Unfortunately, standardized validation techniques for comparing model performance have not been used.


\[ q_t = a_0 + a_1 \cdot p_2^\alpha + a_2 \cdot z_t + e_t \]

The equations were estimated using a conventional, truncated, two-stage least squares procedure while searching for the best value of the exponent. This approach clearly reflected the purpose of the model. Just was attempting to estimate the effects of instability on consumer and producer welfare and these effects have been shown to depend crucially upon the assumed shape of the demand functions [Reutlinger, 1976].

The Chambers et al. [1981] model represents a more radical departure from previous models. Their parameter estimates were obtained by first setting up the log-likelihood function for a posited disequilibrium market model and then maximizing this likelihood function with
respect to the parameters. It is argued in Chapter IV of this study that the use of a price disequilibrium model to represent a quantity constrained situation, such as the beef import market, leads to a serious problem of specification bias.

Autoregressive error terms were considered a problem by virtually all modelers. Paulsen et al. [1976, p. 12] employed an autoregressive least squares procedure to correct for first order auto-correlation. Arzac and Wilkinson [1979a, p. 298] employed a truncated two-stage least squares procedure suggested by Fair [1970], although they presented only their uncorrected parameter estimates. This procedure accounts for both auto-correlation and the distributed lag bias associated with the use of lagged dependent variables. In some equations, Roberts and Heady [1980, p. 107] employed a one-step Gauss-Newton estimator suggested by Fuller [1978] for this problem.

**Level of aggregation**

The level of aggregation used in a model depends partly upon the modeler's objectives and partly upon the technical characteristics of the system. Aggregation across individual consumers requires very strong restrictions upon either the structure of consumer preferences, or upon the distribution of income [Green, 1976, p. 143]. While the problems associated with aggregation across consumers (or producers) have generally been regarded as less serious than other estimation problems [Houthakker and Taylor, 1970, p. 200], considerable attention has been given to the appropriate type of aggregation across commodities.
In their path breaking study, Hildreth and Jarrett [1959] were primarily interested in devising a methodology for analyzing the livestock sector, without a strong interest in individual commodities. After careful consideration of the aggregation problems involved, they chose to aggregate all livestock commodities for their analysis. Similarly, they aggregated all the feeds into one group.

At the other extreme, a number of models have used a highly disaggregated livestock system. For instance, Paulsen et al. [1976] and Roberts and Heady [1980] have separated their livestock sectors into five commodities: beef, pork, sheep, chicken, and poultry. Shonkwiler [1979] also used a highly disaggregated procedure, with the following livestock subdivisions modeled separately: cattle-beef, hog-pork, chicken-broiler, layer-egg, and dairy cow-milk.

An intermediate approach is exemplified by Arzac and Wilkinson [1979a] who considered only beef (disaggregated into two classes), pork and chicken. This classification was also used by Freebairn [1972]. Bain [1977] and Hayenga and Hacklander [1970] considered only beef and pork in their model.

In time series modeling of the livestock-feed subsector, a great deal of aggregation is clearly necessary. However, most recent models have disaggregated total beef production into two classes, fed and nonfed beef [e.g., Arzac and Wilkinson, 1979a; Bain, 1977]. Freebairn [1972, p. 164] advocated this on the grounds that: (1) fed beef satisfies different wants and has a higher income elasticity of demand;
(2) fed beef is the main output from feedlots while most nonfed beef is produced by a separate group of producers; and (3) almost all the imported beef is of a comparable quality to U.S. nonfed beef.

Obviously, total beef production includes a wide range of different quality products, and so the use of any two classes of beef still involves substantial aggregation. Moreover, the appropriate classification procedure is by no means obvious. Bain [1977] distinguished two approaches to beef quality disaggregation: (1) the production (fed/nonfed) approach, and (2) the end use (table/processing) approach.

Ryan [1980] has argued that, on the demand side, the relevant distinction is between processing and table quality beef. Given this distinction, the use of a nonfed beef variable misspecifies the quantity of low quality, processing beef by excluding the low quality cuts derived from fed cattle from this category and may lead to bias in the estimated parameter estimates. Following Woods [1975], Ryan used an estimate of 23.5 percent for the proportion of processing beef derived from fed carcasses. This proportion is similar to the 25.5 percent used by Colman [1966] and reasonably close to the 29 percent used by the U.S. Department of Agriculture [American Meat Institute, 1980b].

Since nonfed beef can be related to processing quality beef through the use of relatively simple identities, there would seem to be considerable advantage in combining both approaches in the same model.
Complexity of model structure

An econometric model is inherently an approximation of the underlying economic system. In most cases, economic theory does not provide a guide to the exact functional form appropriate for a particular relationship. The use of a particular functional form is essentially the imposition of a maintained hypothesis. The validity of the hypothesis will affect the performance of the model, but the hypothesis cannot be tested using the hypothesis tests associated with the estimation of the model. In practice, the modeler has considerable flexibility in choosing the exact set of structures to represent the system. Two general approaches have been used in choosing the set of structures. One approach is to attempt to represent the structure as closely as possible, using both theory and empirical testing of alternative forms. A second approach is to choose a simple linear approximation to the structure.

Attempts to represent the structure of individual equations as closely as possible have included the use of nonlinear equations and the imposition of symmetry conditions on demand systems. Roberts and Heady [1980, p. 20], for instance, used ratio and nonlinear variables in some of their equations. A number of recent studies of the demand for meat [e.g., Christensen and Manser, 1977; Fisher, 1979] have incorporated theoretical restrictions derived from the assumptions of utility maximization.

The second approach of using simple linear relationships as an approximation to potentially more complex structures has been advocated
very strongly by Shonkwiler [1979, p. 23]. He argues that modeling should be undertaken to obtain a plausible structural form which lends itself to adjustment and updating, rather than to obtaining the most precise structural form. Simple, linear structures have frequently been chosen for entirely different reasons. Freebairn [1972], for instance, employed a linear model since this model provided the state transformation function for his optimal control model. This approach can frequently be justified as providing a local, Taylor series, approximation to any underlying nonlinear set of structures.

**Expectation formation**

Given the relatively long time lags involved in meat production, and the need to store grain for extended periods, decisions must frequently be made on the basis of expectations about the distribution of future values of the price variables. Representing the process by which these expectations are formed is an important part of the modeling process.

While static economic theory has long been based upon a set of axioms about the behavior of rational economic agents, dynamic theory has rarely been based on such a firm theoretical foundation. In particular, models of expectation formation have generally been based upon ad hoc specifications, rather than a rigorous theoretical framework such as that provided for static decision making. In this respect, the concept of rational expectations introduced by Muth [1961] represents an improvement over other approaches to expectation formation.
A large number of models for the process of expectation formation have been proposed and many of these have been used in models of the livestock-feed subsector. Some of the models used include: (1) naive expectations, (2) adaptive expectations, (3) Almon polynomial distributed lags, (4) arithmetic lags, (5) quasi-rational expectations [Nerlove, Grether, and Carvalho, 1979] and 6) rational expectations. Of these, the first four belong to the family of distributed lag functions [Judge et al., 1980, p. 631] while the last two have been developed under the maintained hypothesis that expectations are formed rationally.

Although Muth's concept of rational expectations represents an important advance, many of the theoretical and practical problems associated with it remain to be resolved. Simon [1979, p. 505] criticizes the concept of rational expectations on the grounds that it ignores the process by which expectations are formed. In addition, the concept can be criticized for assuming too much knowledge in a world of imperfect knowledge and high costs of obtaining information. Strong versions of the rational expectations hypothesis have also been criticized for imposing identical expectations on all agents [Handa, 1982, p. 562].

The identical expectations assumption may be particularly vulnerable in the beef industry. If expectations are not identical, but there is costless intertemporal arbitrage, then better informed individuals will eliminate deviations between the expected future price and the true rational expectation. Thus, the futures market price for a particular commodity might be expected to be an unbiased expectation
of the future price, despite the fact that participants in the market do not have identical expectations.

In an activity such as feeder calf production, the possibilities for such arbitrage are much more limited. To illustrate this, we consider a situation in which there are two groups of cow-calf producers, one with rational expectations, and another whose members form their expectations according to some nonrational rule such as an average of recent prices. The behavior of the producers with naive expectations will probably generate inventory and price cycles in the market. The rational expectations producers, taking advantage of their knowledge of the structure of the market, and hence of its cyclical properties, could then develop adaptive plans to maximize their profits. Attempts by these producers to supply more calves during the high-price phase of the cycle and fewer during the low-price phase would result in an evening out of the cyclical price behavior. This outcome would be consistent with a situation in which all producers had identical, rational expectations.

In practice, however, the adjustment costs implicit in adaptive plans may prevent this arbitrage process from occurring. In a recent study, Bentley and Shumway [1981] concluded that adaptive planning over the U.S. cattle cycle would lead to lower producer profits than a policy of steady, sustained herd growth.

Clearly, no single approach to the formation of expectations can be specified as unambiguously appropriate in a study of the livestock-feed subsector. The approach chosen will depend upon both the
tractability of the associated estimation problem and the performance of the subsequent estimates.

Of the expectation formation approaches which have been used in studies of the livestock-feed subsector, the simplest to apply is undoubtedly that of "naive" expectations. However, this approach does not appear to be a plausible representation of decision makers' behavior and has not generally performed satisfactorily. Once the weights have been chosen, arithmetic weight structures are also relatively simple to apply and have performed well in some applications [e.g., Freebairn and Rausser, 1975, p. 682].

Simple versions of the adaptive expectations approach to specifying expectation formation are relatively easy to formulate. A simple adaptive expectation model without consideration of trend can be written as:

\[(Y_t^* - Y_t^*) = \alpha (Y_{t-1}^* - Y_{t-1})\]

Where:

- \(Y_t\) = the actual value of the variable \(Y\) at time \(t\),
- \(Y_t^*\) = the expected value of the variable held at time \(t-1\), and
- \(\alpha\) = the coefficient of adjustment (0 < \(\alpha\) < 1).

The behavioral hypothesis underlying this specification is that the expectations are revised upwards by a fraction of the error in the forecast of the previous period. By imposing strong restrictions on the shape of the lag distribution, they also reduce the number of parameters to be estimated to a relatively low level. Unfortunately, the
Koyck transformation used to convert the equation into observable form usually introduces autocorrelation into the error term. This, together with the lagged dependent variables which are introduced by the transformation, causes estimation problems for equations incorporating this assumption.

If the time series of a particular variable can be represented by a first-order moving-average model in the first differences of the variable, then expectations which are formed adaptively will be "partly rational" [McCallum, 1976, p. 50] in the sense that they contain all the information which is available from the history of the series itself.

While adaptive expectations are only "rational" under some circumstances, the behavioral hypothesis upon which they are based is reasonably plausible. Since the case for using purely rational expectations is not as clearcut as it might appear on first examination, the choice of expectation procedure will inevitably involve some consideration of observed performance in the resulting models.

Ryan [1978, pp. 80, 81] reports some price expectation equations using the type of consistent rational expectations estimator proposed by McCallum [1976]. In his discussion, Ryan emphasized that the variables included in the expectation equations needed to be selected with a view to obtaining correct signs if implausible predictions were not to be obtained. This selection process makes the resulting expectations equations highly subjective. A problem with McCallum's procedure seems to be that there are so many potential estimators, many of which may yield very different results.
Fisher [1982] has recently provided a useful discussion of the restrictions implied by the rational expectations hypothesis. While incorporation and testing of these restrictions is obviously an important area for future research, it is clear from Fisher's discussion that even a simple linear model presents a difficult, nonlinear estimation problem once these restrictions are introduced. It seems likely that testing of these restrictions will require the use of smaller models than the type considered here.

In this general literature survey, we have considered potential methods by which the livestock-feed subsector may be modeled, and a number of key aspects of previous econometric models. We have not discussed the specification of particular components of the various models, nor the synthesis of these components into integrated models. These aspects of the models are considered in Chapter V, with the specification and estimation of the model developed in this study.

Chapter IV is in some respects a continuation of this chapter. It deals with an issue which is of considerable importance to the study of the livestock subsector but which could not be directly integrated into the analytical model which is developed and used in the later sections of this study. However, the issues involved did influence the specification of the model, being responsible, in particular, for the use of quarterly rather than annual data.
CHAPTER IV. ESTIMATING THE IMPACT OF BEEF IMPORT RESTRICTIONS IN THE U.S. IMPORT MARKET

As we noted in Chapter II, imports of beef into the United States are subject to quantitative restrictions imposed under the Meat Import Acts. As can be seen from Table 4.1, the import restraints have been a binding constraint on imports in only 9 of 17 years in which the Meat Import Acts have been in effect. The fact that these restrictions are not always binding introduces some difficult problems for estimation of structural parameters in this market. In this chapter, we first consider the estimation problems arising in this situation and some potential approaches to estimation and then turn to one approach, the price-disequilibrium approach, which has been proposed for this situation.

Estimation Procedures for Quantity Constrained Markets

If the quantitative import restrictions were always binding, they would greatly simplify the estimation of the U.S. beef import demand function. Given the fixed quantity of imports allowed, the model could be estimated with an endogenous import price. This is essentially the approach which has been taken in many studies [e.g., Freebairn and Rausser, 1975; Reeves, 1979] even though imports have only been constrained in some years.

Even if the import restraints are only binding in some years, it becomes possible to obtain the same degree of econometric simplification
Table 4.1. United States imports of mgat subject to the meat import law (product weight basis)

<table>
<thead>
<tr>
<th>Calendar year</th>
<th>Final global restraint level</th>
<th>Actual imports (million pounds)</th>
<th>Binding/nobinding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>-</td>
<td>613.9</td>
<td>Nonbinding</td>
</tr>
<tr>
<td>1966</td>
<td>-</td>
<td>823.4</td>
<td>Nonbinding</td>
</tr>
<tr>
<td>1967</td>
<td>-</td>
<td>894.9</td>
<td>Nonbinding</td>
</tr>
<tr>
<td>1968</td>
<td>990.1</td>
<td>1,000.9</td>
<td>Binding</td>
</tr>
<tr>
<td>1969</td>
<td>1,045.4</td>
<td>1,084.2</td>
<td>Binding</td>
</tr>
<tr>
<td>1970</td>
<td>1,160.1</td>
<td>1,170.4</td>
<td>Binding</td>
</tr>
<tr>
<td>1971</td>
<td>1,158.7</td>
<td>1,132.7</td>
<td>Binding</td>
</tr>
<tr>
<td>1972</td>
<td>-</td>
<td>1,355.6</td>
<td>Nonbinding</td>
</tr>
<tr>
<td>1973</td>
<td>-</td>
<td>1,355.6</td>
<td>Nonbinding</td>
</tr>
<tr>
<td>1974</td>
<td>-</td>
<td>1,079.1</td>
<td>Nonbinding</td>
</tr>
<tr>
<td>1975</td>
<td>1,215.0</td>
<td>1,208.8</td>
<td>Binding</td>
</tr>
<tr>
<td>1976</td>
<td>1,233.0</td>
<td>1,231.7</td>
<td>Binding</td>
</tr>
<tr>
<td>1977</td>
<td>1,271.8</td>
<td>1,249.8</td>
<td>Binding</td>
</tr>
<tr>
<td>1978</td>
<td>1,492.3</td>
<td>1,485.7</td>
<td>Binding</td>
</tr>
<tr>
<td>1979</td>
<td>1,569.9</td>
<td>1,553.8</td>
<td>Binding</td>
</tr>
<tr>
<td>1980</td>
<td>-</td>
<td>1,422.0</td>
<td>Nonbinding</td>
</tr>
<tr>
<td>1981</td>
<td>-</td>
<td>NA</td>
<td>Nonbinding</td>
</tr>
</tbody>
</table>


From 1968 to 1970, it was legal to tranship meat to the United States via Canada; therefore, it was possible for total imports to exceed the quota by a small amount [Bain, 1977, p. 54].

For various reasons, it was not possible for importers to exactly fulfill the restraint limit. Clearly, however, the quota was the factor determining import levels in these years.
if the level of imports can be viewed as predetermined. Obviously, the process of ordering imported beef, arranging for transport, shipping and then distributing of the meat within the United States takes some time. The shipping time alone is generally four to six weeks between Australia or New Zealand and the major ports on the U.S. East Coast. Given these time lags, the assumption of predetermined imports seems necessary for a monthly model and reasonable for a quarterly model.

In an annual model, it becomes difficult to justify treatment of imports as either predetermined or exogenous except for purely practical reasons. For the year as a whole, the supply of imports is endogenous up to a limit imposed by the import quota restraint. Using the notation of Chambers, Just, Moffitt, and Schmitz [1981], the market structure for imported beef can be characterized algebraically as:

\[
\begin{align*}
ED &= ED(P, M, Z, H) \\
ES &= ES(P^*, M^*, Z^*, H^*) \\
QM &= ED = ES \text{ for } QM < \bar{Q} \\
QM &= \bar{Q} \text{ for } ED = ES > \bar{Q}
\end{align*}
\] (4.1) (4.2) (4.3)

Where:

- \(ED\) is the U.S. excess demand for imports,
- \(ES\) is the excess supply curve of the Rest of the World (ROW),
- \(QM\) is the actual quantity of imports,
- \(\bar{Q}\) is the predetermined quantity restraint for imports,
- \(P\) is a vector of prices,
- \(M\) is consumer income,
Z and H are vectors of shift parameters, and * denotes the same variables in the rest of the world.

This situation is depicted in Figure 4.1 for two arbitrary levels of the import quota, \( \bar{Q}_1 \) and \( \bar{Q}_2 \). With quota level \( \bar{Q}_1 \), the level of imports is determined solely by the import quota and this causes the price to rise from its free trade equilibrium level, \( P_E \), to the higher level, \( P_1 \). For quota level, \( \bar{Q}_2 \), by contrast, the quota has no effect on either the quantity transacted or the price. Under quota \( \bar{Q}_2 \), the price is given by \( P_E \) and the quantity by \( Q_E \).

The market situation represented in Figure 4.1 is a simultaneous equations version of the limited-dependent variable case first analyzed by Tobin [1958]. One estimation procedure, which seems intuitively reasonable in this situation, is merely to estimate the functions using only those observations for which the restraint was not binding. This procedure would be very inefficient in this case since only 8 of the 17 years from 1965 to 1981 would be available for estimation (see Table 4.1). In addition, Heckman [1976] has pointed out that this approach involves sample truncation which can seriously bias the resulting parameter estimates.

Tobin [1958] has proposed estimators for the limited-dependent variable case. While Tobin dealt only with the single equation case, his analysis has since been generalized and applied in the simultaneous equations case [Sickles and Schmidt, 1980].

The most theoretically satisfactory approach to estimating annual excess supply and demand curves for beef imports would appear to be the
Figure 4.1. Supply, demand, and quantity transacted in a market with a quantity constraint
use of a simultaneous limited-dependent variable approach. Unfortunately, the maximum likelihood estimators used for this type of estimation are likely to become complicated and expensive if a reasonably large structural model is to be estimated. If only estimates of the demand function for beef imports are desired, then a much simpler approach is to use data of a shorter periodicity so that imports can be taken as predetermined in the specification of the model. As Johnston [1972, p. 380] points out ... "enforced aggregation over time periods can turn a recursive model into a simultaneous one with all the resultant estimation problems."

In a recent article, Chambers, Just, Moffitt, and Schmitz [1981], hereinafter CJMS, have proposed the use of price-disequilibrium econometrics as a procedure to take into account the effects of the quantity restraints on the U.S. beef import market. In the next section, we will examine the extent to which their approach overcomes the problems introduced by the quantity constraints and the effect of their specification on the resulting parameter estimates.

The Disequilibrium Approach

In the first part of their article, CJMS postulate that the "ex post" supply function is shifted upwards by the existence of the quantitative import restraint. Because the restraints are negotiated on an annual basis, the supply function is not merely raised, but rather becomes completely vertical in an annual model. Their specification is, however, appropriate for a model dealing with subperiods of a year. When
the annual restraint is binding, imports in any subperiod of the year are still price responsive, but entitlement to import is scarce and has a value or shadow price. The marginal cost of importing is increased because importing one unit of meat uses up a valuable unit of entitlement to import. As a result, the supply curve of imports in any subperiod is raised by the value of an entitlement to import.

It does not seem appropriate to term this effect a source of continuing disequilibrium. Before January 1 of each year, the Secretary of Agriculture must publish the quantity which determines the import restraint level for the coming year [Conable, 1980, p. 1]. Because meat importers are aware of the likely effect of the restraint well in advance, the restraints cause a change in the structure of the market rather than a disequilibrating shock. Thus, the existence of the restraint leads to a new equilibrium price rather than to a disequilibrium outcome.

If the shadow price of entitlement to import were observable, as it would be if entitlements were freely traded, the change due to the import restraint could be incorporated in a conventional simultaneous equation model as a shift in the import supply function. Thus, conventional techniques could conceptually yield estimates of both the "ex ante" and the "ex post" curves. Because the shadow price is not readily observable, the estimation problem becomes much more difficult since any change in the shadow price is an unobservable change in the structure of the supply equation.
The actual model used by CJMS differs from equations (4.1)-(4.3) in that equation (4.3) has been replaced by a Walrasian price adjustment rule (4.4) and an associated short-side rationing rule (4.5):

\[ \Delta P_t = \gamma (ED_t - ES_t) \]  \hspace{2cm} (4.4)

\[ QM_t = ES_t \text{ for } \Delta P_t > 0, \text{ and} \]  \hspace{2cm} (4.5)

\[ QM_t = ED_t \text{ for } \Delta P_t \leq 0 \]

Where:

\( \gamma \) is a price adjustment parameter, \( (\gamma > 0) \)

In their model, price adjusts in each period from its level in the previous period and then, at the new price, the quantity transacted is determined by the "short-side" of the market. Thus, in Figure 4.2, price \( P_1 \) (where \( \Delta P > 0 \)) and price \( P_t \) (where \( \Delta P < 0 \)) both correspond to quantities \( Q_1 \) and \( Q_t \), which are less than the free trade equilibrium quantity, \( Q_E \). The assumption of a structural upward shift in the supply curve to \( ES' \) also leads to a smaller transacted quantity, \( Q_R \), but for an entirely different reason.

The actual empirical model used by CJMS is a short-side price-disequilibrium model [Bowden, 1978, p. 80]. Deviations from equilibrium in this model occur only because prices do not adjust fully from last period's price to the current equilibrium price. A current equilibrium point is defined by the intersection of the supply and demand curves in this model and disequilibrium at any instant is defined in relation to this equilibrium value. The implicit equilibrium in the CJMS model
Figure 4.2. Supply and demand in a market with partial price adjustment.
should have been that associated with the import restraints, not the
now nonexistent free trade or "ex ante" equilibrium. Unfortunately,
CJMS specified the free-trade supply function in their empirical model,
even though the process generating their observations must correspond
to the restrained or "ex post" supply curve, ES*. This leads to an
omitted-variable problem because variables to indicate the degree of
restrictiveness of the import restraint, e.g., the shadow price of
entitlement, have been omitted from the supply function. Alternatively,
the problem can be thought of as one of structural change, with the
position of the supply function changing every time the value of import
entitlement changes.

The problem of structural change might not be serious, if the
import restraints had only a minor effect in the market, or if the
shadow price of entitlement had been stable. However, the import
restraints are a dominant feature of the market and their effect
definitely changed during the CJMS sample period. In their sample
period (January 1974-October 1976), the import restraint was nonbinding
(zero entitlement value) in 1974 but binding (positive entitlement
values) in 1975 and 1976 (see Table 4.1). The value of the shadow
price of entitlement may also have varied considerably both between
and within 1975 and 1976.

The omitted variable problem seems almost certain to lead to bias
in the CJMS maximum likelihood estimates, as it does in the conventional
regression case [Dhrymes, 1970, p. 227]. The shadow price of entitle-
ment is endogenous and so it will be correlated with the error terms in
the model, increasing the likely severity of the bias. At the very least, if the other parameter estimates are unbiased, the "ex ante" supply curve estimate must be biased upwards because the shadow price has a one-sided distribution -- the actual import supply function must lie on or above the free-trade function.

CJMS chose to estimate their model by a maximum likelihood procedure. Their estimation procedure required maximization of a nonlinear likelihood function. The various algorithms for nonlinear maximization [Goldfeld and Quandt, 1972, Chapter 1] have differing performance characteristics and require starting values whose selection influences whether the solution will be a global maximum rather than merely a local maximum or a saddle point. Information on the algorithm used, the selection of starting values, and tests that they have located a global maximum of the likelihood function, would have been useful in evaluating their empirical results.

Another aspect of the CJMS specification, which gives rise to concern, is the implied timing of responses in their model. In particular, they specify the supply of imports as a function of Australian price and other economic variables in the current month. Because meat generally takes four to six weeks to travel from Australia to the major importing ports on the U.S. East Coast, this specification does not appear to be realistic.

The import restraints undoubtedly pose serious problems for estimation in this market. However, once realistic lags are introduced, the supply of imports becomes predetermined in a monthly model. Taking
advantage of the fact that imports are predetermined in any month, it becomes possible to reestimate the import demand function in a theoretically satisfactory manner. Reestimating the CJMS demand equation in price-dependent equilibrium form over their sample period resulted in the following OLS estimates:

\[
\ln \left( \frac{HP}{CPI} \right)_t = 4.99 - 0.18 \ln QM_t + 0.042 \ln \left( \frac{PP}{CPI} \right)_t \\
\quad - 0.44 \ln \left( \frac{M}{CPI} \right)_t - 0.11 \ln PLONF_t \\
\quad (12.0) (0.13) (0.25) (1.38) (0.10)
\]

\[ R^2 = 0.16; DW = 0.28; \text{figures in parentheses are standard errors} \]

Clearly, the equilibrium model specified in Equation 4.6 does not appear to fit the data satisfactorily. None of the estimated coefficients is significant at the 10-percent level (two-tailed test), the Durbin-Watson statistic indicates positive autocorrelation of the

---

\(^1\) The variables used follow the descriptions given by CJMS [1981, p. 129], i.e., monthly data for January 1974-October 1976 for:

- CPI = U.S. consumer price index; all items 1967=100 [Bureau of Economic Analysis, 1975-1977],
- HP = retail price of ground beef, c/lb. [USDA, 1979c],
- M = U.S. personal income in millions of dollars [Bureau of Economic Analysis, 1975-1977],
- PLONF = seven states cattle placed on feed, thou. [USDA, 1976, 1978a],
- PP = retail pork price, c/lb. [USDA, 1978b], and
- QM = imports of beef and veal, mil. lb. carcass weight [Chambers et al., 1981, p. 132].
residuals and the $R^2$ indicates very low explanatory power. This single equation was then reestimated in a version which allows for price disequilibrium in order to provide a test for the hypothesis of price equilibrium and to obtain an improved estimate of the elasticity of demand for imports. Any price disequilibrium observed in this model could be caused by factors such as slow adjustment of prices or delays in revising price expectations. It would not be caused by the import law since imports are always assumed predetermined. The model used was:

$$(P_t - P_{t-1}) = (1-\mu) \cdot (P^*_t - P_{t-1}) + e_t$$ (4.7)

Where:

- $P_t$ is $\ln \frac{(HP/CPI)_t}{P^*_t}$
- $P^*_t$ is the equilibrium price as specified in Equation (4.6),
- $\mu$ is a coefficient of friction in price adjustment, $0 \leq \mu \leq 1$,
- $e_t$ is a random error term.

Equation (4.7) was first estimated by ordinary least squares to obtain starting values which were then used in the Gauss-Newton nonlinear least squares estimator with analytical derivatives [Barr et al., 1979, p. 317]. The resulting equation estimate (with asymptotic standard errors given in parentheses) was:
\[(P_t - P_{t-1}) = (1 - 0.88) \cdot (7.42 - 0.60 \ln QM_t + 0.82 \ln (PP/CPI)_t \]
\[\hspace{1cm} (0.055) (26.8) (0.36) (0.68)\]
\[\hspace{1cm} - 0.4 \ln (M/CPI)_t - 0.18 \ln PLONF_t - P_{t-1}) \]
\[\hspace{1cm} (3.1) (0.22)\]

Only the parameter estimates for \(\mu\) and the own-price flexibility coefficient were significant at the 10 percent level (one-tailed test) and these are of particular interest. A value of zero for \(\mu\) implies complete price adjustment in one period (i.e., an equilibrium model) while a value of unity implies a total lack of price responsiveness. Using this model, the equilibrium hypothesis of complete price adjustment \((\mu = 0)\) is rejected. This result provides tentative support for the assumption by CJMS that price disequilibrium is more appropriate than price equilibrium for this market. The equation implies a price flexibility of \(-0.60\) which, when inverted, leads to a demand price elasticity of \(-1.66\). This is noticeably more elastic than the estimate of \(-0.97\) obtained by CJMS, although part of the difference might be due to the change from quantity-dependent to price-dependent form.

The test for \(\mu = 0\) described above provides only a tentative test for price disequilibrium since the estimated value of \(\mu\) may partially reflect autocorrelation of the residuals. Attempts were made to obtain estimates for a more complex nonlinear model with autoregressive disturbances, but it was not possible to obtain satisfactory estimates using this data set. Resolution of this question will probably require further analysis with larger data sets.
While it has been possible to obtain some estimates of the demand function parameters, there does not seem to be any straightforward way to obtain improved estimates of the supply function. Detailed specification of the effects of import restrictions and the export controls used by exporting countries [Reeves, Longmire, and Reynolds, 1980] and, possibly, use of techniques such as limited-dependent variable analysis [Tobin, 1958] seem necessary to obtain improved estimates of the underlying supply function.

CJMS have made a useful contribution through their concise exposition of an interesting type of price disequilibrium econometrics and the suggestion that these procedures may be useful for estimation with monthly data in this market. Unfortunately, they omitted the quantity constraint in their specification of the empirical model and this omission could lead to serious bias in their parameter estimates. Reestimation of their demand function without this potential source of bias resulted in a somewhat more price-elastic estimate than they obtained. The problems arising from the CJMS specification emphasize the need for extreme caution in the specification of a particular disequilibrium model for the market situation under investigation.
CHAPTER V. SPECIFICATION AND ESTIMATION
OF AN ECONOMETRIC MODEL

In previous chapters, we have described the structure of the individual components of the U.S. livestock-feed subsector and discussed some of the modeling issues involved in constructing a model of this system. In this chapter, it remains to integrate the components of the system and to specify and estimate the equations of a model which can be used to represent the behavior of the system as a whole.

The first section of this chapter is concerned with a synthesis of the system from its various components. In the second section, we turn to the procedures used to obtain estimates of the parameters of the system. In subsequent sections, we consider the specification and estimation of individual equations within the components of the system. The sections of this chapter dealing with the individual equations of the model cover four of the five stages in model construction, those of specification, estimation, verification, and revision. The final stage, that of validation of the model, is discussed in Chapter VI.

Systems Synthesis

Three aspects of the system need to be considered when synthesizing the components of the system: (1) the physical flows which define the system, (2) the corresponding financial flows and prices which guide the evolution of the system, and (3) the dynamic relationships of the system.
Figure 5.1 illustrates some of the more important activity relationships in the system under investigation. The complexity of the interactions between components of the subsector is clearly evident from this figure which is itself a considerable simplification, ignoring both the coordination processes of the system and its intertemporal linkages.

The beef industry is the most complicated single component of the overall system depicted in Figure 5.1. It involves the longest lags of any component of the system and its behavior depends greatly upon two levels of decisions: those regarding cow inventories, and those regarding subsequent placements of cattle on feed.

The size of the inventory of breeding cows largely determines the size of the subsequent calf crop. Some calves are slaughtered and the veal produced becomes a part of final meat consumption. While veal production is unimportant in relation to total meat production, the number of calves slaughtered has been a significant (albeit declining, as noted in Chapter II) leakage from the supply of calves for feeding.

The availability of cattle for placement on feed depends upon the size of past calf crops, the number of feeder cattle imported and the number of calves previously slaughtered. A well-developed market for feeder steers and heifers facilitates the allocation of feeders between placement on feed and retention on pasture. Heifers not placed on feed may be prepared for slaughter from pasture or be allocated to the breeding herd. This allocation is guided by the expected future
Figure 5.1. Major activity relationships in the U.S. livestock-feed system relevant to this study
profitability of maintaining cows and the opportunity cost of keeping cows rather than slaughtering them.

Those cattle placed on feed generally yield carcasses which are graded as USDA Choice or better. The meat from these animals provides the great majority of meat used for table cuts. However, as noted in Chapter II, around 20 percent of the meat produced from these carcasses is generally used for processing purposes and this provides a direct link between the supply of table and processing quality beef.

Table and processing quality beef are largely handled by the same marketing firms, but processing quality beef is likely to undergo transformation prior to reaching the final consumer. Although the time lags involved in the physical marketing process are likely to be relatively short, there is evidence of delays of about a month in price adjustment between the farm and retail level [Miller, 1979, p. 146].

The pork industry is somewhat simpler in structure than the beef industry. However, it does involve the maintenance of two sets of inventories: a breeding hog inventory and a market hog inventory. While a feeder pig market exists to coordinate the placement of feeder pigs between individual firms, virtually all pigs born are ultimately placed on feed. Both hog feeding and cattle feeding are major sources of demand for feed grains and this is a source of interaction between the production of pork and of beef.

Broiler production involves relatively short, but still significant, lags in production. It is related to the other meat production
activities through the market for feed, although it does not compete directly for many other production resources.

The major source of interaction between the meats occurs at the level of consumer demand. Previous studies have found relatively strong demand substitutability between meats and, usually, a strong relationship between meat demand and consumer incomes.

The feed grain market affects all three meat producing industries considered in this study. In addition to these linkages with the domestic livestock industries, the feed grain industry is affected by government policy, by food demand, and by export demand.

While the equations of the model have generally been estimated one at a time, it is important to bear in mind their relation to the system as a whole. Having looked at the structure of the overall system, we now turn to the structure of the model used to represent the system and the method of estimation.

The Structure of the Model and Its Method of Estimation

Model structure

The structure of the estimated model was based upon the structure of the system depicted in Figure 5.1, together with the price coordinating mechanisms and intertemporal linkages of the system.

Quarterly data were chosen for the analysis because of the problems introduced by the limited-dependent variable nature of beef imports in an annual model. Although it was recognized that production and
inventory responses are generally not greatly affected by current price in a quarterly model, it did not seem appropriate to impose, a priori, the strict recursiveness conditions\(^1\) required for estimation by Ordinary Least Squares (OLS). Accordingly, a simultaneous-equations procedure was used to estimate the equations.

Although nonlinearities in either the variables or the coefficients of the model were not ruled out, the basic intent was to estimate the model in as near as possible to linear form in both the variables and the coefficients. Linear models have performed well in representing the behavior of the livestock-feed subsector in earlier studies [e.g., Freebairn and Rausser, 1975; Arzac and Wilkinson, 1979a]. In addition, the range of estimation techniques is best developed, and least expensive, for this class of problem.

The size of the model was determined by the minimum number of equations necessary to represent the system at the level of disaggregation consistent with the objectives of the study. The result was a model of 55 equations of which 27 are stochastic behavioral relations and the remaining 28 are identities.

Of the published models of the livestock-feed subsector that were available, the one closest in structure to the requirements of this study was the model developed by Enrique Arzac and Maurice Wilkinson [1979a]. The structure of their model was used as a basis for the

\(^1\)These conditions, (1) a triangular coefficient matrix and (2) a diagonal error covariance matrix, require that the value of the variables can be calculated sequentially and that the errors in separate equations be uncorrelated.
construction of the model used in this study, with a number of major modifications to allow for investigation of particular policy issues.

The major differences between this model and the Arzac and Wilkinson model are: (1) disaggregation of beef consumption into table/processing beef instead of fed/nonfed beef to allow for the possibility of bias due to inclusion of the entire fed carcass in the high-quality meat category [Ryan, 1980], (2) disaggregation of nonfed beef production into: cow beef; bull beef; and nonfed steer and heifer beef. This disaggregation was undertaken in order to allow analysis of the effects of the Meat Import Act of 1979 [U.S. Congress, 1979], (3) inclusion of beef and pork inventory behavior, (4) use of an explicit grain stocks equation (This allows account to be taken of the effects of government inventory changes on private stock-holding behavior.), (5) allowance for the change in regime resulting from introduction of the Farmer-Owned Reserve grain storage program, and (6) the use of deflated prices in the supply, as well as the demand, equations. This transformation was introduced to mitigate anticipated problems of spurious regressions, due to a common trend in variables, and of multicollinearity between the explanatory variables.

The behavioral equations of the model can usefully be considered in a number of groups: (1) meat demand, (4 equations), (2) meat marketing and inventory (6 equations), (3) beef supply (4 equations), (4) placements and price of feeder steers (2 equations), (5) cow and calf inventories (3 equations), (6) pork production (3 equations), (7) chicken production (1 equation), and (8) corn production and marketing (4 equations).
These groups provided a basis for structuring the model, and in some cases, affected the method of estimation used for equations within a particular block. The estimation procedures used for the equations of the model will now be discussed prior to a detailed consideration of the specification and estimation procedures used for the individual equations.

**Estimation technique**

Most of the equations of the model were estimated using quarterly data for the period 1962I-1979IV. This provided a total of 72 observations for use in estimating the parameters of the model. Since there was a total of 63 predetermined variables in the final model, the direct implementation of the two-stage least squares (2SLS) estimator was technically feasible. However, it has frequently been found that the use of 2SLS yields estimates which are similar to OLS estimates in cases where there are almost as many predetermined variables as there are observations [Maddala, 1978, p. 208].

To overcome this problem, the model was divided into blocks and the simultaneous-equation block was estimated using primarily the truncated two stage least squares method. The set of regressors for the first stage regressions was chosen so that the estimator would be equivalent to an instrumental variable estimator. In any equation, the set of first-stage regressors consisted of a common set of predetermined variables used in every equation, plus any predetermined variables appearing in this equation.
For estimation purposes, use was made of the block-recursive nature of the system. The four blocks considered were: (1) poultry meat supply (1 stochastic equation), (2) calf crop and feeder calf inventory (2 stochastic equations), (3) corn production (2 stochastic equations), and (4) beef-pork production and meat demand (22 stochastic equations). Only block (4) was a simultaneous block and, in estimating the equations of this block, it was possible to treat the variable whose values were determined in the other three blocks as predetermined [Dhrymes, 1970, p. 311]. The instrumental variable or truncated two-stage least squares approach applied to the estimation of block (4) should provide consistent estimates of the parameters of the model although, like 2SLS, the estimates will not be fully efficient.

It is frequently claimed that truncated two-stage least squares is not consistent. However, the consistency of the particular estimator used in this study can readily be demonstrated. Writing the ith equation as:

\[ y_i = y_i \beta_i + x_i g_i + e_i \]  

(5.1)

Where:

- \( y_i \) is an \( n \times 1 \) vector of the normalized endogenous variable in the ith equation,
- \( y_i \) is an \( n \times g \) matrix of the other endogenous variables in the ith equation,
- \( \beta_i \) is a \( g \times 1 \) vector of coefficients on the other endogenous variables,
$X_1$ is an $n \times k$ matrix of the predetermined variables in the equation,

$G_1$ is a $k \times 1$ matrix of coefficients on the exogenous variables,

and

$e_t$ is an $n \times 1$ vector of error terms.

It will be convenient to rewrite this equation as:

$$y_i = [Y_1 X_1] \delta_i + e_t$$  \hspace{1cm} (5.2)

Where:

$$\delta_i = \begin{bmatrix} \beta_i \\ G_i \end{bmatrix}$$

The truncated two-stage least squares procedure consists of replacing the matrix $Y_1$ by a matrix, $\hat{Y}_1$, which consists of predicted values of the columns of $Y_1$ derived from ordinary least squares using the matrix $[X_s X_1]$ of explanatory variables; where $X_s$ is the basic set of variables used in forming the instruments, $\hat{Y}_1$, and $X_1$ is the set of predetermined variables in the equation. The second-stage regression can be written as:

$$\hat{\delta} = [\hat{Y}_1 X_1]'[\hat{Y}_1 X_1]^{-1}[\hat{Y}_1 X_1]' y_i$$  \hspace{1cm} (5.3)

Expanding the inverse in (5.3) results in:

$$\hat{\delta} = \left[ \begin{bmatrix} \hat{Y}_1 & \hat{Y}_1' X_1 & X_1' \hat{Y}_1 & X_1' X_1 \end{bmatrix}^{-1} [\hat{Y}_1 X_1]' y_i \right]$$  \hspace{1cm} (5.4)
Recalling that \( \hat{Y}_1 \) can be written as \( \hat{Y}_1 = Y_1 - \hat{V}_1 \), where \( \hat{V}_1 \) is the matrix of errors in prediction of \( Y_1 \) and that \( \hat{V}_1 \) is orthogonal to both \( \hat{Y}_1 \) and \( [X_sX_s'] \), allows us to simplify (5.4) to:

\[
\hat{\delta} = \begin{bmatrix}
\hat{Y}_1 Y_1 & \hat{Y}_1 X_1 \\
X_1 Y_1 & X_1 X_1
\end{bmatrix}^{-1} [Y_1X_1]' y_1
\]  

(5.5)

or

\[
\hat{\delta} = ([Y_1X_1]'[Y_1X_1])^{-1} [Y_1X_1]' y_1
\]  

(5.6)

This is clearly an instrumental variable estimator for \( \delta \), where \( Y_1 \) has been used as an instrument for \( Y_1 \) and \( X_1 \) acts as its own instrument [see Johnston, 1972, p. 278-81]. The inclusion of the \( X_1 \) variables in the first stage regression is crucial to establishing the equivalence of the truncated two-stage least squares estimator and an instrumental variable estimator: it ensures that the \( X_1' \cdot \hat{V}_1 \) terms vanish because of the orthogonality of predicted and residual values from a least-squares regression.

Having established that the estimator used is an instrumental variable estimator, it is an easy matter to demonstrate the consistency of the approach. By assumption, the exogenous variables \( X_1 \) and \( X_s \) are uncorrelated in the limit with the error term in the equation: i.e., \( \text{plim} \frac{1}{n} [X_sX_1]'u = 0 \). As a result, \( \hat{Y}_1 \), which is a linear combination of \( [X_sX_1] \), will be uncorrelated with \( u \). Substituting (5.2) into (5.6) gives:
\[ \hat{\delta} = \left( \hat{Y}_1X_1' \right)^{-1} \left( Y_1X_1 \right) \delta + \left( \hat{Y}_1X_1' \right)^{-1} \left( Y_1X_1 \right) u \]  

(5.7)

Thus,

\[ \text{plim} \hat{\delta} = \delta + \text{plim} \left( \frac{1}{n} \hat{Y}_1X_1' \right)^{-1} \left( Y_1X_1 \right) u \]  

(5.8)

The correlation between the disturbance terms in most of the equations was regarded as sufficiently small so that no great loss in efficiency would result from estimation of the equations on a single equation basis. In addition, when one is not completely confident of the appropriate specification for some of the equations, the advantages of system methods of estimation such as three-stage least squares (3SLS) are considerably diminished. However, in the case of the meat demand equations, it was felt that the correlation between the error terms would be sufficiently high to justify estimation of these equations as a system using truncated 3SLS.

Autocorrelation of the residuals has been detected in most models of the livestock-feed subsector. This problem is even more serious in a simultaneous-equations model with lagged dependent variables than in the single equation case. All of the endogenous variables in a simultaneous equations model are correlated with the error terms of all the equations [Johnston, 1972, p. 351]. As a result, an autocorrelated error term in any equation may be correlated with any lagged endogenous variables appearing in this equation. Instruments formed using the
lagged endogenous variable may then be correlated with the error terms and can, in this case, result in inconsistent parameter estimates.

Two approaches were used to reduce the seriousness of this problem. The first approach involved the selection of the variables used in the first stage of the estimation procedure. The second approach was to estimate under the assumption of autocorrelated residuals using a procedure suggested by Fuller [1978].

To reduce the potential problems caused by autocorrelated residuals, the basic set of variables used in the first stage regressions was selected so as to exclude first order lags of endogenous variables. While this selection procedure need not eliminate the autocorrelation problem, it should considerably diminish its severity since the correlation between an autoregressive error term and its lagged values diminishes exponentially.

The set of variables used in the first stage of the truncated 2SLS regressions was selected partly on the basis of the importance of particular variables and partly with a view to minimizing the correlation between lagged dependent variables and the error terms. The resulting set included almost all of the exogenous variables of the model and a subset of the more important endogenous variables, particularly those lagged two or more periods. The basic set used in forming the instrument, consisted of the 27 variables: BCOWS_{t-1}, HBR_{t-2}, KFC_{t-1}, KFC_{t-2}, PF_{t-3}, RBSP_{t-2}, RBSP_{t-3}, RBSPA_{t-4}, BM, CHPDN, CPU, (ICT_{t-1} + COSPRUS), EC, GCPF, ICG, KC, KFC, MCOWS, PCDUM, PPEX, Q2, Q3, Q4, USPOP, WRMP,
WRPP, and YZC. The definitions of these variables are given in Appendix A.

If the correlation between the explanatory variables and the error term of each equation has been approximately removed by the use of the first stage regression, then the presence of autocorrelated residuals will have the same effects as it does in the single equation case. Most importantly, coefficients obtained will be unbiased, even though they will be inefficient, and the sampling variances of the estimators are likely to be under-estimated [Johnston, 1972, p. 246].

In one equation of the final model, the parameter estimates obtained after correction for autocorrelation were preferred to those obtained using the uncorrected estimator. These estimates were obtained using a one-step estimator suggested by Fuller [1978] for dealing with estimation of a single equation in a simultaneous system where the residuals are autocorrelated. The basic method has been documented in detail for the related problem of regression with lagged dependent variables [Fuller, 1976, p. 439].

Fuller's method is an adaptation of the one step Gauss-Newton procedure for estimating equations with autocorrelated errors. Following Fuller [1978], we write the equation of interest as:

\[ y_1 = Y_2 \beta + X_1 \gamma_1 + Y_3 \gamma_{3,-1} + U_1 \]  \hspace{0.5cm} (5.9)

where the elements of \( U_1 \) are assumed to satisfy
\[ u_{t1} = \rho_1 u_{t-1,1} + e_t \quad \text{subject to } |\rho_1| < 1 \]

\[ e_t \sim \text{NID}(0, \sigma^2) \]

It is also assumed that \( e_t \) is independent of the lagged values of all endogenous variables in the system. The matrix \( Y_2 \) contains observations on endogenous variables other than \( Y_1 \) in the equation. \( X_1 \) is the matrix of exogenous variables included in the equation and \( Y_3,-1 \) is the matrix of lagged endogenous variables included in the system. The matrix of exogenous variables included in the system, but not in the equation, is denoted \( X_2 \) and the matrix of lagged endogenous variables not included in the equation is \( Y_4,-1 \).

The method of estimation consists of the following five steps:

1. A regression of \( Y_2 \) and \( Y_3,-1 \) on a set of exogenous and lagged exogenous variables. (No lagged endogenous variables are included in this regression.)
2. A regression in which the values of \( Y_2 \) and \( Y_3,-1 \) in (5.9) are replaced by their predictions from step (1),
3. Calculation of the estimated residuals of equation (5.9), using:
\[ \hat{u}_{t1} = y_1 - \hat{y}_2 - \hat{X}_1 y_1 - \hat{Y}_{3,-1} y_3, \]

(Using these residuals, an initial estimate of \( \rho \) can be obtained from the regression of \( u_{t1} \) against its first order lag.)
4. Transformation of all the variables appearing in Equation (5.9) by the transformation matrix \( T \) appropriate for first order autocorrelation [Johnston, 1972, p. 260], and
5. Estimation of the parameters of (5.9) by 2SLS using the following Taylor Series approximation to the correct value of \( \rho \).
where \( y_1, y_2, x_1 \) and \( y_{3,-1} \) in (5.10) refer to the variables after transformation in step (4) above and \( \Delta \rho = \rho - \hat{\rho} \). In this estimation process, the lagged endogenous variables may be included in the first stage regressions since the remaining error term is assumed uncorrelated with the lagged endogenous variables. The lagged error term \( U_{1,-1} \) is replaced by its estimate from step (3), \( \hat{U}_{1,-1} \), which is treated as a predetermined variable and so is included in the list of first stage regressors. The standard error for the final estimate of \( \rho \) is given by the standard error of \( \Delta \rho \), since the original estimate is treated as a constant in the regression of (5.10).

Using SAS [Barr et al., 1979], the procedure described above was implemented in three stages:

(a) 2SLS, using only exogenous variables in the first stage, was used to obtain initial parameter estimates as in steps (1) and (2) above.

(b) The residuals from step (1) were regressed against a column of ones by autoregressive least squares with the intercept suppressed. The estimate of \( \rho \) obtained, \( \hat{\rho} \), was used to transform all of the variables in the problem, including a column of ones for use as an intercept in step (c).

(c) The 2SLS estimator was applied to the transformed variables as in step (5) above. The transformed column of ones was used in place of the usual intercept term in this regression.
In a number of equations, a lagged value of the dependent variable was included on the right-hand-side of the equation. In this situation, the resulting parameter estimates will be biased, even in large samples, if the errors are autocorrelated [Johnston, 1972, p. 307]. In addition, the Durbin-Watson statistics for detecting autocorrelation will be biased against rejecting the null hypothesis of no autocorrelation [Johnston, 1972, p. 309].

Where a lagged dependent variable occurred in an equation estimated by two-stage least squares, the value of the lagged dependent variable was replaced by its predicted value from the first stage regression. This is a variant of the two-stage least squares approach to dealing with the problems of lagged dependent variables [Judge et al., 1980, p. 666] and will result in consistent, but not fully efficient, parameter estimates. Given these consistent parameter estimates, the calculated Durbin-Watson statistics will still be asymptotically valid and so have been presented for these equations. Where an equation was estimated by OLS, Durbin's h-statistic has been presented as a test for autocorrelation.

An $R^2$ statistic has been reported for each equation. While this statistic is not well-defined [Basmann, 1962], it is widely recognized and generally gives a useful indication of the extent to which the specified model fits the data. Another statistic, the ratio of the equation's standard error to the mean of the dependent variable ($S/M$) has also been reported as an alternative indicator of the goodness of fit of equations estimated by 2SLS.
Once an equation had been estimated, its diagnostic statistics and estimated coefficients were first examined to verify that the implied relationship was worthy of further testing. Equations were reestimated with different specifications in these cases: where the overall equations did not appear to explain the data satisfactorily; where individual, key parameters were statistically insignificant; or where the signs or magnitudes of the coefficients were regarded as implausible. An equation which had been verified in these respects was then tentatively retained in the model for subsequent testing in the validation stage.

The validation of equations was primarily done using a structured simulation approach. Individual blocks of equations were simulated as a test that the equations of this block performed satisfactorily. A number of tests of the model as a whole were also undertaken before the final structure of the model was obtained. The information from the individual block simulations was found useful in locating the causes of problems, such as unstable simulation behavior, when these emerged in the model as a whole. The results presented in this chapter reflect the processes of specification, estimation, and revision. Preliminary versions of some equations are presented in those cases where these are of some interest in themselves. The results of validation tests for the final model, as a whole, are presented in Chapter VI.
Retail Demand for Meat

The retail meat demand equations of the model were estimated in per capita quantity-dependent form, using a linear functional form, and taking advantage of the homogeneity and symmetry restrictions suggested by economic theory. The specification of these equations will be discussed first, followed by presentation and discussion of the results.

The per capita quantity demanded of each meat was specified as a function of the price of each meat, a composite price of all other commodities and per capita consumer disposable income. The specification used is a considerable simplification from the general theoretical case where consumption is specified as a function of all prices and income. This reduction in the number of variables entering the demand equations is based upon the assumption that the utility function is separable between meats and other commodities [Green, 1976, p. 153]. Some form of separability has been invoked in almost all applied studies of demand [e.g., Heien, 1982, p. 213] in order to make the estimation process feasible.

The specification of the demand functions as simple, linear functions of the variables follows Arzac and Wilkinson [1979a], Freebairn and Rausser [1975], and most other analysts whose concern has been with the livestock subsector as a whole. Even though the demand functions were derived without reference to an explicit utility function, it is still possible to incorporate some of the restrictions derived from economic theory, as suggested by Fisher [1979, pp. 221, 222]. Consideration was given to estimating a Houthakker-Taylor model incorporating the possibility
of habit formation [Intriligator, 1978, p. 239] but this was not done because of the unsatisfactory results reported by Reeves [1979, p. 234].

One alternative to the direct specification of the demand function is the specification of an indirect utility function, from which the demand functions are derived via Roy's Identity [Varian, 1978, p. 93]. This approach is suitable for testing hypotheses about the underlying utility function by using a flexible functions form of the utility function [e.g., Christensen and Manser, 1977], or for imposing restrictions on behavior by specifying a restrictive functional form such as the Klein-Rubin utility function [Intriligator, 1978, p. 227].

The use of demand functions derived from a flexible approximation to the utility function (such as the translog function), has been found to be considerably more expensive than direct estimation of demand functions [Fisher, 1979, p. 226]. In addition, it yields equations which are highly nonlinear both in the parameters and in the variables. For these reasons, the utility function approach was not used to specify the demand equations of the model.

Another important issue in the specification of demand functions is the choice of functional form for the variables. While theory offers little guidance regarding the choice of functional form, the Box-Cox procedure [Zarembka, 1974, p. 81] provides a means of estimating an appropriate functional form from the data. Pope, Green, and Eales [1980] used this technique to investigate U.S. demand for beef and other meats. They concluded [1980, p. 782] that the specification of a linear demand function could not be rejected for beef with any of
the four demand functions used. For pork, a linear functional form was not rejected for their static demand model. Of the four meats to be considered in this study, poultry meat was the only one for which the linear specification was rejected. Since poultry demand is of relatively minor importance in this study, it was decided to continue with a linear functional form in all equations. The linear specification provides a local, Taylor-series approximation to any more complex underlying functional form.

A single meat demand function can be represented as:

\[ q = f(p_1, ..., p_n, y) \]  (5.11)

where \( p_i, i=1, ..., n \) are the prices which affect meat consumption and \( y \) is consumer income. Using the properties derived from the consumer's problem of utility maximization, it can be postulated that this function is homogeneous of degree zero in all prices and income. Choosing one of the prices as a numeraire, and drawing upon the properties of a homogeneous function [Chiang, 1974, p. 403], Equation (5.11) may be rewritten as:

\[ q = \left( \frac{1}{p_n} \right)^0 \cdot f\left( \frac{p_1}{p_n}, \frac{p_2}{p_n}, ..., 1, \frac{y}{p_n} \right) \]  (5.12)

or as

\[ q = g\left( \frac{p_1}{p_n}, \frac{p_2}{p_n}, ..., \frac{p_{n-1}}{p_n}, \frac{y}{p_n} \right) \]  (5.13)

Homogeneity may be imposed as a restriction in the estimation of the demand functions by specifying functions in the form of Equation
Alternatively, it may be tested as part of the estimation process when using a function in the form of Equation (5.11). Pope, Green, and Eales [1980] took the latter approach and concluded that the homogeneity restriction should be rejected. Rejection of this hypothesis is dependent upon the validity of the estimates obtained in its absence and it seems questionable whether satisfactory estimates could be obtained without it. For the data set used in this analysis, the correlations between the nominal prices ranged from 0.88 to 0.97, suggesting that multicollinearity was likely to be a serious problem without some form of deflation.

Because of both the strong theoretical basis for homogeneity and the desire to alleviate problems of multicollinearity in estimation, homogeneity was imposed upon the demand equations. This was done by dividing all prices by the consumer price index which represented the price of all other consumer products. After deflation, the price correlations ranged from 0.10 to 0.83, with most correlations nearer the lower end of this range. As well as mitigating potential multicollinearity problems, imposition of the homogeneity constraint reduced the number of parameters to be estimated by four.

The only other constraint from demand theory which is relevant to estimation of an incomplete demand system, such as the demand for meats, is the symmetry restriction [Fisher, 1979]. This restriction can be derived from the symmetry of the substitution effects in the Slutsky equation [Henderson and Quandt, 1980, p. 30]. The Slutsky equation is written:
Where:

- $Q_j$ is quantity of good $j$ consumed,
- $p_j$ is price of good $j$,
- $y$ is total consumer expenditure, and
- $U$ is the consumer's utility level.

The compensated cross partial derivatives representing the substitution effect are known to be symmetric and so:

$$\frac{\partial Q_j}{\partial p_j} = \frac{\partial Q_j}{\partial p_j} \bigg|_{U=\text{const.}} - Q_j \frac{\partial y}{\partial y}$$

Using (5.15) and (5.16), it follows that:

$$\frac{\partial Q_j}{\partial p_j} = \frac{\partial Q_j}{\partial p_j} + \left[ Q_i \cdot \frac{\partial y}{\partial y} - Q_j \cdot \frac{\partial y}{\partial y} \right]$$

Since the two income effects included in the brackets on the R.H.S. of (5.16) were estimated to be very close to zero for individual meats and were also similar in magnitude, the symmetry constraint was imposed directly on the Marshallian price effects, i.e., $\frac{\partial Q_j}{\partial p} = \frac{\partial Q_j}{\partial p}$. This restriction reduced the remaining number of independent parameters to be estimated from 16 to 10.

The restriction that cross-price effects be symmetric was imposed across the system of meat demand equations using the SYSREG procedure.
in SAS [Barr, et al., 1979, p. 407]. The final equations were also estimated as a system of four equations because it was expected that the error terms of these equations would be relatively highly correlated.

Price controls appeared to have a very large effect on the beef market between June and September of 1973 [Kosters and Ahalt, 1975, p. 72]. A binding price control should reduce the quantity transacted by moving consumers off their demand curves and making effective demand equal to the short side of the market, i.e., the quantity offered by suppliers. This effect was allowed for by using a dummy variable for the third quarter of 1973 in the beef demand equations.

Initial parameters estimates of the demand equations were obtained on the assumption that tastes were unchanging. These initial estimates included some key parameter estimates which were not consistent with the results of previous research. In particular, the estimated income elasticity for pork was negative, and the income elasticity of demand for table beef was only slightly higher than for processing beef. Since these findings seemed counter-intuitive, and contradicted all previous research results, a time trend was included in these equations to allow for the possibility of changes in preferences.

The final estimates for the meat demand equations are presented in Table 5.1, together with brief definitions of the variables used. The overall $R^2$ for this system was quite high, and the estimated correlations across equations were also reasonably high, suggesting

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1The correlation between the error terms of the processing beef and table beef equations was 0.60, and that between processing beef and pork was 0.56. Only the chicken/pork correlation was below 0.3.
Table 5.1. 3SLS estimates of the meat demand functions using symmetry constraints

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>XTBC</th>
<th>XPBC</th>
<th>XPKC</th>
<th>XCNC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>6.22</td>
<td>3.25</td>
<td>18.05</td>
<td>4.29</td>
</tr>
<tr>
<td></td>
<td>(3.20)</td>
<td>(3.49)</td>
<td>(12.23)</td>
<td>(3.74)</td>
</tr>
<tr>
<td>RPTB</td>
<td>-10.75</td>
<td>2.24</td>
<td>-0.031</td>
<td>1.31</td>
</tr>
<tr>
<td></td>
<td>(-10.59)</td>
<td>(2.26)</td>
<td>(-0.046)</td>
<td>(1.21)</td>
</tr>
<tr>
<td>RPGB</td>
<td>2.24</td>
<td>-16.65</td>
<td>6.69</td>
<td>2.48</td>
</tr>
<tr>
<td></td>
<td>(2.24)</td>
<td>(-13.27)</td>
<td>(9.45)</td>
<td>(1.85)</td>
</tr>
<tr>
<td>RPPK</td>
<td>-0.031</td>
<td>6.69</td>
<td>-17.97</td>
<td>1.62</td>
</tr>
<tr>
<td></td>
<td>(-0.046)</td>
<td>(9.45)</td>
<td>(-21.12)</td>
<td>(1.53)</td>
</tr>
<tr>
<td>RPCN</td>
<td>1.31</td>
<td>2.48</td>
<td>1.62</td>
<td>-14.89</td>
</tr>
<tr>
<td></td>
<td>(1.19)</td>
<td>(1.84)</td>
<td>(1.52)</td>
<td>(6.17)</td>
</tr>
<tr>
<td>YZC</td>
<td>7.13</td>
<td>3.23</td>
<td>3.54</td>
<td>2.07</td>
</tr>
<tr>
<td></td>
<td>(8.49)</td>
<td>(12.39)</td>
<td>(5.22)</td>
<td>(5.63)</td>
</tr>
<tr>
<td>PCDUM</td>
<td>-0.98</td>
<td>-0.29</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>(-1.67)</td>
<td>(-0.66)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>-0.051</td>
<td>--</td>
<td>-0.076</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>(-3.96)</td>
<td>(7.35)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q₂</td>
<td>0.15</td>
<td>-0.072</td>
<td>-0.59</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>(0.85)</td>
<td>(0.49)</td>
<td>(-3.82)</td>
<td>(6.92)</td>
</tr>
<tr>
<td>Q₃</td>
<td>0.38</td>
<td>0.44</td>
<td>-0.46</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>(2.10)</td>
<td>(2.97)</td>
<td>(-2.93)</td>
<td>(7.97)</td>
</tr>
<tr>
<td>Q₄</td>
<td>-0.12</td>
<td>0.31</td>
<td>0.99</td>
<td>0.021</td>
</tr>
<tr>
<td></td>
<td>(0.64)</td>
<td>(2.10)</td>
<td>(6.40)</td>
<td>(0.16)</td>
</tr>
</tbody>
</table>

R² for the system = 0.94

The variables appearing in the table are: PCDUM = price control dummy for 1973.3; RPTB = real price of table beef $/lb.; RPGB = real price of ground beef $/lb.; RPPK = real price of pork, $/lb.; RPCN = real price of chicken, $/lb.; T = time in quarters, 1 in 1960.1; XTBC = per capita consumption of table beef, lb.; XPBC = per capita consumption of processing beef, lb.; XPKC = per capita consumption of pork, lb.; XCNC = per capita consumption of chicken, lb.; YZC = real per capita disposable income $'000; Q₂, Q₃, Q₄ are quarterly dummy variables.

Figures in parentheses are t-statistics for H₀: coeff. = 0.
that noticeable gains in efficiency may have been realized by estimating these equations as a system.

The own-price coefficients in Table 5.1 all had the expected negative signs and were statistically significant. In this model, the own-price coefficients were also much larger than any of the cross-price coefficients; this contrasts with the Arzac and Wilkinson model [1979a, p. 300] where the cross-price coefficient for low quality beef was larger than the own-price coefficient in their high-quality beef demand equation. Reeves [1979, p. 239] reported severe instability problems associated with large estimated cross-price effects between his high and low-quality beef. In initial simulations of the model estimated in this study, the unrestricted demand equations also appeared to lead to instability problems.

The size and variability of the cross-price effects are much lower in the constrained 3SLS estimates than in the unconstrained estimates calculated for comparison purposes. In addition, the number of negative cross-price effects (complementarities) in the system has been reduced from five to two (and these two are both small and statistically insignificant). If the assumption of symmetry is accepted, then this suggests that estimated negative cross-price effects are most likely due to the attempt to estimate a large number of parameters relative to the information available in the data set. The results in Table 5.1 provide little support for the interesting hypothesis advanced by Hayenga and Hacklander [1970, p. 539] that some meats may be complements because of a desire by consumers for variety in the diet.
In both the table beef and the pork equation, the time trend variable was found to be statistically significant and to result in a substantial increase in the estimated income elasticity coefficient. Both of the estimated trend coefficients suggest a relatively rapid shift in consumer preferences away from these meats. The coefficient in the XTBC equation suggests a fall of 0.2 pounds per capita per year. Continued for a five year period, this shift in preferences would reduce table beef demand by one pound. This is reasonably important relative to per capita consumption of 15.5 pounds per quarter over the sample period. The estimated shift in preferences away from pork is slightly larger than for table beef and could become very important relative to average quarterly consumption of 16.8 pounds during the sample period.

Considerable support for the hypothesis of a decline in demand for beef and pork is provided by a paper by Braschler [1982]. On the basis of a Chow test for structural change, rather than a trend test for continuous change, Braschler concluded that the structure of demand for pork and, particularly, beef changed around 1970. A shift in preferences away from both table beef and pork, but not processing beef and chicken, might be at least partially explained by the rapid growth of fast food outlets during the 1960s and 1970s. Van Dress [1979] notes that expenditures on food away from home increased from $1 out of every $4 spent on food in 1960 to $1 out of every $3 in 1978 and that sales of franchised fast food firms increased from $7 billion to $17 billion between 1972 and 1978.
Price and income elasticities calculated for the equations presented in Table 5.1 are given in Table 5.2. These elasticities appear to be generally plausible in sign and magnitude. As expected, the own-price effects are larger in absolute value than the cross-price elasticities. The cross price elasticities are not symmetric since the symmetry constraint was applied only to the linear cross-price coefficients.

Table 5.2. Price and income elasticities of demand for meat at the sample means

<table>
<thead>
<tr>
<th>Price Quantity</th>
<th>RPTB</th>
<th>RPGB</th>
<th>RPPK</th>
<th>RPCN</th>
<th>YZC</th>
</tr>
</thead>
<tbody>
<tr>
<td>XTBC</td>
<td>-0.71</td>
<td>0.078</td>
<td>-0.001</td>
<td>0.03</td>
<td>1.34</td>
</tr>
<tr>
<td>XPBC</td>
<td>0.20</td>
<td>-0.77</td>
<td>0.39</td>
<td>0.073</td>
<td>0.81</td>
</tr>
<tr>
<td>XPKC</td>
<td>-0.0019</td>
<td>0.22</td>
<td>-0.74</td>
<td>0.036</td>
<td>0.62</td>
</tr>
<tr>
<td>XCNC</td>
<td>0.15</td>
<td>0.15</td>
<td>0.12</td>
<td>-0.63</td>
<td>0.67</td>
</tr>
</tbody>
</table>

Variables are as defined in Table 5.1 or in Appendix A.

The estimated income elasticities of demand reported in Table 5.2 are generally a little higher than those reported in previous studies but, except for the low quality beef estimate, fall within the range observed in previous studies. Using annual data for 1956 to 1971, Freebairn and Rausser [1975, p. 678] obtained income elasticities of 1.61, -0.21, 0.46, and 0.75 for fed beef, nonfed beef, pork, and chicken. Arzac and Wilkinson [1979a, p. 299] used quarterly data for 1957I to 1975IV and obtained estimates of 1.02, 0.45, 0.65, and 0.52 for the same commodities. The income elasticity observed for high
quality beef (table beef) in this study is within the range of these two observations but the processing beef estimate is well above the previous estimates for nonfed beef. Part of this difference may be due to the change in definition from nonfed to processing quality beef (see Appendix A for details), part to the use of a later sample period in this study, and part to the use of symmetry restrictions in the estimation process. The estimated income elasticities for pork and chicken fall in the range of the previous estimates.

The own-price elasticities are in the same range as those reported by Freebairn and Rausser [1975, p. 678] who also used per capita consumption as the dependent variable. The estimated own-price elasticities for both classes of beef are, however, considerably lower than those obtained by both Arzac and Wilkinson [1979a, p. 299] and by Reeves [1979, p. 236]. Arzac and Wilkinson obtained estimates of -1.86 and -2.97 for fed beef and nonfed beef, respectively. Part of the difference between the results of this study and the Arzac and Wilkinson study may be due to the different categorization of fed and nonfed beef. This study and the Arzac and Wilkinson study are in agreement on one point: The own price elasticity of demand appears to be higher for low-quality beef than for high quality beef.

The lack of agreement between studies on fundamental parameters such as the elasticity of demand for various types of beef is disturbing, given the importance of these parameters. Some of the divergence in results may reflect the differing definitions used to disaggregate
beef and this point will be addressed in Chapter VIII. However, the problem of structural change noted by Braschler [1982] and the extreme difficulty noted by Reeves [1979, p. 239] in obtaining satisfactory demand function estimates suggests that the difficulties in obtaining more precise knowledge are likely to be substantial.

Meat Marketing

In this study, interest focused primarily upon farm and retail price levels, rather than upon the wholesale level. As a result, the margins or price spreads used in the study refer to the entire farm-retail margin, rather than to the farm-wholesale and wholesale-retail margins separately. Two sets of variables are of interest in this study: (1) the level of marketing margins for each meat, and (2) the determination of meat inventory levels. The specification and results for each of these sets of variables will be considered separately.

Marketing margins

The marketing industry for farm products uses two classes of inputs, (1) farm products, and (2) other marketing services, to produce a final product in the form of food at retail. If this industry has constant costs per unit of farm product, faces a perfectly elastic supply of inputs (and a perfectly elastic demand for by-products) and is competitive, then the equilibrium marketing margin will be able to be represented as a mark-up on the farm price [see e.g., Tomek and Robinson, 1981, p. 119]. Whether the mark-up is a constant, or proportional to the farm price, will depend upon whether marketing costs are a constant
per unit, e.g., delivery costs, or vary with the price of the item, e.g., the opportunity cost of holding inventories.

Gardner [1975, p. 400] illustrates that marketing margins need not be a constant cost per unit of farm product processed, even if the marketing industry has constant returns to scale in the production of the retail product. This occurs because the proportions in which farm products and other inputs are combined depends upon their elasticity of substitution and the relative supply elasticities of the two inputs. However, if it is assumed that the supply of other marketing inputs is perfectly elastic, and that the short-run elasticity of substitution between marketing inputs is zero, then a margin equation specification can be consistent with Gardner's more general model.

The relative importance of the level of throughput and the mark-up related variables in determining the market margin is largely an empirical matter. Inspection of the USDA price spread data suggests that the percentage mark-up [e.g., USDA, 1982e] has been relatively stable over time and that the farm-retail margin has tended to be more stable than the farm price. It was assumed that the elasticity of substitution between meat and the other resources used in the marketing process is very low and that other marketing costs are determined exogenously. As a result, a margin equation was chosen, rather than the derived-demand approach formulated by Gardner [1975].

The farm-retail price spread equations were originally specified in the form:
\[ M_{i,t} = a + b \cdot FP_{i,t} + c \cdot FP_{i,t-1} + d \cdot W_{i,t} + e \cdot BP_{i,t} + f \cdot Q_{i,t} \]  \hspace{1cm} (5.17)

Where:

- \( M_{i,t} \) = the margin for meat \( i \) at time \( t \),
- \( Q_{i,t} \) = the quantity of meat \( i \) produced,
- \( W_{i,t} \) = wage rates in marketing meat \( i \),
- \( FP \) = farm price of meat \( i \), and
- \( BP \) = price of by-products.

The \( FP_{i,t} \) variables were included to represent the portion of marketing costs which can be viewed as a percentage mark-up. The lagged farm price was included to allow for the possibility of "stickiness" in adjustment of prices. Wage rates in meat packing were used as a proxy for wage rates in the entire marketing chain. By-product prices were included because they appeared to be fairly important in relation to total farm returns. During the 1970-1981 period, by-product returns have averaged around 14 percent of farm beef returns and 8 percent of hog returns [USDA, 1982e, pp. 33, 37] and have tended to be a relatively variable component of value. The quantity variables included in the equations should reflect any cost changes associated with deviations away from the equilibrium level of throughput. The by-product variable was postulated to have a negative sign while all of the other variables were postulated to have a positive sign.

The by-products variable presents a statistical problem since U.S. production of by-products appears to have a significant effect on their prices [Blake and Clevenger, 1980, p. 105]. Obviously, however, it was
beyond the scope in this study to develop a model of the by-products market. Despite the element of endogeneity in its behavior, this variable was ultimately specified as an exogenous variable, rather than deleted. Maddala [1978, p. 204] has argued that misclassification of endogenous variables as exogenous is typically less serious than exclusion of the variables.

The final margin equations obtained were:

\[
\begin{align*}
\text{MCB} &= -5.19 + 0.86 \ STP + 0.68 \ STP_{t-1} \\
&\quad + 8.89 \ WRMP - 0.28 \ BBPA \\
&\quad - 0.86 \ Q2 - 1.14 \ Q3 - 1.03 \ Q4 \\
(S/M = 0.03, R^2 = 0.99, DW = 0.72, 2SLS, 1962I-1979IV) \\
\end{align*}
\]

\[
\begin{align*}
\text{MPB} &= 5.59 + 0.30 \ CWP + 6.20 \ WRMP \\
&\quad + 0.71 \ BBPA - 1.05 \ Q2 + 0.64 \ Q3 \\
&\quad + 2.02 \ Q4 \\
(S/M = 0.10, R^2 = 0.92, DW = 0.26, 2SLS, 1962I - 1979IV) \\
\end{align*}
\]

In this and all subsequent equations, the terms included in parentheses below the equations summarize the properties of the estimated equations: S/M is the ratio of the equation standard error to the mean of the dependent variable; R^2 is the estimated coefficient of determination, DW is the Durbin-Watson statistic and the sample period used is indicated by the initial and final quarters used for estimation. The R^2 value is presented for comparison purposes even though its range is (-\infty, 1) as emphasized by Basmann [1962].
\[ MPK = 5.96 + 0.70 \text{ HOP} + 8.35 \text{ WRMP} \]
\[ (3.36) \quad (5.36) \quad (13.66) \quad (5.20) \]
\[-0.47 \text{ PBPA} - 0.16 \text{ Q2} + 0.05 \text{ Q4} + 1.29 \text{ Q4} \]
\[ (-0.65) \quad (-0.14) \quad (0.04) \quad (1.08) \]
\[(S/M = 0.06, R^2 = 0.97, DW = 0.81, 2SLS, 1962I - 1979IV)\]

\[ MCN = 6.13 + 0.62 \text{ CHFP} + 0.19 \text{ CHFP}_{t-1} + 0.85 \text{ WRFP} \]
\[ (4.86) \quad (7.64) \quad (2.62) \quad (0.93) \quad (5.21) \]
\[ + 0.0040 \text{ XCN} - 0.85 \text{ Q2} - 0.047 \text{ Q3} + 1.20 \text{ Q4} \]
\[ (2.65) \quad (-1.85) \quad (-0.10) \quad (2.71) \]
\[(S/M = 0.03, R^2 = 0.97, DW = 1.60, 2SLS, 1962I - 1979IV)\]

Where:

1. Full definitions of all variables are given in Appendix A.
Q2,Q3,Q4 = dummy variables for quarters 2, 3, and 4 of the calendar year.

All of the marketing margin equations were estimated in nominal terms because no suitable deflator variable representing the cost of other marketing inputs was available. The equations presented are linked to other equations of the model by a series of identities which relate real and nominal prices, and quantities produced, consumed, and stored. An identity is also used to relate choice beef production to table beef production. As well as the identities associated with the calculation of per capita quantities and those dealing with price deflation, there are two identities to allocate fed beef production between table and processing uses and one to relate the prices of these meats to the price of choice beef. All of these identities are presented with the complete model in Chapter VI.

The coefficients in the choice beef margin equation are all of the expected sign. The relatively large coefficient on \( STP_{t-1} \) suggests a tendency for choice beef marketing margins to respond slowly to changes in farm prices. The wage rate variable, WRMP, was highly significant, although the coefficient on this variable may partly reflect the effects of other factors such as wage rates in retail stores. The beef by-products variable has the expected sign but was not significantly different from zero. The throughput variable was not significant and so has been excluded from the final model.

The Durbin-Watson statistics (DW) indicated that autocorrelation was a problem in all of the margin equations except possibly the
chicken equation. These equations were also estimated using Fuller's method to adjust for autocorrelation. The adjustment made only slight differences to the estimated coefficients, as was the case in the Arzac and Wilkinson study [1979a, p. 303]. Unfortunately, the corrected equations were found to perform relatively poorly in simulation. This experience seems to be fairly common in applied modeling work [Howrey et al., 1978, p. 41]. Following Arzac and Wilkinson [1979a] only the uncorrected estimates were retained for further analysis.

The margin equation for processing beef was originally estimated with both current and lagged cow price variables. The resulting estimates included a negative coefficient on the current price and a larger, positive coefficient on the lagged price. Although both coefficients were significant, this pattern of response appeared implausible and was found to lead to instability in dynamic simulations. Accordingly, the equation was modified to include only the current price variable. A quantity variable was included in the initial model estimates but proved to be insignificant and was also dropped. The by-products variable is significant but has a positive sign, rather than the hypothesized negative sign. This result may be due to the endogeneity of this variable. When output is large and the price low, both the margin and the by-product price are likely to be low. Given this possible explanation for the estimated coefficient, the variable was retained in the equation.

The original estimate of the pork margin equation contained a much larger coefficient on the lagged variable than on the current price
and this also appeared to lead to unstable prices. Again, the lagged price was deleted in deriving the form of the final equation. All of the variables in the final pork margin equation have the expected signs.

In the chicken equation, the throughput variable had the expected sign and appears to be significant. The lagged farm price of chicken appears to be significant, and has a considerably smaller coefficient than the current price. No by-products variable was included since the value of by-products is insignificant in this industry.

While the margin equation estimates obtained were not without flaws, they do appear to provide a satisfactory basis for the link between the farm and retail components of the model. Before turning to the supply side of the model, we will consider the two meat inventory equations which, with the identities presented in Chapter VI, complete the linkage between the farm and retail levels.

**Meat inventories**

Private stocks of any commodity are generally held for one of two reasons: (1) working inventories or (2) speculative inventories. Given the small size of meat inventories noted in Chapter II, the relative perishability of meat products and the high cost of storage, it seems likely that meat inventories are held primarily as working or pipeline stocks, rather than for speculative purposes. The specification of the meat demand equations was based upon this assumption.

Working inventories are held for two primary reasons: (1) to reduce the transactions costs associated with continual delivery of
small batches of a commodity and, (2) as a precaution against the costs associated with running out of stock of a particular commodity. An optimal level of stock-holding can be derived for each of these motivations. In each case, the optimal inventory depends positively upon expected sales and negatively upon inventory holding costs [see e.g., Beare, 1978, p. 166].

The demand for closing inventories of each meat was originally specified as:

$$\text{INV}_i = a + bQ^*_i + cP_i + dRI$$  \hspace{1cm} (5.22)

Where:

- $\text{INV}$ is the closing inventory of meat $i$,
- $Q^*_i$ is expected consumption of meat $i$,
- $P_i$ is the current price of meat $i$, and
- $RI$ is the real rate of interest.

The $Q^*_i$ variable was included to represent the level of expected sales and was hypothesized to have a positive impact on inventories. Since inventories are relatively small, and relatively perishable, it was assumed that the quantity could be adjusted to any desired level within one quarter. The price variable and the real interest rate variable reflect the cost of holding inventories and were expected to have negative signs. Nominal interest rates, as well as the estimated real interest rate, were also tried in some versions of the equations. It was assumed that expectations about meat consumption demand were formed adaptively and the equation was transformed into a form containing only
observable variables by use of the Koyck transformation [Johnston, 1972, p. 300].

During the estimation process, the own-price and interest rate variables were found to be insignificant and, in most cases, not to be of the hypothesized sign. The effect of interest rates was also not significantly greater than zero in any case. Despite this, it has been retained in the pork inventory equation because it was of the correct sign.

The final inventory equation estimates were:

\[
\begin{align*}
\text{BINV} & = -14.51 + 0.018 \text{XPB} + 0.19 \text{BM} \\
& + 0.65 \text{BINV}_{t-1} - 25.18 \text{Q2} \\
& - 34.73 \text{Q3} + 45.18 \text{Q4} \\
& (S/M = 0.11, R^2 = 0.83, DW = 1.42, 2SLS, 1962I - 1979IV) \\
\end{align*}
\]

\[
\begin{align*}
\text{PKINV} & = -58.21 + 0.069 \text{XPK} - 1.84 \text{RINT} + 0.47 \text{PKINV}_{t-1} \\
& - 15.26 \text{Q2} - 107.13 \text{Q3} - 31.28 \text{Q4} \\
& (S/M = 0.14, R^2 = 0.69, DW = 1.86, 2SLS, 1962I - 1979IV) \\
\end{align*}
\]

Where:

BINV is ending beef cold storage stocks, mil. lb.,

XPB is consumption of processing beef, mil. lb.,
BM is imports of beef, mil. lb.,
PKINV is ending pork cold storage stocks, mil. lb., and
RINT is estimated one-period ahead real interest rate, %.

Equation (5.23) suggests that the level of beef imports is an important influence on the level of beef cold storage stocks. While not included in the original, theoretically-based specification, this variable was introduced because it was felt that the longer lead time in obtaining imported beef supplies would result in larger stocks being held. While not statistically significant, the throughput variable, XPB, does have the expected sign and is plausible in magnitude. The implied elasticity of inventory demand with respect to total processing beef consumption is 0.14 in the short-run and 0.40 in the long-run. The lack of significance of both price and interest rate variables, included as measures of holding costs, is not particularly surprising. Beare [1978, p. 168] notes that this finding is common in time series studies of investment demand.

The only statistically significant causal variable in the pork inventory equation is total consumption of pork. The estimated effect of the real interest rate is extremely small, as well as statistically insignificant: an increase of 5 percentage points in the real interest rate would reduce pork inventories by only 3.5 percent. The lagged dependent variable is highly significant.

Interestingly, both the beef and the pork inventory equations suggest that expectations are revised quite rapidly. If we assume that there are no adjustment costs associated with changing the level
of inventories, then the coefficient of adjustment in Equation (5.23) is given by one minus the coefficient on the lagged dependent variable. The resulting adjustment parameter for beef is 0.35 and that for pork is 0.53.

Neither of the inventory equations estimated is totally satisfactory. Some consideration was given to ignoring inventory behavior altogether in the manner of Arzac and Wilkinson [1979a]. Ultimately, these equations were retained since it was believed that the impact of inventories on the dynamic behavior of the model might be significant, particularly in the case of a change in the level of beef imports.

**Beef Supply**

Livestock supply response behavior is particularly complex because live cattle are both a capital input into subsequent meat production and an immediate source of potential output. A sustained increase in beef prices requires the maintenance of a larger cattle inventory as the basis for higher long-run production. In the short-run, such an increase in inventory will require a reduction in the output of at least some classes of cattle. The resulting negative supply responses have a marked effect on the dynamic behavior of the system as a whole.

In this section, we will first briefly review the theoretical basis for beef supply response, and the relationship of this response to the behavior of the system as a whole. Then, some previous empirical results will be reviewed. Finally, the specification and estimation of the disaggregated supply equations of the model will be discussed.
The theory of supply response

The standard neoclassical theory of production suggests that the supply of output will be positively related to the price of output [Silberberg, 1978, p. 114]. In addition, supply would generally be expected to respond negatively to the price of inputs. However, estimates of supply response for beef have generally found negative own-price responses. The standard theory appears to need modification to take into account the fact that cattle are both a capital and a consumption good.

Reutlinger [1966] provides a simple theoretical model for short-run beef supply response. The basic idea of this model is that total beef cattle slaughterings can be divided into two components, one which is related to the inventory of cattle, and another which is related to the change in the desired cattle inventory.

Reutlinger [1966, p. 910] proposed that the effects of desired inventory changes were not important in determining the supply of steers, but that they were for cows and for heifers which could be retained for breeding. For steers, he postulated that beef supply was primarily a function of the inventory level, with, in addition, a lagged price variable. The market supply of cows, heifers, and bulls, however, included the effects of changes in inventory demand. He postulated a Nerlovian partial adjustment model to explain changes in inventory levels. Any change in the inventory of cows was postulated to be achieved partly by changes in the rate of culling and partly by holding back heifers from slaughter.
While Reutlinger [1966] disaggregated total beef production into steers, heifers, and cows, he did not distinguish between different prices for beef. Using a single beef price, he concluded that the price response for cow slaughter should be negative. For heifers, he concluded that the price response was theoretically ambiguous. For steers, he postulated a positive supply response.

In a classic article, Jarvis [1974] demonstrated that beef supply responses might also depend upon changes in the desired age structure of the herd. If an increase in price increases the optimal age of slaughter, then a negative short-run supply response might be observed for all classes of cattle. Conversely, a reduction in the optimal age of slaughter might generate a positive short-run supply response.

The basic theoretical formulation used by Jarvis [1974, p. 492] considers only a single animal and a simplified version of his model for a steer will be presented for illustration. The present value of profit from fattening a steer for slaughter at age $T$ can be presented as:

$$ PV_o(T) = p \cdot W(T) \cdot e^{-rT} - \int_{t=0}^{T} c \cdot f(t) \cdot e^{-rt} dt - R_o $$

(5.25)

Where:

- $PV_o$ is the value of profit at time $t = 0$ from feeding a steer to age $T$,
- $p$ is the market price of steer beef,
- $W(t)$ is the weight of the steer at time $t$,
- $r$ is the discount rate,
c is the cost of feed, 
f is the rate of feed consumption, and 
R is the cost of a replacement calf.

Maximizing (5.25) with respect to T yields the first order condition

\[ p \cdot W'(T) - p \cdot W(T) \cdot r - c \cdot f(T) = 0 \] (5.26)

This condition implies that, at the optimal age of slaughter, the value of the marginal increase in weight should be equal to the opportunity cost of holding the animal, plus the cost of feed consumed per unit of time.

The second order condition for profit maximization requires that

\[ p \cdot W''(T^*) - p \cdot W'(T^*) \cdot r - c \cdot f(T^*) < 0 \] (5.27)

where \( T^* \) is the value of \( T \) which satisfies (5.26).

Using the implicit function theorem [Chiang, 1974, p. 220], it is possible to obtain an estimate of the comparative-static effect of a change in price on the optimal length of feeding, from the first order condition (5.26). The result is

\[
\frac{\partial T^*}{\partial p} = \frac{r \cdot W(T^*) - W'(T^*)}{\left[ p \cdot W''(T^*) - p \cdot W'(T^*) \cdot r - c \cdot f(T^*) \right]}
\] (5.28)

Since the denominator is the second order condition, it is known to be negative and so the sign of (5.28) depends only upon the numerator. From (5.26), this can be seen to be equal to \(- \frac{c}{p} f(T)\), which is unambiguously negative. Thus, \( \frac{\partial T^*}{\partial p} \) will be positive and the optimal feeding period will be positively related to the price of beef. As a result,
Jarvis predicted that an increase in price would lead to a short-run decrease in the supply of steers, i.e., that the supply curve would be negatively sloped. By a similar argument, he concluded that the short-run supply of cows would also be negatively sloped.

Reeves [1979, pp. 79-89] has recently generalized the model proposed by Jarvis for steers. Instead of a single life-span, Reeves based his analysis on the case of maximization of returns over an infinite planning horizon. This formulation overcomes a serious deficiency of the Jarvis analysis; it ignores the opportunity gains which could be realized from a replacement steer. Perrin [1972, p. 67] has demonstrated that this type of reformulation may make a substantial difference in determining the optimal replacement age of any durable asset. For the beef industry case, Reeves concluded that an increase in beef prices would most likely lower the optimal slaughter age for steers, and hence lead to a short-run increase in the supply of steer beef.

Reeves' reformation of the Jarvis model is relatively simple, but has a marked effect upon the results obtained. Instead of the single lifetime case analyzed in (5.26), he considered an infinite time horizon in which each rotation of steers is replaced at the end of a "rotation" of length T.

\[
J_o(T) = \sum_{K=1}^{\infty} \left[ p \cdot W(T) - R(p) - F(T) \right] e^{-KrT}
\]  \hspace{1cm} (5.29)

Where:

- \( K \) is the number of steer finishing "rotations,"
- \( T \) is the (constant) length of a fattening rotation,
R is replacement cost, assumed for generality to be a function of p,

\[ F(T) \text{ is the cost of feeding, compounded to the end of the feeding period, e.g., } F(T) = \int_{t=0}^{T} c \cdot f(t) \cdot e^{(T-t)} \, dt. \]

The infinite geometric series in (5.29) can always be transformed [Allen, 1938, p. 450] into a present capital value expression because \( e^{-KrT} \) is less than one for any positive values of K, r, and T. This leads to the following formulation for the present capital value:

\[ J_0(T) = [p \cdot W(T) - R(p) - F(T)] \left[ e^{rT} - 1 \right]^{-1} \]

The first order condition for a maximum of this function with respect to the choice variable T is given by

\[ F = \frac{[p \cdot W'(T) - F'(T)]}{(1-e^{-rT})} [p \cdot W(T) - R(p) - F(T)] = 0 \quad (5.30) \]

Making use of the implicit function theorem, we can derive an expression for the response of the optimal age of slaughter implied by (5.30) to a change in the parameter, p. This is given by

\[ \frac{\partial T^*}{\partial p} = \frac{r e^{rT} (e^{rT} - 1)^{-1} [W(T) - R'(p)] - W'(T)}{\partial F/\partial T} \quad (5.31) \]

Since the denominator of (5.31) is the second order condition for profit maximization, it must be negative at a maximum profit point. Thus, the sign of (5.31) depends only upon the sign of the numerator. This depends upon the sign of \([W(T) - R'(p)]\) and the relative magnitude of \(W'(T)\) and \(r \cdot (e^{rT} - 1)^{-1} [W(T) - R'(p)]\). Since \(W(T)\) is the effect
of a small change in price on the gross returns received for a finished steer, and \( R'(p) \) is the effect of the price change on the cost of a feeder steer, the term \( [W(T) - R'(p)] \) is the derivative of the total margin obtained for finishing a steer. In the short-run, steer finishing is likely to be an increasing cost industry because of constraints on the supply of low cost, efficient feeding facilities, or of high quality feedstuffs. As long as a reasonably large supply of steers is available for finishing, it is likely that the finishers' margin will increase in the short-run, when the beef price increases. The term \( (e^{rT} - 1)^{-1} \) in the numerator of (5.31) corresponds to the term \( r^{-1} \) used in the familiar discrete-case capitalization formula. Thus, its effect should approximately cancel the \( r \) term in its expression.

The sign of the numerator in (5.31) then depends approximately on the relative magnitude of the change in the finishers' margin, and \( W'(T) \). If \( W'(T) \) is small near the optimal age of turnoff, as seems likely, then the numerator of (5.31) is likely to be positive. Since the denominator is negative, this means that the entire expression will be negative. Thus, Reeves has demonstrated that, under quite plausible and general conditions, the optimal age of steer slaughter may decrease with an increase in the price of beef.

Reeves' result could be made much stronger, at the expense of some generality, by treating the cost of replacements as exogenous. If this were done, as it was in the Jarvis formulation used in (5.26), then the numerator of (5.31) would almost certainly be positive and
correspondingly negative. Thus, reformulation of the simple Jarvis model given in (5.26) reverses its conclusion that the short-run supply response for steers should be negative and suggests that it should probably be positive.

Reeves also reexamined the Jarvis model for cows and concluded that an increase in the price of all beef should actually lower the optimal culling age for cows because it would then be more profitable to maintain a younger and more productive herd. This aspect of response would suggest a positive short-run supply response for cows, as well as for steers, although it seems unlikely that this effect would outweigh the negative supply effects associated with a change in the total desired inventory of cows. Since an increase in the price of beef would be associated with both an increase in the desired inventory of cows, and a reduction in their optimal age, it should be associated with a disproportionate increase in the demand for replacement heifers.

The reexamination of the Jarvis results by Reeves suggests that a negative supply response for steers has little theoretical justification. The inventory demand model proposed by Reutlinger still provides a justification for a negative supply response for cows and bulls, and possibly for heifers.

**Empirical evidence on supply response**

The evidence on beef supply response obtained from earlier studies is by no means consistent. In a recent study, Gutierrez, DeBoer and Ospina [1982, p. 66] summarized the results of six studies on beef
supply response. In five of the six studies, the supply elasticity for female cattle was negative, with the elasticities ranging from -1.20 to -0.011. Only one study reported a positive elasticity for females and this was only 0.049. For male cattle, two studies reported positive supply elasticities while four reported negative elasticities. The elasticities were generally somewhat lower for males, however, and ranged from -0.668 to 0.162.

Recent studies of the U.S. beef market have tended to disaggregate cattle other than along male/female lines. Once heifers have been placed on feed, it is unlikely that they will be withdrawn for use in the breeding herd. Thus, steers and heifers placed on feed can usefully be aggregated. To keep the problem manageable, most studies have combined cows, bulls, and nonfed steers and heifers into another aggregate, nonfed steers and heifers.

Using the fed/nonfed categorization, Arzac and Wilkinson [1979a, p. 300] obtained a positive own-price supply response and a negative response to grain price, although neither of these coefficients was statistically significant. Reeves [1979; p. 242] obtained a positive coefficient for the difference between the price of fed beef and of feeder calves. Again, however, this coefficient was not significantly different from zero. Freebairn [1972, p. 216] reported a significant negative own-price coefficient on the supply of fed beef. In a later version of the model, presented in Freebairn and Rausser [1975, p. 682] the coefficient on the price of fed beef was constrained to zero.
For nonfed beef, Arzac and Wilkinson [1979a, p. 301] obtained a significant, negative coefficient for the price of feeder steers, in addition to a negative effect from placements of cattle on feed. Reeves [1979, p. 243] estimated an equation for cow beef supply and obtained a significant negative coefficient for the expected price of feeder calves. His equation for nonfed steers and heifers included a negative supply response for the price of fed beef. Freebairn and Rausser [1975, p. 683] reported a negative supply response of nonfed beef production with respect to the expected price of feeder calves.

**Specification and estimation**

The specification of the beef supply equations was based primarily upon the model developed by Reutlinger [1966], taking into account the contributions of Jarvis [1974] and Reeves [1979]. Given the behavioral similarity of steers and heifers once they have been placed on feed, the supply of beef from fed steers and heifers was considered together. Cow beef was considered separately because of the need to incorporate this variable in consideration of the Meat Import Act of 1979. The two remaining components, nonfed steer and heifer beef, and bull beef, were each explained by a separate equation.

The supply of beef from fed steers and heifers was postulated to depend primarily upon placements of steers and heifers on feed two quarters previously, the price of fed steers (a proxy for steer and heifer prices) and the price of feed grain. Based on the theoretical argument by Reeves [1979], it was expected that the own-price variable
and the placements variable would have a positive sign while the feed grain price would have a negative sign.

The model for the supply of beef from fed steers and heifers was formulated as

\[ FSHBS = f(FSP, PCORN, PPEX, \text{PF}_{t-2}) \]

Where:

- \( FSHBS \) = supply of beef from fed steers and heifers, mil. lb.,
- \( FSP \) = price of fed steers, $/100 lb.,
- \( PCORN \) = farm price of corn, $/bu.,
- \( PPEX \) = the price of other farm inputs (index), and
- \( \text{PF} \) = placement of cattle on feed, thou.

The producer's supply function is known to be homogeneous of degree zero in all prices and this assumption may be imposed as it was in the case of the consumer's demand functions. The constraint was imposed by deflating the price of fed steers and the price of corn by the index of prices paid for other farm inputs. As in the case of the consumer's demand functions, this assisted by reducing both the correlation between the explanatory variables and the number of explanatory variables.

The model for beef supply from fed steers and heifers did not perform satisfactorily in its original formulation. While the sign of the real fed steer price variable was positive, it was not significantly different from zero. In addition, the coefficient on the real price of corn was positive, contrary to expectations, and also not significant.
Taking into account the possibility of lags in response to prices, the model was reformulated with the prices lagged one period. The final equation is

\[ FSHBS = 843.71 + 5.35 \text{ RFSP}_{t-1} + 0.50 \text{ PF}_{t-2} \]
\[ - 398.28 \text{ PCDUM} - 1292.53 \text{ Q2} - 23.29 \text{ Q3} + 79.76 \text{ Q4} \]

\[ (3.73) \quad (1.87) \quad (19.7) \quad (-1.56) \quad (-12.93) \quad (-0.29) \quad (1.00) \]

\[ (S/M = 0.06, \quad R^2 = 0.86, \quad DW = 1.61, \quad OLS, \quad 1962I - 1979IV) \]

Where:

- \text{RFSP} = \text{the real price of fed steers deflated by PPEX, } \$/100 \text{ lb.}, \]

and

- \text{PCDUM} = \text{dummy variable for price controls in 1973III.} \]

The variable for the real price of corn was excluded from the final equation because its coefficient was not of the expected sign. The price elasticity of response, at the sample means, in Equation (5.32) is only 0.08, suggesting a very limited price response. This result supports Arzac and Wilkinson's [1979a, p. 299] conclusion that the main impact of the beef price is upon decisions taken prior to the final beef supply decision, e.g., upon the placement on feed decision.

The specification of the cow-beef supply equation was based upon a slight modification of the model developed by Reutlinger [1966]. One component of cow slaughter, was assumed to be derived from the normal process of culling, and to be analogous to the depreciation component in investment models. The other component was postulated to
be derived from changes in the desired size of the inventory, analogous to the net investment component in an investment model. The first component of slaughter was specified as

\[ \text{CBS}_1 = a + b \cdot \text{TCOWS} + c \cdot \text{RBCP} \] (5.33)

Where:
- \( \text{CBS}_1 \) is the depreciation component of cow slaughter,
- \( \text{TCOWS} \) is the opening inventory of beef and dairy cows, thou., and
- \( \text{RBCP} \) is the real price of beef cows, $/100 \text{ lb.}

The net investment/disinvestment component of cow beef supply can, following Reutlinger [1966, p. 912], be specified as a constant fraction of the change in the inventory of beef cows. Thus,

\[ \text{CBS}_2 = d \cdot [\text{BCOWS}_{t+1} - \text{BCOWS}_t] \] (5.34)

Where:
- \( \text{CBS}_2 \) is the investment/disinvestment component of total cow beef supply, mil. lb., and
- \( \text{BCOWS} \) is the opening inventory of beef cows, thou.

In an early version of the model, Equations (5.30) and (5.31) were added to obtain a total supply equation. An endogenous variable for the change in the inventory of beef cows, generated in the beef cow inventory equation, was used in this and the two remaining beef supply equations. This specification was found to lead to instability in the behavior of the overall model, and so these equations were replaced with equations which included price level variables, rather than inventory change variables on the right-hand-side.
The final version of the cow-beef supply equation was obtained by replacing (5.34) with a model derived from a partial adjustment model

$$CBS_2 = a[b + cRBSPA - dRBCP - BCOWS]$$  

(5.35)

Where:

$RBSPA$ is the average real price of beef steers in this and the preceding three quarters, $/100$ lb., and

$RBCP$ is the real price of cow beef, $/100$ lb.

The size of the coefficient $a$ in (5.35) reflects both the Nerlovian partial adjustment parameter and the proportion of cow herd inventory adjustments which are achieved by changing the rate of slaughter of cows, rather than by changes in the rate of retention of replacement heifers.

After addition of (5.35) and (5.33), the final form of the estimation equation was obtained. The estimated equation is given as Equation (5.36)

$$CBS = -603.17 + 0.041 \text{TOWS} + 15.34 \text{RBCP}$$  

$$- 20.35 \text{RBSPA} - 112.80 \text{Q2} - 5.69 \text{Q3} + 161.77 \text{Q4}$$  

$$(-3.27) \ (12.14) \ (5.13) \ (5.36)$$

(S/M = 0.095, $R^2 = 0.86$, DW = 1.02, 2SLS, 1962I - 1979IV)

Where:

$CBS$ is the total supply of beef from cows, mil. lb., and all other variables are as previously defined.
As expected, the TCOWS variable had a positive sign and appears to have been the most important determinant of the cow beef supply decision. The estimated coefficient is not capable of an immediate interpretation since its coefficient is influenced by both the investment/disinvestment component (in Equation (5.34)) and the replacement component. Taking RBSPA as a proxy for the expected returns from feeder calf production, a negative supply response would be expected and has been obtained. The estimated elasticity (at the sample means) of cow beef supply with respect to this variable is -1.29. The positive impact of RBCP on cow-beef supply is also as expected and the coefficient estimate corresponds to an elasticity of 0.65. While these results appear very reasonable, they must be interpreted with some caution since the correlation between RBCP and RBSPA was 0.90 during the sample period, and so the possibility that multicollinearity affected these estimates cannot be ruled out.

The specification of the nonfed steer and heifer component reflects the primarily residual nature of this component. The key variable in the specification was the inventory of one-year old steers and heifers (potential feeders) lagged three quarters. The other major explanatory variables were included to represent withdrawals from this stock for (1) placement onto feed and (2) entry of heifers into the cow herd. A dummy variable for the effects of the price controls in 1973II was also included.

Although it is a residual component of supply, it is by no means unimportant. The sample mean of 545 million pounds per quarter was 60 percent of the level of cow-beef production.
An own-price variable was originally specified but none of the available published series was really appropriate. Both the price of fed steers and the price of feeder steers were tested in earlier versions of the model but these resulted in large negative coefficients which caused explosive behavior in any model in which they were included. Given the questionable applicability of the data series available, no current own price variable was included in the final model.

The final equation for the supply of beef from nonfed steers and heifers is

\[
\text{NFSHBS} = 747.53 - 0.093 \text{PF}_{t-1} - 0.069 (\text{PF}_{t-2} + \text{PF}_{t-3}) + 5.68 \text{RBCP} - 14.32 \text{WRBSPA} + 0.045 \text{KFC}_{t-3} - 232.17 \text{PCDUM} + 64.75 \text{Q2} + 206.05 \text{Q3} + 1.74 \text{Q4}
\]

\[
(4.89) \quad (-3.24) \quad (-4.76) \quad (5.37) \\
(8.86) \quad (-8.86) \quad (12.31) \\
(-1.97) \quad (0.52) \quad (1.66) \quad (0.02)
\]

\((S/M = 0.21, R^2 = 0.83, DW = 1.02, \text{Restricted 2SLS, 1962I - 1979IV})\)

Where:

- \(\text{NFSHBS}\) is the supply of beef from nonfed steers and heifers, mil. lb,
- \(\text{PF}\) is the number of cattle placed on feed, thou.,
- \(\text{WRBSPA} = (0.67 * \text{RBSPA} + 0.33 * \text{RBSPA}_{t-4})\),
- \(\text{KFC}\) is the inventory of calves available for feeding, thou.,

and
the equation was estimated subject to the linear restriction that

\[ \text{Coeff. WRBSPA} = -2.52 \times \text{Coeff. RBCP}. \]

All the coefficients of (5.37) have the expected signs. The strong positive coefficient on \( KFC_{t-3} \) indicates a reasonably strong relationship between the supply of nonfed steer and heifer beef and the total inventory of calves available for placement on feed some three quarters earlier. Placements on feed during the previous three quarters reduce the availability of range-fed steers on heifers for slaughter, and hence, the supply of beef from these animals. The dummy variable for beef supplied under the strict controls of the third quarter of 1973 suggests that these caused a significant reduction in the quantity supplied. This may have been caused by withholding of cattle from slaughter in the expectation of higher prices once the controls were removed.

The inclusion of the restriction in Equation (5.37) requires particular explanation. The original formulation of this equation included, like the original cow-beef supply equation, the change in the inventory of cows as an endogenous explanatory variable. However, the resulting formulation includes the use of a rate of change variable to explain the level of cow-beef supplies. This feature appeared to result in instability problems when simulated in the beef supply block of the model.

As a consequence of the instability problems, this equation was reestimated using only the price level variables which were included
in the cow inventory equation. To reduce the number of independent explanatory variables in the equation, and to maintain the link with the cow inventory equation, the coefficients on these variables were constrained in approximately the ratio of the coefficients in the cow inventory equation. Both the coefficients for the pair of price variables and the coefficients in the original equation have an interesting interpretation: they suggest that only a small part of any change in the size of the beef cow herd is achieved by varying the rate of slaughter of nonfed heifers. This can be seen more clearly in the original equation which is presented as Equation (5.38).

\[
\text{NFSHBS} = 557.01 - 0.10 \text{PF}_{t-1} - 0.065 (\text{PF}_{t-2} + \text{PF}_{t-3})
\]
\[
(3.67) \quad (-3.21)
\]
\[
- 0.26 (\text{BCOWS}_{t+1} - \text{BCOWS}_t) + 0.036 \text{KFC}_t - 348.09 \text{PCDUM} + 30.92 Q2 + 99.04 Q3 - 118.34 Q4
\]
\[
(-2.85) \quad (0.23) \quad (0.71) \quad (-1.43)
\]
\[
(S/M = 0.20, R^2 = 0.82, DW = 1.20, 2SLS, 1967I - 1979IV)
\]

The average dressed weight of cows slaughtered was approximately 500 pounds during the sample period. If the total change in the inventory of cows during a quarter was achieved solely by retaining heifers which would otherwise be consigned to slaughter, then the coefficient on the change in beef cow numbers would be approximately two.\(^1\) The

\(^1\)Since NFSHBS is denominated in millions of pounds and BCOWS is expressed in thousands of head.
coefficient of 0.26 on this variable suggests that only around 13 percent of a change in beef cow numbers is achieved in this way. The price coefficients in (5.37) are capable of a similar interpretation when their magnitude is compared with the beef cow inventory equation presented in a subsequent section. When this is done, the result is very similar to the result obtained from (5.38).

The final beef supply equation is the supply of beef from bull slaughter. This is a minor component of total beef supply, averaging only 110.5 million pounds per quarter, as compared with 906.1 million pounds for cow beef and 3,679.1 million pounds for total fed beef. Consideration was given to either excluding it from consideration, as Reeves [1979] did, or expressing it as a constant proportion of cow beef production. Exclusion of this component did not seem desirable since the very lean beef obtained from bulls probably competes strongly with imported beef. Bull beef production does not appear to be totally insignificant in relation to average imports of 419.8 million pounds per quarter. The approach of expressing bull meat production as a simple proportion of cow beef seemed attractive since bulls are primarily kept for breeding. A separate structural equation approach was finally chosen because it was found that it performed far better at predicting bull beef supplies in a simulation of the beef supply equations.

As was the case with the nonfed beef equation, and the cow-beef equation, the original version of this equation included the change in the beef cow inventory among its explanatory variables. The final
version, presented as Equation (5.39) contains exactly the same explanatory variables as the CBS Equation (5.36), but the relative magnitude of some of their coefficients is noticeably different.

\[
BBS = -462.57 + 0.011 \text{TCOWS} + 4.10 \text{RBCP} - 3.20 \text{RBSPA}
\]

\[
= -42.88 \text{PCDUM} + 3.73 \text{Q2} + 21.93 \text{Q3} + 22.82 \text{Q4}
\]

\[
(-11.27) \quad (15.8) \quad (6.32) \quad (-7.23)
\]

\[
(-2.07) \quad (0.61) \quad (3.61) \quad (3.63)
\]

\[(S/M = 0.16, R^2 = 0.83, DW = 0.38, 2SLS, 1962I - 1979IV)\]

The signs of the coefficients of (5.39) were as expected, and as obtained for cow beef in (5.36). By comparison with Equation (5.36), the coefficient on RBCP was large relative to the RBSPA coefficient. Given the very small average level of BBS, the coefficient on the TCOWS variable seemed a little high relative to those obtained in (5.36). These divergences may, however, well reflect slight differences in the supply response of bull and cow beef. Since the equation appears to predict satisfactorily and included signs which were consistent with theory, it was included in the final model.

Placements of Cattle on Feed

During the sample period of this study, an average of 70 percent of total beef production was derived from fed steers and heifers. As was observed in the Arzac and Wilkinson study [1979a, p. 299], and earlier in this study (Equation (5.32)), price movements appear to have relatively little effect upon the supply of fed beef once
cattle have been placed on feed. Thus, the factors which influence the placement of cattle on feed have a particularly important impact upon the behavior of the livestock-feed subsector.

Given the well-developed market existing in feeder livestock, it seems reasonable to specify a structural sub-model consisting of a supply and a demand equation for feeders. This basic specification has been adopted in most recent models which have analyzed the U.S. livestock subsector in any detail [e.g., Arzac and Wilkinson, 1979a; Bain, 1977; Freebairn and Rausser, 1975]. A notable exception to this approach is the study by Ospina and Shumway [1980] which took an alternative approach of dealing only with inventory decisions, rather than with the flow of placements.

Once supply and demand equations for placements have been formulated, they may be estimated directly in the structural form. Alternatively, they may be converted into a pair of partial reduced forms in which the two endogenous variables of this subsystem are expressed as functions of the variables which are exogenous to the subsystem. The partial reduced form approach was used by Arzac and Wilkinson [1979a], Reeves, [1979, p. 245] and Freebairn and Rausser [1975, p. 680], even though all of the other equations in their models were specified directly as structural forms.

The use of partial-reduced forms has the usual disadvantages of the unrestricted reduced form approach to estimation. In particular, much of the information contained in the restrictions on the structural forms is lost, e.g., the restriction that the price of corn does not
enter the feeder cattle supply function. In addition, it becomes more difficult to relate the estimated parameters to prior knowledge about parameter magnitudes or to specific maintained hypotheses regarding the formation of expectations.

The use of the unrestricted reduced forms appears to have been a strategy of necessity, rather than of choice. Reeves [1979, p. 245] attempted to obtain estimates of the structural parameters and only resorted to the reduced-form approach because the structural estimates were unsatisfactory. Freebairn and Rausser [1975, p. 680] reported similar difficulty in obtaining satisfactory parameter estimates. The repeated estimation problems suggest either that the market does not perform in accordance with the theory providing the basis of the specifications, or that the data used are inadequate. However, the data used in these equation appear to be reasonably comprehensive. The basic supply/demand framework used for these equations also appears to be appropriate. One possible source of problems in this submodel is the restrictiveness of the models used to represent the formation of price expectations. Because of the complexity of estimating models involving rational expectations [Fisher, 1982], models of the livestock sub-sector have tended to use procedures in which price expectations are formed using only lagged values of the price series themselves.

The supply equation for placement of cattle on feed was originally specified as

$$PF = a + bKFC + cRBSP + d(BCOWS_{t+1} - BCOWS_t) + eRFC$$ (5.40)
Where:

PF is placements of cattle on feed, thou.,
KFC is the inventory of feeders available, thou.,
RBSP is the real price of feeder steers, $/100 lb., and
RFC is an index of range feed conditions.

It was expected that the coefficients on KFC and RBSP in (5.40) would be positive. Changes in the beef cow inventory were expected to have a negative impact on the supply of placements because a portion of these changes are made by varying the retention rate for replacement heifers. The range feed conditions variable was postulated to have a negative sign; better pasture conditions would encourage producers to hold steers and heifers to higher weights before placing them on feed.

In initial testing of this equation, the range feed conditions variable was found to be unsatisfactory, being both insignificant and of the incorrect sign. As a consequence, this variable was dropped from the model. The resulting estimate of this equation, which was used extensively in testing of the model, was

\[
PF = 1304.42 + 0.13 \text{KFC}_{t-2} + 30.18 \text{RBSP} - 0.81 \text{BCOWS}_{t+1} \\
(1.69) \quad (7.40) \quad (4.03) \quad (-3.78) \quad (5.41)
\]

\[
- \text{BCOWS}_t \quad - 225.03 Q2 + 262.67 Q3 + 2673.32 Q4 \\
(-0.94) \quad (1.07) \quad (10.91)
\]

\(R^2 = 0.82, \text{ DW } = 0.82, \text{ 2SLS, 1962I - 1979IV})
All of the coefficients in this equation had the expected signs and all (except the seasonal dummies) appeared to be statistically significant. The elasticity of placement supply with respect to feeder price was 0.30 at the sample means, suggesting relatively little price response. The coefficient for the change in the inventory of beef cows appeared to be quite large, particularly in relation to the corresponding coefficient in the equation for nonfed beef supply. This coefficient suggests that a large proportion of any change in the inventory of beef cows is achieved by retaining heifers which would otherwise be placed on feed for beef production. The value of the seasonal coefficient for the fourth quarter of the calendar year is very large in relation to the average level of placements.\(^1\) Larsen [1972] attributed a seasonal peak in the fourth quarter to the seasonal deterioration in pasture quality and completion of grazing on crop residues.

As noted in the case of the beef supply equation, the use of the change in beef cow inventory as an explanatory variable was found to lead to instability in the behavior of the overall model. Accordingly, the feeder supply equation was respecified using the price variables which appear in the beef cow inventory equation instead of the change itself. To keep the number of explanatory variables manageable, and to maintain the link with beef cow inventory changes, these variables were restricted to enter the equation in approximately the same ratio that they entered the beef cow inventory equation.

\(^1\)During the sample period, an average of 5,767 cattle were placed on feed each quarter.
The feeder supply equation which appears in the final version of the model is

\[
PF = 364.05 + 0.18 \text{KFC} + 39.08 \text{RBSP} + 31.90 \text{RBCP} \\
- 80.38 \text{WRBSPA} - 329.35 Q2 + 425.56 Q3 + 2983.45 Q4 \\
(R^2 = 0.87, DW = 0.82, Restricted 2SLS, 1962I - 1979IV, Estimated subject to the restriction that coeff. WRBSPA = -2.52 \times \text{coeff. RBCP}).
\]

In the final version, KFC and RBSP have slightly larger coefficients than KFC_{t-2} and RBSP in (5.42). The KFC variable was used in place of the variable KFC_{t-2} used in (5.41), since it was felt that this would probably better capture the dynamic behavior of the system.

While some animals are placed on feed at around 18 months, feeder calves are frequently placed on feed as early as 8 months of age. The KFC variable reflects primarily calves born 12 months previously and this is probably a more representative age for placement on feed. The coefficients on the restricted pair of variables are higher than on the same variables in the cow inventory equation. As previously noted, Reeves [1979, p. 88] provides a potential justification for such a relationship. In his analysis, a rise in the profitability of maintaining a cow herd leads to both a larger desired inventory and a lowered optimal age for the cow herd. Lowering the age of the herd requires additional slaughter of older cows. Increasing the inventory
while reducing its age may thus result in a total demand for replacement heifers which is larger than the net change in the cow inventory.

The demand equation for placements on feed was specified as a function of the real expected price of fed cattle, the real price of corn and the price of the feeder steer. Three simple approaches to the specification of expectations were considered (1) naive expectation, (2) geometrically weighted expectations [Freebairn and Rausser, 1975] and (3) exponentially weighted forecasts [Bessler, 1982]. Only the equations derived from the exponentially weighted forecast appeared to be satisfactory, and only these models will be discussed here.

The demand for feeders was originally specified in quantity dependent form. The assumption of adaptive expectations (a special case of exponentially weighted expectations) resulted in the inclusion of a lagged dependent variable once the equation had been transformed so as to include only observable variables. The initial version of this equation was

\[
PF = -1718.43 - 253.08 \text{RPCORN} + 19.93 \text{RFSP} - 17.54 \text{RBSP} \\
\quad (-2.07) \quad (-1.90) \quad (0.97) \quad (-1.17) \quad (5.43)
\]

\[
+ 0.93 PF_{t-1} + 2399.32 Q2 + 3190.21 Q3 + 5010.0 Q4 \\
\quad (13.43) \quad (9.59) \quad (13.01) \quad (21.8)
\]

\[(R^2 = 0.92, DW = 2.65, 2SLS, 1962I - 1979IV)\]
Where:

RPCORN is the real price of corn, $/bu.,

RFSP is the real price of fed steers, $/100 lb., and

all other variables are as defined previously.

All of the coefficients of (5.43) had the hypothesized sign and the coefficient on RPCORN was statistically significant at the 5 percent level (one-tailed test). Unfortunately, neither of the meat price variables was statistically significant, except at the 20 percent level. However, the coefficients on all of the variables appeared to be plausible, if a little low, with short-run elasticities of -0.11 for corn price, 0.20 for the price of fed steers and -0.17 for the price of feeder steers. Solving (5.43) for RBSP, instead of PF suggested a coefficient of just over one for the price of fed steers — a result which was viewed as highly plausible. Given the adaptive expectations model used to derive Equation (5.43), the coefficient on PF<sub>t-1</sub> is equal to (1 - α) where α is the coefficient of adjustment [Johnston, 1972, p. 302]. The results of (5.43) suggest a coefficient of adjustment of 0.07 which seems to be rather low for this market where participants are generally well-informed about prices. This estimate probably reflects some type of partial adjustment process as well as adaptive expectations.

When simulated in the context of the complete model, Equation (5.43) caused very poor predictive performance. Since the maintained hypothesis implicit in the structure cannot be tested using conventional tests of significance, this result was interpreted as informal
evidence against the structure specified. As a result, a number of alternative specifications for the feeder demand equation were investigated.

Reestimation of the feeder demand Equation (5.43) in price dependent form yielded a rather different form which was found to generate satisfactory predictions both in the context of the complete model and of the feeder cattle submodel. This version of the feeder demand equation is given by

$$RBSP = -34.27 + 1.30 \text{ RFSP} - 3.16 \text{ RPCORN} - 0.00269 \text{ PF} + 0.00496 \text{ PF}_{t-1} + 12.82 Q2 + 13.09 Q3 + 18.96 Q4$$

\[(R^2 = 0.89, \text{ DW} = 1.06, \text{ 2SLS, 1962I - 1979IV})\]

This equation cannot be derived from a simple, exponentially-weighted forecast model of the type considered by Bessler [1982, p. 16]. It must be regarded as primarily a statistical relationship which does, however, provide very good predictive performance as a price-linkage equation. As in previous studies where the reduced-form approach was used, the signs of the coefficients can still be interpreted intuitively.

The signs of both RFSP and RPCORN in (5.44) are as expected, and they are both plausible in magnitude. The coefficient of 1.30 on RFSP suggests a slightly more than proportionate short-run increase in the price of feeders would result from an increase in the price of fed
beef. An exogenous increase in the supply of feeders would have a negative impact upon the current price of feeder steers, with a price flexibility of -0.27.

The relatively large, positive coefficient on $\text{PF}_{t-1}$ has two potential behavioral interpretations. A high level of placements in the previous period suggests that expectations about future profitability were relatively favorable. Some degree of persistence of such expectations would tend to maintain prices in the subsequent period. This adaptive expectations model alone cannot be used to justify Equation (5.44) since, in this model the coefficient on the $\text{PF}_{t-1}$ is constrained to be smaller in absolute value than that on PF.

The second possible behavioral interpretation involves the effect on the expected price of fed steers. If all the variables on the right-hand-side of (5.44), except $\text{PF}_{t-1}$ are held constant, then an increase in $\text{PF}_{t-1}$ must be associated with an increase in RBSP. Thus, when determining the price they are willing to pay for feeder cattle, purchasers may revise their expectations of the future price of fed cattle upwards if they believe the current price is depressed because large placements in the previous quarter are now influencing prices in the finished cattle market. This interpretation of (5.44) is more consistent with the rational expectations approach where decision makers take into account all of the available information in formulating their expectations, than the adaptive expectations approach which relies only upon the information in a weighted combination of lagged values of the variable.
The essentially ad hoc nature of the specification used to complete the feeder cattle market was cause for some concern. It was felt possible that the collinearity between PF and PF\textsubscript{t-1} might have resulted in the estimated relationship between the magnitudes of their coefficients. To investigate this possibility, the equation was reestimated with these two coefficients constrained in the ratio observed in (5.43). This resulted in PF and PF\textsubscript{t-1} coefficients of -0.0038 and 0.0036 respectively and similar coefficients on the other explanatory variables. However, the predictions generated by this equation were found to be markedly inferior from those generated by (5.44), both in the feeder cattle submodel and in the overall model.

Examination of the coefficients of the final pair of feeder cattle market equations does not give a clear indication of whether this submodel is dynamically stable. While the simulation results suggested that they would be stable, this was felt to be insufficient validation. As a further test for stability, this subsystem was solved for the characteristic roots of its homogeneous form. Only after confirming that these roots were, in fact, stable was the model including (5.44) finally accepted.

The evidence of this analysis, and previous studies, suggests that the conventional approaches to the specification of expectations may not be appropriate for this model. The finding of Spreen and Shonkwiler [1981] that the prices of feeder steers and slaughter steers move simultaneously suggests a high degree of sophistication among participants in this market.
Although it was not possible to investigate the rational expectations approach to formulating expectations in this model, the result obtained in (5.44) does appear to be consistent with this framework. Further investigation of the nature of expectations and the process of their formation in this market appears to be necessary.

Cow and Calf Inventories

The inventory of breeding cows is a crucial variable in the U.S. livestock subsector. The level of this inventory largely determines the size of the subsequent calf crop and so exerts a major influence on subsequent beef production. In addition, the supply of beef from cows is a major, and volatile, component of total beef production. Given the importance of the beef cow inventory, the specification and estimation of this equation will be discussed first in this chapter.

An equation to explain the size of the calf crop is discussed following consideration of the cow inventory equation. Although the dairy cow inventory is exogenous to the model, it exerts a major influence on the size of the calf crop and so enters this equation. The slaughter of calves is explained by a third equation which is presented at the end of this section. These three behavioral equations are the most important influences upon the inventory of young calves available for feeding at any time. The actual calculation of this inventory is done via an identity which is discussed at the end of this section.
**Beef cow inventory**

The beef cow inventory was specified using a partial adjustment model of the Nerlovian type. It was believed that the change in the beef cow inventory during any quarter should be specified as an endogenous variable, since this variable and the price of cow beef were expected to be simultaneously determined.

The desired inventory of breeding cows was postulated to be a function of the expected price of feeder steers, the current price of cow beef and the real rate of interest. The expected price of feeder steers was expected to have a positive sign since cows are kept primarily to produce calves for sale as feeders. The price of cow beef largely determines the cost of holding a cow in inventory and was expected to have a negative impact on cow inventory demand. The real rate of interest affects the cost of holding a cow in inventory and was also expected to have a negative sign.

The use of an inventory demand equation assumes that the supply of cows desired will be forthcoming. This approach has been used in most recent models of the U.S. livestock subsector [e.g., Freebairn and Rausser, 1975; Arzac and Wilkinson, 1979a; Reeves, 1979]. Moreover, in these models, any change in inventory demand was accommodated without a change in price, i.e., the supply of replacement heifers was assumed to be perfectly elastic. In this study, the inclusion of variables from the cow inventory equation in the feeder supply equation provides a channel by which changes in the inventory of beef cows influence the price of feeders. These effects may be important, given the large
impact of cow inventory changes on the demand for replacement heifers predicted by Reeves' theoretical analysis, and obtained in this study.

Previous studies have generally expressed the inventory of cows as a function of an arithmetically weighted average of recent feeder steer prices and of the price of cow beef. This approach appears to have given good results and a justification for the use of such a simple, nonrational specification for expected feeder steer prices has been given in Chapter III.

Freebairn and Rausser [1975, p. 682] estimated the change in beef cow inventory, and Reeves [1979, p. 204] used closing inventories as the dependent variable. Both of these approaches allow for simultaneity between the price of cow beef and the inventory of cows. Arzac and Wilkinson [1979a, p. 300], by contrast, explained the opening inventory of cows as a function of lagged prices. This specification obviously does not allow for feedback from changes in inventory through cow price, to the final desired inventory change. If, for example, we begin with an increase in the desired beef cow inventory, the resulting reduction in cow beef supply raises the price of cow beef and this feeds back by dampening the initial inventory change. Incorporation of beef cow inventory change as a simultaneous variable was felt likely to be both more realistic and to have a stabilizing effect on the behavior of the model. Accordingly, this approach was used in the specification of this equation.

The final estimated equation for the change in the inventory of beef cows is
\[(BCOWS_{t+1} - BCOWS_t) = -237.84 + 48.39 \text{ WRBSPA} - 19.66 \text{ RBCP} \]
\[\text{(5.45)}\]
\[\text{(-0.57)} \quad (7.94) \quad (-4.29) \quad (5.45)\]
\[- 0.04 \text{ BCOWS} + 34.32 \text{ Q2} - 277.54 \text{ Q3} - 345.66 \text{ Q4} \]
\[\text{(-4.29)} \quad (0.40) \quad (-3.03) \quad (-3.93)\]
\[(R^2 = 0.69, DW = 1.77 \text{ after correlation for 1st order autocorrelation, A2SLS, } p = 0.20, 1962I - 1979IV)\]
\[(1.63)\]

Where:

- \(BCOWS_t\) is opening inventory of beef cows, thou.
- \(WRBSPA\) is the expected price of feeder steers, $/100/lb.
  \((= 0.67 \cdot RBSPA + 0.33 \cdot RBSPA_{t-4})\), and
- \(RBCP\) is current price of beef cows, $/100 lb.

Equation (5.44) was estimated on a quarterly basis, for consistency with the rest of the model, even though the data for BCOWS were only available on an annual basis up to 1972 and a semi-annual basis thereafter. The quarterly series for BCOWS was obtained by linear interpolation from these annual and semi-annual series. Given the nature of the data used, the overall explanatory power of this equation was regarded as satisfactory.

The coefficients reported in (5.45) are all of the hypothesized sign. The variable WRBSPA can be interpreted as the expected price of feeder steers and the coefficient corresponds to an estimated short-run elasticity of 0.07 at the sample means. In the long-
run, the elasticity of beef cow inventory, with respect to the expected price of feeder steers, is estimated to be 1.85. The variable RBCP represents the current opportunity cost of keeping a cow in the herd. The estimated short-run elasticity with respect to this variable was only -0.02 at the sample means. However, after full adjustment, this elasticity increases to -0.51. Cumulating the short-run elasticities over a period of four quarters leads to one-year elasticities of 0.28 and -0.08 for WRBSPA and RBCP, respectively. These estimates are reasonably close to the estimates of 0.2 and -0.1 obtained by Freebairn and Rausser [1975, p. 680].

The use of a weighted average of feeder steer prices in (5.45) follows Freebairn and Rausser [1975], who used these weights to represent price expectations throughout their model. The equation was originally estimated without this restriction and it was observed that the relative magnitude of the coefficients on RBSPA and RBSPA_{t-4} was very close to the relative magnitude of these weights. In order to reduce the number of explanatory variables and the correlations between them, this restriction was imposed in estimation. The reduction in the correlation between the explanatory variables may have been useful; the simple correlation between RBCP and WRBSPA is 0.77, considerably below the correlation of 0.90 between RBCP and RBSPA.

The autoregressive 2SLS procedure suggested by Fuller [1978] was used in this equation in order to remove indications of autocorrelation.

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\(^1\) This long-run estimate was obtained by setting BCOWS\(_t\) equal to BCOWS\(_{t+1}\) and solving for the coefficient on this variable.
in the original version of the model. It was found that the parameter estimates changed only slightly after the reestimation, but the predictive performance of the model, including the lagged error term, improved after the transformation. Accordingly, this specification was retained even though the estimated autoregressive parameter was only significantly greater than zero at the 10 percent level.

**Calf crop**

The calf crop is primarily determined by the size of the breeding herd at the beginning of the period. Given the high cost of maintaining a breeding cow, producers have a strong incentive to ensure that she produces a calf once a year, or is culled from the herd to be replaced by another, more productive breeding cow. For this reason, the annual calf crop has consistently been approximately 90 percent of the total cow herd.

Although the calving rate is clearly not very responsive to economic factors, it seems possible that it would be influenced to some degree by the profitability of calf production. When calf prices are high, it becomes more profitable to spend more on nutrition, shelter, and veterinary care for the cow herd, in order to increase the number of calves born, and their survival rate. In addition, Reeves' analysis discussed earlier in this chapter suggests that when the price of calves is higher, producers will wish to maintain a younger, and hence more productive herd. Accordingly, a variable to represent the price of feeder steers was included in the specification.
Until relatively recently, the only data available for the U.S. calf crop have referred to the year as a whole. In the absence of reliable knowledge about the seasonal pattern of calvings, there appeared to be only two options: (1) to impose the seasonal calving pattern observed in recent years (with some arbitrary assumptions about the quarterly distribution of calving within each half year) or (2) to estimate an essentially annual equation, as Arzac and Wilkinson [1979a] did. Since industry experts suggested that the pattern of calvings has been shifting towards increased use of fall calvings, the first approach was rejected. The use of an annual type of equation seems reasonable when it is recalled that placements on feed at any time include a range of age and weight groups.

After experimenting with several specifications of this equation, the following version was chosen for use:

\[ KC = 6047.94 + 90.17 \text{RBSPA}_{t-4} + 0.69 \text{TCOWS} \]

\[ (4.01) \quad (10.83) \quad (21.49) \quad (5.46) \]

\[ (R^2 = 0.92, DW = 0.33, OLS, 1962I - 1979IV) \]

Where:

TCOWS is the total inventory of cows, thou.

This equation was estimated using quarterly observations, but is actually quasi-annual. The dependent variable was calculated by applying the observed annual calving rate to the quarterly cow inventory (see Appendix A for details). As a result, the predictions of this model are essentially annual estimates, with some account taken of
the trend in cow inventories within the year. Because the data series used contains no information about the seasonal pattern of calvings, no quarterly dummy variables were included in the equation.

Clearly, the total cow inventory (TCOWS) is the most important determinant of the calf crop in (5.46). The inclusion of the intercept and price variable has reduced its coefficient considerably relative to the coefficient of 0.91 obtained in an annual regression without the price or intercept terms. The estimated elasticity, at the sample means, for this variable is 0.76 which seems a little low, but the equation needs to be considered on its overall predictive performance.

The RBSPA\textsubscript{t-4} variable in (5.46) represents the level of feeder steer prices during the period in which the breeding decisions that largely determined the size of the current calf crop were made. The apparent significance of this coefficient suggests that steer prices do exert some influence on the size of the calf crop. The elasticity, at the sample means, of the calf crop, with respect to the lagged steer price, is 0.092. This relationship suggests a hitherto ignored channel by which prices may influence the behavior of the system. Reeves [1979, p. 248] included a feeder calf price in his equation for the inventory of young feeder calves, but attributed its positive coefficients to attraction of imported feeders. This effect does not enter Equation (5.46) and so the coefficient can only be interpreted as a response of the domestic calf crop.

The extremely low Durbin-Watson statistic in (5.46) caused some concern. As Granger and Newbold [1974] have emphasized, significance
tests are not usually reliable in the presence of such an indication of autocorrelation. In this case, it was felt that the problem was primarily due to the quasi-quarterly nature of the data, rather than to pure misspecification. To test this, essentially the same equation was estimated using annual data and adjusting for autocorrelation. This equation strongly confirmed the significance of the lagged price of feeder steers, and the general order of magnitude of the coefficients. The quarterly equation (5.46) was retained because parameter estimates are still consistent in the presence of autocorrelation, and because it appeared to predict the size of the calf crop extremely well.

The other endogenous variable which influences the supply of calves available for feeding is the level of calf slaughter. The equation explaining the level of this variable will be discussed prior to presentation of the identity which determines the availability of young feeder cattle.

**Calf slaughter**

Calf slaughter rates depend partly upon the price received for veal, but primarily upon the level of derived demand for feeder calves. In addition, the size of the dairy herd may influence the rate of calf slaughter since some dairy-type calves are less suited to subsequent feeding, either because of the breed of the animal, or because of an unwillingness by dairy farmers to incur the costs of raising the calves to weaning age.
The two variables included in the calf slaughter equation were the expected price of feeder steers and the inventory of milk cows. The expected price of feeder steers was specified under the assumption of adaptive expectations such that

\[(RBSP^*_t - RBSP^*_t-1) = \alpha(RBSP^*_t - RBSP^*_t-1)\]

Where:

\(RBSP^*_t\) is the expectation of future values of RBSP held at time \(t\).

Employing the backshift operator, \(B\), [Sargent, 1979, p. 171] and transposing, yields the following expression for \(RBSP^*_t\).

\[RBSP^*_t = \frac{\alpha RBSP^*_t}{(1 - (1-\alpha) B)}\]

A linear version of the calf slaughter equation can now be expressed as

\[SC = a - b \cdot RBSP^*_t + c \cdot MCOWS\]

Where:

\(SC\) is calf slaughter, thou., and

\(MCOWS\) is the the inventory of dairy cows, thou.

Substituting for \(RBSP^*_t\) and transforming results in an equation containing only observable variables

\[SC = a \cdot a - b \cdot RBSP + c \cdot MCOWS_t - (1-\alpha) \cdot c \cdot MCOWS_{t-1} + (1-\alpha) \cdot SC_{t-1}\]

Since we were not specifically interested in obtaining estimates of the true parameters of the model, but rather in obtaining a suitable
specification for the equation, the restrictions on the coefficients implied in this nonlinear form of the equation were not imposed and the equation was estimated in its simple linear form. As a further simplification, the lagged value of MCOWS was deleted from the equation.

The estimated equation used in the analysis was

\[
SC = 54.12 + 0.036 \text{MCOWS} - 5.29 \text{RBSP} + 0.77 \text{SC}_{t-1} \\
- 87.48 \text{Q2} + 166.23 \text{Q3} + 154.36 \text{Q4} \\
(0.80) \hspace{1cm} (4.25) \hspace{1cm} (-6.26) \hspace{1cm} (17.1) \hspace{1cm} (5.47) \\
(-3.66) \hspace{1cm} (6.31) \hspace{1cm} (6.29) \\
(R^2 = 0.98, DW = 1.69, 2SLS, 1962I - 1979IV)
\]

This equation appeared to fit the data quite well and to yield satisfactory predictions. The coefficient on \(\text{SC}_{t-1}\) suggests a relatively high value (0.23) for the coefficient of adjustment on expectations. At the sample means, the coefficient on RBSP suggests an elasticity of -0.24 in the short-run and -1.06 in the long-run. Since expectations are adjusted fairly rapidly, this suggests considerable responsiveness of calf slaughter to the price of feeder cattle.

The main reason for the deletion of MCOWS\(_{t-1}\) from the equation was the high correlation between this variable and its current value. If we assume, for a moment, that the two variables are perfectly correlated, then the observed coefficient on MCOWS can be interpreted as approximately equal to \(a \cdot c\). This would indicate a value for \(c\) of around 0.16, i.e., that each increase of 100 in the dairy cow inventory would increase the level of calf slaughter by 16 percent. Another interpretation of the coefficient
on the MCOVS variable might, however, be as purely a trend effect. Since the level of the milk cow inventory declined throughout the sample period, it may be serving as a proxy for a number of omitted variables such as changes in consumer preferences regarding veal.

Inventory of feeders

The inventory of young cattle available for placement on feed is determined by the identity

\[ KFC = KC_{t-4} - ID + FCIM - SC_{t-1} - SC_{t-2} - SC_{t-3} - SC_{t-4} \]  \hspace{1cm} (5.48)

Where:

- \( KFC \) is the inventory of feeders, thou.,
- \( ID \) is dairy herd replacements, thou., and
- \( FCIM \) is imports of feeder calves, thou.

Consistent with the equation for placements on feed, (5.41), feeders were assumed to be ready to be placed on feed at approximately 12 months of age. Dairy herd replacements were treated as an exogenous withdrawal from the inventory of feeder cattle and feeder calf imports as an exogenous addition to the inventory. Calf slaughter in the previous four quarters is treated as a leakage from the system. Since KC is expressed on an annual basis, as are FCIM and ID, subtraction of four quarters of calf slaughter provides consistency of units.

Pork Production

The three equations of the pork supply section of the model were specified on the same basis as the three quarters utilized by Arzac and
Wilkinson [1979a, p. 301]. The first equation explains the inventory of breeding hogs, the second, the inventory of market hogs, and the third, the supply of pork.

Prior to 1970, quarterly USDA data on hog inventories were reported for a group of ten major states. Since 1970, these data have been reported on a 14 state basis, introducing a marked structural change in the data series. Attempts were made to splice the two series using the ratio of the 14 states to the 10 state breeding inventory obtained from annual data. However, this procedure did not appear to be sufficient to overcome the change in coverage of the data. Equations estimated using the resulting spliced data set exhibited very low explanatory power.

To overcome the problem of the data, and to minimize problems of structural change in this section of the model, these equations were estimated using only data from 1970I to 1979IV. Although the specification followed that of Arzac and Wilkinson, the parameter estimates frequently differed considerably from those obtained by Arzac and Wilkinson [1979a, p. 301] for their 1964II to 1975IV sample period.

The inventory of breeding hogs was explained by a simple equation including the lagged price of pork, the price of corn and the lagged inventory of breeding hogs. In contrast with earlier periods, the number of pigs saved per litter, did not exhibit a noticeable trend during the sample period and so was excluded from the equation. The estimated equation is given by
\[ HBR = 1274.27 + 13.26 \text{RFPPK}_{t-1} - 305.55 \text{RPCORN}_{t-1} \\
(2.57) \quad (3.52) \quad (-4.65) \quad (5.49) \]
\[ + 0.87 HBR_{t-1} + 134.35 Q2 - 443.54 Q3 - 178.50 Q4 \\
(15.06) \quad (1.24) \quad (-3.99) \quad (-1.64) \]
\[ (R^2 = 0.90, \text{DH} = 1.82, \text{OLS, 1970I} - 1979IV) \]

Where:

- \( HBR \) is the inventory of breeding hogs, thou.,
- \( \text{RFPPK} \) is the real farm price of pork, \$/100 lb.,
- \( \text{RPCORN} \) is the real farm price of corn, \$/bu., and
- \( \text{DH} \) is Durbin's \( h \) statistic for autocorrelation.

All of the coefficients of this equation have the expected signs and all are plausible in magnitude. The short-run elasticity of breeding hog inventories with respect to last quarter's pork price is 0.08 and with respect to lagged corn price is -0.104. In the long-run, these elasticities are 0.61 and -0.80, respectively. While the coefficient on lagged inventory was reasonably large, the economic variables do appear to exert a major influence on this inventory.

The equation for the inventory of market hogs was originally specified following the hogs-on-feed inventory equation in the Arzac and Wilkinson model [1979a, p. 301], that is, including the same explanatory variables as (5.50) plus the inventory of breeding hogs. After some experimentation with the specification of this equation, the following estimate was obtained
\[ \text{HMKT} = -3324.47 + 10.31 \text{RFPPK}_{t-1} + 4.00 \text{HBR}_{t-1} \]
\[ + 0.293 \text{HMKT}_{t-1} + 4458.55 \text{Q2} + 3575.07 \text{Q3} + 3959.48 \text{Q4} \]
\[ (R^2 = 0.96, \text{DH} = 0.11, \text{OLS, 1970I - 1979IV}) \]

Where:

\text{HMKT} is the inventory of market hogs, thou.

The primary determinants of HMKT in (5.50) are clearly the lagged values of the breeding hog inventory and the market hog inventory. Although it is not statistically significant, the coefficient on the lagged pork price has been retained because it has the correct sign and is plausible in magnitude. At the sample means, it implies a short-run response elasticity of 0.01, which is consistent with the rather limited opportunities to vary the inventory of market hogs once earlier decisions about the number of breeding hogs have been taken.

The final equation in the pork supply block relates the supply of pork to the previously determined level of inventories. In addition to the inventory levels, it was expected that prices would influence the supply of pork to some extent. The theoretical argument advanced by Reeves [1979], and discussed earlier in this chapter, regarding the optimal turnoff age of steers is directly applicable to market hogs. It was expected, therefore, that an increase in the price of pork would
probably result in a reduction in the optimal slaughter age,\textsuperscript{1} and, hence, in an increase in the supply of pork. The price of corn also was included in the equation, but without any expectation as to the appropriate sign for this variable.

The empirical evidence on pork supply response is somewhat mixed. Arzac and Wilkinson [1979a] reported a positive and significant current-period coefficient on the nominal price of pork in a quarterly equation. Meilke [1977] obtained negative weights for the first three quarters using a polynomial distributed lag, and positive coefficients for the remaining ten quarters of his lag distribution. Yeboah [1980] obtained only positive coefficients on the hog-corn ratio in his study of pork supply response.

Several specifications of this equation were investigated, using both current and lagged values of the price variables. In all of the equations estimated, the price of pork entered with a large, negative coefficient. The corn price coefficient was insignificant and generally very small in magnitude. Since corn is less important in hog-feeding than in cattle-feeding, it is possible that this variable does not adequately reflect the cost of feed. Accordingly, this variable was dropped from the equation. The negative, and highly significant supply response on the price of pork, using either the current or lagged pork

\textsuperscript{1}While the theory, as presented by Jarvis [1974] would suggest, holding a hog to a higher slaughter weight when the price increases, this ignores the possibility of replacing nearly finished hogs with younger and more rapidly growing hogs. Once this possibility is involved, in the manner suggested by Perrin [1972] for any asset replacement decision, Reeves' positive supply response is likely to emerge.
price, presented a different problem. While the theory suggests that a positive supply response is likely, it does not completely rule out the possibility of negative supply response, particularly once the formation of price expectations is introduced. Thus, an equation including a negative pork supply response was initially included in the model.

A negative supply response need not necessarily cause instability in a model. In a simple, two-equation supply/demand model, the dynamic stability of the model can be inferred from the slopes of these two equations [Samuelson, 1947, p. 265]. However, in a multiple market model, such as this one, the stability of the system can only be determined in light of the coefficients of the entire system. In the initial testing stage, an indication of the stability of the model including this negative supply response, was obtained by dynamic simulation of the model over the sample period. The results of these simulations suggested that the models incorporating the estimated negative supply responses were highly unstable. The predicted path of the endogenous variables exploded and negative hog inventories were frequently predicted in simulations using the historic values of the exogenous variables.

The simulation performance of the model, including a negative pork supply response, was taken as evidence that this model was unstable. Since the negative supply response appeared to be the cause of the problem, and was contrary to expectations, this coefficient was restricted to zero. The final pork supply equation is
PKS = -378.36 + 0.074 HMKT\(_{t-1}\) + 0.081 HBR\(_{t-2}\) 
\((-1.53)\) \((3.95)\) \((0.08)\) \((5.51)\)
- 516.76 PCDUM + 326.69 Q2 - 110.25 Q3 + 192.37 Q4 
\((-3.77)\) \((3.53)\) \((-1.79)\) \((3.13)\)
\((R^2 = 0.91, DW = 1.92, OLS, 1970I - 1979IV)\)

Where:

PKS is the supply of pork, mil. lb.

The relatively high explanatory power of (5.51), together with the apparent lack of serial correlation suggest that the supply of pork is largely explained by the level of hog inventories in previous quarters. The breeding hog inventory lagged two quarters was retained because its coefficient was plausible in magnitude, even though it was not statistically significant. The large coefficient on the PCDUM variable suggests that expectations of higher prices in the future caused a marked reduction in supplies during the period of price controls.

**Broiler Production**

The specification of the young chicken production equation was also derived from the Arzac and Wilkinson model [1979a, p. 301]. However, in this case, comparable data were available for a period similar to do that which they used (1960II - 1975IV) and their specification proved to be satisfactory, even though the actual coefficient estimates differed substantially.
The chicken supply equation is

\[ \text{CHPDN} = 38.31 + 5.90 \text{RFCNP}_{t-1} - 35.95 \text{RPCORN}_{t-1} + 1.35 \text{LP} 
\]

\[ + 0.87 \text{CHPDN}_{t-1} - 100.41 \text{PCDUM} + 202.04 \text{Q2} + 49.98 \text{Q3} 
\]

\[ - 130.98 \text{Q4} \]

\( (R^2 = 0.99, \text{ DH } = 0.01, \text{ OLS, 1962I - 1979IV}) \)

Where:

- CHPDN is the supply of young chicken meat, mil. lb.,
- RFCNP is the real price of chicken received by farmers, \$/lb.,
- and
- LP is the index of labor productivity in poultry production.

All of the coefficients of (5.52) had the anticipated sign and were plausible in magnitude. In the short-run, the coefficient on RFCNP\(_{t-1}\) indicated a supply elasticity of 0.097 while the elasticity with respect to the lagged price of corn was -0.050. The corresponding long-run elasticities were 0.74 and -0.38, respectively. The labor productivity variable had the expected positive sign and this factor appears to have been an important determinant of the level of chicken supply.

The coefficient of 0.87 on the lagged dependent variable suggests that full adjustment of chicken production to a change in its explanatory variables is reasonably slow. This is consistent with the success
which has been achieved in predicting chicken supply using lagged annual explanatory variables [Freebairn and Rausser, 1975; Lee and Seaver, 1971], but in marked contrast to the coefficient of 0.065 reported in the Arzac and Wilkinson [1979a, p. 301] study.

Corn Supply and Demand

Following Arzac and Wilkinson [1979a] supply and demand for corn were determined by a system of only four simple behavioral equations. The first of these equations determines the level of U.S. domestic consumption of corn, including both the demand for feed and food. The second determines the quarterly demand for corn inventory. An identity is used to relate these two sources of demand, plus the (assumed) predetermined level of export demand to the total supply of corn. The final two (annual) equations in this section of the model explain the area planted to corn, and the production of corn. Each of these equations will be discussed, in turn, in the remainder of this section.

Corn domestic consumption demand

Total U.S. domestic demand for corn was specified as a function of its own price, the total number of animal units on feed at the beginning of the quarter, and the level of real personal disposable income. The animal units variable was intended to represent the largely predetermined effect of the inventory of animals on feed upon total demand for grain. The factors, including the price of corn, which determine the inventory of animals on feed are dealt with in the other sections of the model. The weights for the aggregate animal units
variable were obtained from published USDA sources, as detailed in Appendix A. For all classes of livestock except chicken, these weights were held constant throughout the sample period. Because of the rapid improvement of feed conversion in the broiler industry, feed consumption per unit of broiler production was specified to decline through time. The details of calculation of the poultry grain consumption factor are given in Appendix A.

The effect of corn price on the current quarter's consumption was expected to be relatively small because most of the decisions determining grain consumption within a quarter would have been made previously. However, some within-quarter flexibility remains through decisions such as early turn-off of cattle in response to an increase in price. This coefficient was expected to be negative in sign.

The real disposable income variable was included as a proxy for those factors influencing food demand for corn which, as noted in Chapter II, has been a rapidly growing component of demand. This variable should be directly related to those sources of food demand which are highly income-elastic. In addition, it should serve as a time-trend proxy for the technological advances which have increased the range of food uses for corn.

Although the specification used was very closely related to that used by Arzac and Wilkinson [1979a, p. 301], it proved difficult to obtain satisfactory results with this equation. In particular, initial estimates generally included a positive, but insignificant coefficient on the price of corn. After examination of the residuals, it appeared
that the major market disruptions between 1973III and 1974IV were exerting a disproportionate influence on the parameter estimates. A dummy variable was included to represent the effects of price controls and abnormal world grain market conditions during this period [Kosters and Ahalt, 1975].

The final equation for domestic corn demand is

\[ X_{DC} = 394.08 - 107.67 \text{RPCORN} + 0.78 \text{YZ} \]
\[ + 244.52 \text{DUM5560} + 0.012 \text{AU} - 171.78 \text{Q2} - 320.67 \text{Q3} \]
\[ + 188.78 \text{Q4} \]
\[ (R^2 = 0.81, DW = 2.16, 2SLS, 1962I - 1979IV) \]

The final equation appears to be satisfactory. The coefficient for the real price of corn is very close to being significant at the 5 percent level and is clearly significant at the 10 percent level.\(^1\) The estimated elasticity of demand, at the sample means, is \(-0.28\), a figure which seems quite plausible.

The variable YZ appears to be highly significant, despite the relatively small importance of food demand during most of the sample period. While the animal units on feed variable has the correct sign, it just exceeds the critical value (1.296) for significance at the 10 percent level using a one-tailed test. The estimated elasticity

\(^1\)Theil [1971, p. 605] points out that test statistics should be interpreted with care when the data set has contributed to the final specification, however.
associated with this variable was only 0.48, at the sample means. Some consideration was given to reestimating this equation using Theil's mixed estimation procedure [Theil, 1971, p. 347] with the prior information that this coefficient should yield an elasticity of approximately one at the sample means. This approach was not adopted when it was found that the equation performed tolerably well in simulations of the model.

Corn inventory demand

The three sources of corn demand in this model (1) domestic consumption, (2) corn inventories, and (3) export demand, are not independent, but must be constrained to equal the total available supply of corn. The three demand equations plus the supply-demand balance identity provide us with the four equations necessary for us to solve for the four variables of interest, i.e., the three quantities demanded and the price. This approach has been described as an equilibrium framework since it supposes that price emerges from equilibrium between the quantity supplied and demanded [Baumes and Womack, 1979].

Arzac and Wilkinson [1979a, p. 302] adopted the alternative, disequilibrium framework in which price adjusts according to the change in stocks [Heien, 1977, p. 130]. This is based upon the notion of lags in price discovery. In this situation, the level of ending stocks in any period will be closely related to the change in price during the period. The major difficulty in the implementation of this approach is that quarter to quarter changes in corn stocks are dominated by
seasonal changes which are anticipated by market participants and so are not associated with large price changes.

Because of the problem of seasonal stock changes, the price equilibrium approach was adopted in this study. Attempts to estimate a disequilibrium equation of the form used by Arzac and Wilkinson, for comparison purposes, proved to be unsatisfactory. The coefficients obtained on the stocks variable in these equations were generally positive, and always insignificant.

The use of the equilibrium demand approach has several advantages in this situation. Government stock-holding behavior is important in this market and is believed to exert a partial offsetting effect on the level of private stocks [Sharples and Holland, 1981]. Incorporation of the level of government stocks in the corn inventory demand equation allows us to obtain an estimate of this key structural parameter. In the disequilibrium approach, stocks are purely a residual, and so this effect cannot be directly ascertained.

The price equilibrium approach also allows us to incorporate the structural change resulting from the introduction of the Farmer Owned Reserve (FOR). In this study, the quantity placed in the Farmer Owned Reserve was viewed as endogenous, depending upon the incentives offered to participate in relation to the severity of the restrictions. The behavior of the policymakers and participants, considered together, was postulated to lead to a change in the price responsiveness of the market.
The final corn inventory equation is

\[ ICT = 293.75 - 117.20 \times RPCORN - 1032.08 \times (RPCORN \times FORDUM) \]
\[ + 0.74 \times COSPRUS + 0.50 \times ICG + 0.68 \times ICT_{t-1} + 2077.24 \times FORDUM \]
\[ - 241.85 \times Q2 - 420.68 \times Q3 - 34.39 \times Q4 \]

\[ (r^2 = 0.99, DW = 1.53, 2SLS, 1962I - 1980IV) \]

Where:

- ICT is the total inventory of corn, mil. bu.,
- RPCORN is the real price of corn, $/bu.,
- FORDUM is a dummy variable for the period of operation of the farmer-owned-reserve, (1977IV-), and
- ICG is the level of government corn inventory, mil. bu.

Equation (5.53b) was estimated utilizing data for 1980 because of the limited number of observations available in the period of operation of the FOR. All of the coefficients have the expected signs. The coefficient of RPCORN implies a short-run elasticity of -0.12 at the sample means. After full adjustment of inventories, this corresponds to an elasticity of -0.364. The coefficient of 0.5 on ICG suggests that an increase of one bushel in government stocks is partially offset by a fall of half a bushel in private stocks and so results in only a half-bushel net increase in total stocks. This estimate is lower than the estimate of 0.86 obtained by Sharples and Holland [1981] in their
analysis of the FOR and total private stockholding of wheat. It is, however, considerably higher than the 0.25 net effect reported by Gardner [1981, p. (i)] for both corn and wheat.

The Farmer-Owned-Reserve is estimated to have substantially increased the level of total inventories and their price responsiveness. In the presence of the FOR, the estimated short-run price elasticity of demand for corn stocks is -1.14. After full adjustment, this elasticity becomes -3.57. These estimates suggest that the existence of the FOR, despite the many changes in rules which make estimation of its effects difficult, has, on the average, had a substantial effect on making the level of total storage more price responsive.\(^1\) If this pattern of policy behavior continues, it might be expected to contribute considerably to increased price stability by absorbing shocks emanating either from supply or demand.

**Corn plantings**

The area planted to corn is heavily influenced by government policy variables. The price of soybeans also has an impact because it is the most important competing crop in the major corn-growing areas. During a part of the 1970s, the market price of corn rose considerably above the government support price level and so it was expected that this would also have an effect on the total plantings.

\(^1\)Morton [1982] who treated the size of FOR stocks as exogenous reached the same conclusion in his study of price variability in the grain and livestock sector.
The corn plantings equation was specified as a land demand equation including the real price of soybeans; the real, lagged market price of corn; two policy variables; and the area planted last year. The first policy variable was the real corn effective support price which measures the per bushel level of incentives provided by the feed grain program to plant corn in a particular year. The second policy variable, the real effective diversion rate, measures the incentives provided under the farm program to divert land from corn production. Details of the method used to calculate each of these variables have been given in Appendix A. The lagged-dependent variable was included as an indicator of delays in adjustment of the area planted.

Considerable effort was devoted to estimating an equation including the market price of corn in some form. None of the simple equations estimated with this variable proved to be satisfactory and it was found that the other variables alone accounted for almost all of the variability in total corn plantings. The market price of corn was excluded from the equation as a simplifying approximation, while recognizing that it may be important under some market circumstances.

The equation included in the final version of the model is

\[
ACP = 65.93 + 5.50 \text{RCESP} - 31.9 \text{RCEDR} - 1.41 \text{RSBPM}_{t-1} \\
+ 5.29 \text{DUM66} + 0.13 \text{ACP}_{t-1} \\
(R^2 = 0.98, \text{DH} = 0.29, \text{OLS, 1962 - 1979, annual})
\]
Where:

ACP is the area planted to corn, mil. ac.,
RCESP is the real effective support price for corn, $/bu.,
RCEDR is the real effective diversion rate, $/bu.,
RSBPM is the real soybean price received by farmers for the marketing year, and
DUM66 is a dummy variable to reflect changes in farm program conditions for 1966 and subsequent years.

Equation (5.53c) appears to explain a high proportion of the total variation in corn plantings and, based on Durbin's h-statistic, to be free from autocorrelation. The two most important explanatory variables are clearly the effective support price and the effective diversion rate. The relative magnitude of these two coefficients is surprising, since the calculation of the diversion payment variable used in this study includes a component which also serves as an incentive for producers to participate in the farm program. The significance of the lagged dependent variable suggests the existence of some delays in adjusting the area planted to the area desired, given the relevant prices, but the small coefficient obtained on this variable suggests that these delays are quite slight.

The final behavioral equation of the model uses the estimate of area planted obtained from (5.53c) to calculate grain production.

Grain production

Once the area planted has been established, the production of grain depends only upon: (1) the proportion of this area which is harvested
for grain and, (2) the yield obtained on the area harvested. Clearly, both of these factors are, to some degree, responsive to price in the short run. However, most of the variability in these variables is either predetermined, e.g., by the genetic characteristics of the seed used, or exogenously determined, e.g., by weather conditions.

Following Arzac and Wilkinson [1979a], the corn production equation was specified as a linear approximation to a more complex functional form

\[
\text{COSPRUS} = -5397.6 + 69.9 \text{ACP} + 66.9 \text{YH} \\
\text{(-16.7)} \quad \text{(14.5)} \quad \text{(26.9)}
\]

\((R^2 = 0.99, DW = 0.91, OLS, 1960 - 1979, \text{annual})\)

Where:

\text{COSPRUS} \text{ is the total U.S. production of corn, mil.bu., and}

\text{YH is the yield per harvested acre, bu.}

As Arzac and Wilkinson [1979a] noted, this relationship is not quite an identity since the multiplicative identity would include the area harvested and the yield as its explanatory variables, rather than the area planted, as used in this equation. The validity of a local linear approximation of the type used in (5.54) depends upon the seriousness of the nonlinearity in the estimated equation, and upon the range of the observations encountered. The high \(R^2\) of this equation suggests that it does a good job of predicting within the range of observations over which it was estimated. It also appears to predict very well when simulated dynamically with the entire model.
This completes our discussion of the specification of the model and the estimation of its component equations. In most of this chapter, we have emphasized the characteristics of individual equations of the model, verifying the signs and magnitude of their parameter estimates in relation to theory and past empirical evidence. In the next chapter, we will primarily be concerned with the characteristics of the model as a whole, and the procedures of validating that it provides a reasonably good representation of the system under investigation.
CHAPTER VI. THE STRUCTURE OF THE MODEL AND ITS VALIDATION

The behavioral equations of the model have been presented in Chapter V, together with the details of their specification and estimation, and with some discussion of the revision process used to obtain the final equations. In the first section of this chapter, the set of equations making up the final structure of the model\(^1\) is presented, together with a brief set of variable definitions. In the second section of this chapter, the details of the validation process are presented.

The Structure of the Model

Because both the final estimated equations, and some preliminary estimates, are included in the text of Chapter V, it is difficult to tell at a glance which are the equations of the final model. For ease of reference, and to illustrate the interrelations between all of the equations of the model, the complete set of model equations has been presented in Table 6.1 of this section. A brief description of each variable is then given in Table 6.2 as an aid to interpreting Table 6.1. The full definitions of all variables used, together with their sources, are given in Appendix A.

\(^1\) The full structure of the model includes a number of identities not presented in Chapter V.
Table 6.1. The equations of the complete model

I. Per capita meat demand functions

1. \( XTBC = 6.22 - 10.75 \cdot RPTB + 2.24 \cdot RPGB \)
   \[(3.20)(-10.59) \quad (2.24)\]
   - \( 0.031 \cdot RPPK + 1.31 \cdot RPCN + 7.13 \cdot YZC \)
   \[(-0.046) \quad (1.19) \quad (8.49)\]
   - \( 0.051 \cdot T - 0.98 \cdot PCDUM + 0.15 \cdot Q2 \)
   \[(-3.96) \quad (-1.67) \quad (0.85)\]
   + \( 0.38 \cdot Q3 - 0.12 \cdot Q4 \)
   \[(2.10) \quad (0.64)\]

2. \( XPBC = 3.25 + 2.24 \cdot RPTB - 16.65 \cdot RPGB \)
   \[(3.49) \quad (2.26) \quad (-13.27)\]
   - \( 6.69 \cdot RPPK + 2.48 \cdot RPCN + 3.23 \cdot YZC \)
   \[(9.45) \quad (1.84) \quad (12.39)\]
   - \( 0.29 \cdot PCDUM - 0.072 \cdot Q2 + 0.44 \cdot Q3 \)
   \[(-0.66) \quad (-0.49) \quad (2.97)\]
   + \( 0.31 \cdot Q4 \)
   \[(2.10)\]

\(^a\)See Table 6.2 for variable descriptions. Figures in parentheses under individual coefficients are t-tests for the hypothesis that the coefficient is significantly different from zero.
Table 6.1 (continued)

3. XPKC = 18.05 - 0.031 \cdot RPTB + 6.69 \cdot RPGB \\
   (12.2) (-0.046) (9.45) \\
   -17.97 \cdot RPPK + 1.62 \cdot RPCN + 3.54 \cdot YZC \\
   (-21.12) (1.52) (5.22) \\
   - 0.076 \cdot T - 0.59 \cdot Q2 - 0.46 \cdot Q3 \\
   (7.35) (-3.82) (-2.93) \\
   + 0.99 \cdot Q4 \\
   (6.40) \\

4. XCNC = 4.29 + 1.31 \cdot RPTB + 2.48 \cdot RPGB \\
   (3.74) (1.21) (1.85) \\
   + 1.62 \cdot RPPK - 14.89 \cdot RPCN + 2.07 \cdot YZC \\
   (1.53) (6.17) (5.63) \\
   + 0.91 \cdot Q2 + 1.05 \cdot Q3 + 0.021 \cdot Q4 \\
   (6.92) (7.97) (0.16) \\

(Equations 1-4, estimated by 3SLS, System $R^2 = 0.94$, \\
Sample period 1962I-1979IV)

II. Quantity and Price Identities

5. XTBC = XTB/USPOP \\
6. XPBC = XPB/USPOP \\
7. XPKC = XPK/USPOP \\
8. XCNC = XCN/USPOP \\
9. PTB = RPTB \cdot CPU \\
10. PGB = RPGB \cdot CPU \\
11. PPK = RPPK \cdot CPU \\
12. PCN = RPCN \cdot CPU \\
13. PCB = 0.768 \cdot PTB + 0.232 \cdot PGB
### Table 6.1 (continued)

#### III. Farm-retail margin equation

14. \[ MCB = -5.19 + 0.86 \times STP + 0.68 \times STP_{t-1} \]
   \[+ 8.89 \times WRMP - 0.28 \times BBPA \]
   \[S/M = 0.03, R^2 = 0.99, DW = 0.72, 2SLS, 1962I - 1979IV\] $^b$

15. \[ MPB = 5.59 + 0.30 \times CWP + 6.20 \times WRMP \]
   \[+ 0.71 \times BBPA - 1.05 \times Q2 + 0.64 \times Q3 \]
   \[+ 2.02 \times Q4 \]
   \[S/M = 0.10, R^2 = 0.92, DW = 0.26, 2SLS, 1962I - 1979IV\]

---

$^b$ In all cases where an equation has been estimated on a single equation basis, the summary of the procedure used is enclosed in parentheses below the equation. For equations estimated by two stage least squares (2SLS), the ratio S/M, i.e., the ratio of the equation standard error to the dependent variable mean, is presented as a supplement to the R$^2$ statistic. The remaining three items enclosed in the parentheses are a test for autocorrelation (the Durbin-Watson (DW) statistic or Durbin statistic (DH)), the estimation method and the period of estimation.
Table 6.1 (continued)

16. MPK = 5.96 + 0.70 • HOP + 8.35 • WRMP
   (3.36) (5.36) (13.66)
   - 0.47 • PBPA - 0.16 • Q2 + 0.05 • Q3
   (-0.65) (-0.14) (0.04)
   + 1.29 • Q4
   (1.08)

(S/M = 0.06, \( R^2 = 0.97 \), DW = 0.81, 2SLS, 1962I - 1979IV)

17. MCN = 6.13 + 0.62 • CHFP + 0.19 • CHFP\(_{t-1}\)
   (4.86) (7.64) (2.62)
   + 0.85 • WRPP + 0.0040 • XCN - 0.85 • Q2
   (0.93) (2.65) (-1.85)
   - 0.047 • Q3 + 1.20 • Q4
   (-0.10) (2.71)

(S/M = 0.03, \( R^2 = 0.97 \), DW = 1.60, 2SLS, 1962I - 1979IV)

18. STP = PCB = MCB
19. CWP = PGN - MPB
20. HOP = PPK = MPK
21. CHFP = PCN - MCN
Table 6.1 (continued)

IV. Meat ending inventories

22. \[ BINV = -14.51 + 0.018 \cdot XPB + 0.19 \cdot BM \]
\[ (-0.55) \quad (1.05) \quad (4.19) \]
\[ + 0.65 \cdot BINV_{t-1} - 25.18 \cdot Q2 \]
\[ (7.67) \quad (-2.19) \]
\[ - 34.73 \cdot Q3 + 45.18 \cdot Q4 \]
\[ (-2.67) \quad (3.53) \]

\[ (S/M = 0.11, R^2 = 0.83, DW = 1.42, 2SLS, 1962I - 1979IV) \]

PKINV = \[ -58.21 + 0.069 \cdot XPK - 1.84 \cdot RINT \]
\[ (-1.01) \quad (3.51) \quad (-0.65) \]
\[ + 0.47 \cdot PKINV_{t-1} - 15.26 \cdot Q2 \]
\[ (4.03) \quad (-1.10) \]
\[ - 107.13 \cdot Q3 - 31.28 \cdot Q4 \]
\[ (-7.34) \quad (-2.00) \]

\[ (S/M = 0.14, R^2 = 0.69, DW = 1.86, 2SLS, 1962I - 1979IV) \]

V. Market clearing identities

24. \[ XTB = 0.768 \cdot FSHBS + 0.768 \cdot NFSHBS - BX \]
25. \[ XPB = 0.232 \cdot (FSHBS + NFSHBS) + CBS + BBS + BINV_{t-1} - BINV + BM \]
26. \[ XPK = PKS + PKM + PKINV_{t-1} - PKINV - PKX \]
27. \[ XCN = CHPDN + CHINV_{t-1} - CHINV_t - CHX \]
Table 6.1 (continued)

VI. Creation of farm price variables

28. RFSP = STP/PPEX * 100
29. RBCP = CWP/PPEX * 100
30. RFPPK = HOP/PPEX * 100
31. RFCNP = CHFP/PPEX * 100

VII. Supply of beef

FSHBS = 843.71 + 5.35 • RFSP^t-1
(3.73) (1.87)
+ 0.50 • PF^t-2 - 398.28 PCDUM
(19.7) (-1.56)
- 1292.53 • Q2 - 23.29 • Q3
(-12.93) (-0.29)
+ 79.76 • Q4
(1.00)

(S/M = 0.06, R^2 = 0.86, DW = 1.61, OLS, 1962I - 1979IV)

33. NFSHBS = 747.53 - 0.093 • PF^t-1 - 0.069 • (PF^t-2 + PF^t-3)
(4.89) (-3.24) (-4.76)
+ 5.68 • RBCP - 14.32 • WRBSPA
(8.86) (-8.86)
+ 0.045 • KFC^t-3 - 232.17 • PCDUM
(12.31) (-1.97)
+ 64.75 • Q2 + 206.05 • Q3 + 1.74 • Q4
(0.52) (1.66) (0.02)

(S/M = 0.20, R^2 = 0.83, DW = 1.02, Restricted 2SLS, 1962I - 1979IV)
Table 6.1 (continued)

34. CBS = 603.17 + 0.041 \cdot TCOWS  
\quad (-3.27) (12.14)  
\quad + 15.34 \cdot RBCP - 20.35 \cdot RBSPA  
\quad (5.13) \quad (-9.66)  
\quad - 112.80 \cdot Q2 - 5.69 \quad Q3 + 161.77 \cdot Q4  
\quad (-3.85) \quad (-0.20) \quad (5.38)  
\quad (S/M = 0.095, R^2 = 0.86, DW = 1.02, 2SLS, 1962I - 1979IV)

35. BBS = -462.57 + 0.011 \cdot TCOWS + 4.10 \cdot RBCP  
\quad (-11.27) (15.8) (6.32)  
\quad - 3.20 \cdot RBSPA - 42.88 \cdot PCDUM  
\quad (-7.23) \quad (-2.07)  
\quad + 3.73 \cdot Q2 + 21.93 \cdot Q3 + 22.82 \cdot Q4  
\quad (0.61) \quad (3.61) \quad (3.63)  
\quad (S/M = 0.16, R^2 = 0.83, DW = 0.38, 2SLS, 1962I - 1979IV)

VIII. Placements, price of feeder steers

36. PF = -364.05 + 0.18 \cdot KFC + 39.08 \cdot RBSP  
\quad (-0.55) (11.05) (5.90)  
\quad + 31.90 \cdot RBCP - 80.38 \cdot WRBSPA - 329.35 \cdot Q2  
\quad (7.50) \quad (-7.50) \quad (-1.61)  
\quad + 425.56 \cdot Q3 + 2983.45 \cdot Q4  
\quad (2.09) \quad (14.55)  
\quad (S/M = 0.11, R^2 = 0.87, DW = 0.82, Restricted 2SLS, 1962I - 1979IV)
Table 6.1 (continued)

<table>
<thead>
<tr>
<th>Equation</th>
<th>Coefficients</th>
<th>t-values</th>
<th>R-squared</th>
<th>Durbin-Watson</th>
<th>Sample Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>37. RBSP = -34.27 + 1.30 \cdot RFSP</td>
<td>-4.95, 21.92</td>
<td>(-2.47, -1.51)</td>
<td>0.08</td>
<td>1.06</td>
<td>1962-1979IV</td>
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<td></td>
<td>-3.16 \cdot RPCORN - 0.00269 \cdot PF</td>
<td>(-2.47)</td>
<td>(-1.51)</td>
<td>0.89</td>
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<td></td>
<td>+ 0.00496 \cdot PF_{t-1} + 12.82 \cdot Q2</td>
<td>2.97</td>
<td>2.78</td>
<td>0.98</td>
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<td></td>
<td>+ 13.09 \cdot Q3 + 18.96 \cdot Q4</td>
<td>2.19</td>
<td>2.12</td>
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<td>(S/M = 0.08, R^2 = 0.89, DW = 1.06, 2SLS, 1962I - 1979IV)</td>
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Calf slaughter

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<th>t-values</th>
<th>R-squared</th>
<th>Durbin-Watson</th>
<th>Sample Period</th>
</tr>
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<tbody>
<tr>
<td>38. SC = 54.12 + 0.036 \cdot MCOWS - 5.29 \cdot RBSP</td>
<td>0.80, 4.25</td>
<td>(-6.26)</td>
<td>0.89</td>
<td>1.69</td>
<td>1962-1979IV</td>
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<tr>
<td></td>
<td>+ 0.77 \cdot SC_{t-1} - 87.48 \cdot Q2 + 166.23 \cdot Q3</td>
<td>17.1, -3.66</td>
<td>6.31</td>
<td>0.98</td>
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<td></td>
<td>+ 154.36 \cdot Q4</td>
<td>6.29</td>
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<tr>
<td>(S/M = 0.06, R^2 = 0.98, DW = 1.69, 2SLS, 1962I - 1979IV)</td>
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Calf supply

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<th>t-values</th>
<th>R-squared</th>
<th>Durbin-Watson</th>
<th>Sample Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>39. KC = 6047.94 + 90.17 \cdot RBSPA_{t-4}</td>
<td>4.01, 10.83</td>
<td></td>
<td>0.92</td>
<td>0.33</td>
<td>1962-1979IV</td>
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<tr>
<td></td>
<td>+ 0.69 \cdot TCOWS</td>
<td>21.49</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>(S/M = 0.02, R^2 = 0.92, DW = 0.33, DLS, 1962I - 1979IV)</td>
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Table 6.1 (continued)

40. \( \text{KFC} = \text{KC}_{t-4} - \text{ID} + \text{FCIM} - \text{SC}_{t-1} \)
    \[- \text{SC}_{t-2} - \text{SC}_{t-3} - \text{SC}_{t-4} \]

IX. Cow inventory

41. \( \text{BCOWS}_{t+1} - \text{BCOWS}_t = -237.84 + 48.39 \cdot \text{WRBSPA} \)
    \[(-0.57) (7.94) \]
    \[-19.66 \cdot \text{RBCP} - 0.040 \cdot \text{BCOWS} \]
    \[(-2.68) (-4.29) \]
    \[+ 34.32 \cdot Q2 - 277.54 \cdot Q3 \]
    \[(0.40) (-3.03) \]
    \[-345.66 \cdot Q4 \]
    \[(-3.93) \]

\( (R^2 = 0.69, c^* \text{ DW} = 1.77 \text{ after correction for autocorrelation, A2SLS, } \)
\( \hat{\rho} = 0.20, 1962I - 1979IV) \)
\( (1.63) \)

42. \( \text{BCOWS}_t = \text{BCOWS}_{t-1} + [\text{BCOWS}_{t+1} - \text{BCOWS}_t]_{t-1} \)

43. \( \text{TCOWS} = \text{BCOWS} + \text{MCOWS} \)

\( c^* \text{The } R^2 \text{ statistic in Equation 41 is the } R^2 \text{ calculated using the } \)
\( \text{transformed data.} \)
Table 6.1 (continued)

X. Hog inventories and pork production

44. \[ HBR = 1274.27 + 13.26 \cdot RFPPK_{t-1} \]
   \[ (2.57) \quad (3.52) \]
   \[ - 305.55 \cdot RPCORN_{t-1} + 0.87 \cdot HBR_{t-1} \]
   \[ (-4.65) \quad (15.06) \]
   \[ + 134.35 \cdot Q2 - 443.54 \cdot Q3 - 178.50 \cdot Q4 \]
   \[ (1.24) \quad (-3.99) \quad (-1.64) \]

\( (R^2 = 0.90, \, DH = 1.82, \, OLS, \, 1970I - 1979IV) \)

45. \[ HMKT = -3324.47 + 10.31 \cdot RFPPK_{t-1} \]
   \[ (-1.61) \quad (0.76) \]
   \[ + 4.00 \cdot HBR_{t-1} + 0.293 \cdot HMKT_{t-1} \]
   \[ (9.90) \quad (3.79) \]
   \[ + 4458.55 \cdot Q2 + 3575.07 \cdot Q3 \]
   \[ (7.88) \quad (7.61) \]
   \[ + 3959.48 \cdot Q4 \]
   \[ (9.19) \]

\( (R^2 = 0.96, \, DH = 0.11, \, OLS, \, 1970I - 1979IV) \)
Table 6.1 (continued)

46. \( PKS = -378.36 + 0.074 \times HMK_{t-1} \)
    \[ (-1.53) \quad (3.95) \]
    \( + 0.0814 \times HBR_{t-2} - 516.76 \times PCDUM \)
    \[ (0.08) \quad (-3.77) \]
    \( + 326.69 \times Q2 - 110.25 \times Q3 + 192.37 \times Q4 \)
    \[ (3.53) \quad (-1.79) \quad (3.13) \]
    \( (R^2 = 0.91, DW = 1.92, OLS, 1970I - 1979IV) \)

XI. Chicken production

47. \( CHPDN = -38.31 + 5.90 \times RFCNP_{t-1} \)
    \[ (-0.53) \quad (4.30) \]
    \[ - 35.95 \times RPCORN_{t-1} + 1.35 \times LP \]
    \[ (-3.11) \quad (3.69) \]
    \( + 0.87 \times CHPDN_{t-1} - 100.41 \times PCDUM \)
    \[ (16.41) \quad (2.03) \]
    \( + 202.04 \times Q2 + 49.98 \times Q3 - 130.98 \times Q3 \)
    \[ (13.27) \quad (2.61) \quad (-6.38) \]
    \( (S/M = 0.02, R^2 = 0.99, DH = 0.01, OLS, 1962I - 1979IV) \)
Table 6.1 (continued)

XII. Corn demands and equilibrium

48. ICT $= 293.75 - 117.20 \cdot$ RPCORN
   $\quad (1.49) \quad (-3.79)$
   $\quad - 1032.80 \cdot (\text{RPCORN} \cdot \text{FORDUM})$
   $\quad (-3.79)$
   $\quad + 0.74 \cdot \text{COSPRUS} + 0.50 \cdot \text{ICG}$
   $\quad (27.82) \quad (9.28)$
   $\quad + 0.68 \cdot \text{ICT}_{t-1} + 2077.24 \cdot \text{FORDUM}$
   $\quad (18.84) \quad (3.60)$
   $\quad - 241.85 \cdot Q2 - 420.68 \cdot Q3 - 34.39 \cdot Q4$
   $\quad (-4.02) \quad (4.28) \quad (-0.24)$

(S/M = 0.04, $R^2 = 0.99$, DW = 1.53, 2SLS, 1962I - 1980IV)

49. XDC $= 394.08 - 107.67 \cdot$ RPCORN $+ 0.78 \cdot$ YZ
   $\quad (0.74) \quad (-1.64) \quad (4.56)$
   $\quad + 244.52 \cdot \text{DUM5560} + 0.012 \cdot \text{AU}$
   $\quad (2.10) \quad (1.36)$
   $\quad - 171.78 \cdot Q2 - 320.67 \cdot Q3 + 188.78 \cdot Q4$
   $\quad (-4.18) \quad (-5.09) \quad (3.24)$

(S/M = 0.12, $R^2 = 0.81$, DW = 2.16, 2SLS, 1962I - 1979IV)

50. ICT$_{t-1}$ + COSPRUS = XDC$_{t}$ + ICT$_{t}$ + EC$_{t}$
Table 6.1 (continued)

XIII. Corn production and acreage

51. \[ \text{COSPRUS} = -5397.6 + 69.9 \cdot \text{ACP} \]
   \[-16.7 \quad (14.5) \]
   \[+ 66.9 \cdot \text{YH} \]
   \[26.9 \]
   \[R^2 = 0.99, \quad DW = 0.91, \quad \text{OLS, 1960 - 1979, Annual} \]

52. \[ \text{ACP} = 65.93 + 5.50 \cdot \text{RCESP} - 31.9 \cdot \text{RCEDR} \]
   \[10.9 \quad (3.2) \quad (-9.9) \]
   \[-1.41 \cdot \text{RSBPM}_{t-1} + 5.29 \cdot \text{DUM66} \]
   \[-2.7 \quad (6.22) \]
   \[+ 0.13 \cdot \text{ACP}_{t-1} \]
   \[2.44 \]
   \[R^2 = 0.98, \quad DH = 0.29, \quad \text{OLS, 1962 - 1979, Annual} \]

Animal units identity

53. \[ \text{AU} = 1.33 \cdot (\text{PF}_{t-1} + \text{PF}_{t-2}) + 1.05 \cdot \text{MCOWS} \]
   \[+ 0.2291 \cdot \text{HMKT}_{t-1} + \text{GCPF} \cdot \text{CHPDN} \]

XIV. Definitional identities

54. \[ \text{RBSPA} = 0.25 \cdot (\text{RBSP} + \text{RBSP}_{t-1} + \text{RBSP}_{t-2} + \text{RBSP}_{t-3}) \]

55. \[ \text{WRBSPA} = 0.67 \cdot \text{RBSPA} + 0.33 \cdot \text{RBSPA}_{t-4} \]

\[d\text{In simulation, Equation 51 entered only the fourth quarter and Equation 52 entered only the fourth quarter of the calendar year.} \]
Table 6.2. Summary of variable definitions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Endogenous/Exogenous</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACP</td>
<td>Area planted to corn, thou. ac. (E)</td>
<td></td>
</tr>
<tr>
<td>AU</td>
<td>Grain consuming animal units, thou. (E)</td>
<td></td>
</tr>
<tr>
<td>BBPA</td>
<td>Beef by-product allowance, ¢/lb. (X)</td>
<td></td>
</tr>
<tr>
<td>BBS</td>
<td>Supply of bull beef, mil. lb. (E)</td>
<td></td>
</tr>
<tr>
<td>BCOWS</td>
<td>Beginning beef cow inventory, thou. (E)</td>
<td></td>
</tr>
<tr>
<td>BINV</td>
<td>Ending beef stocks, mil. lb. (E)</td>
<td></td>
</tr>
<tr>
<td>BM</td>
<td>Beef imports, mil. lb. (X)</td>
<td></td>
</tr>
<tr>
<td>BX</td>
<td>Beef exports, mil. lb.</td>
<td></td>
</tr>
<tr>
<td>CBS</td>
<td>Supply of cow beef, mil lb. (E)</td>
<td></td>
</tr>
<tr>
<td>CHFP</td>
<td>Farm price of broilers, ¢/lb. (E)</td>
<td></td>
</tr>
<tr>
<td>CHINV</td>
<td>Ending stocks of chicken, mil. lb. (X)</td>
<td></td>
</tr>
<tr>
<td>CHPDN</td>
<td>Total chicken production, mil. lb. (E)</td>
<td></td>
</tr>
<tr>
<td>CHX</td>
<td>Exports of chicken, mil. lb. (X)</td>
<td></td>
</tr>
<tr>
<td>COSPRUS</td>
<td>U.S. corn production, mil. bu. (E)</td>
<td></td>
</tr>
<tr>
<td>CPU</td>
<td>Consumer price index (X)</td>
<td></td>
</tr>
<tr>
<td>CWP</td>
<td>Utility cow price, Omaha, $/100 lb. (E)</td>
<td></td>
</tr>
<tr>
<td>DUM5560</td>
<td>Grain market dummy, 1973III - 1974IV (X)</td>
<td></td>
</tr>
<tr>
<td>DUM66</td>
<td>Feed grain policy change dummy (X)</td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>U.S. corn exports, mil. bu. (X)</td>
<td></td>
</tr>
<tr>
<td>FCIM</td>
<td>Feeder calf imports, thou. (E)</td>
<td></td>
</tr>
<tr>
<td>FORDUM</td>
<td>Dummy variable for the Farmer Owned Reserve (FOR) (X)</td>
<td></td>
</tr>
<tr>
<td>FSHBS</td>
<td>Fed steer and heifer beef supply, mil. lb. (E)</td>
<td></td>
</tr>
<tr>
<td>GCFP</td>
<td>Chicken feed conversion factor (X)</td>
<td></td>
</tr>
<tr>
<td>HBR</td>
<td>Breeding hog inventory, 14 states, thou. (E)</td>
<td></td>
</tr>
<tr>
<td>HMKT</td>
<td>Market hog inventory, 14 states, thou. (E)</td>
<td></td>
</tr>
<tr>
<td>HOP</td>
<td>Price of hogs, $/100 lb.</td>
<td></td>
</tr>
<tr>
<td>ICG</td>
<td>Ending government corn inventory, mil. bu. (X)</td>
<td></td>
</tr>
<tr>
<td>ICT</td>
<td>Ending total corn inventory, mil. bu. (E)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)The letter E enclosed in parentheses is used to indicate that the variable is endogenous to the model; exogenous variables are indicated by an X.
Table 6.2 (continued)

<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>Dairy replacement heifers, thou.</td>
<td>(X)</td>
</tr>
<tr>
<td>KC</td>
<td>Calf crop, annual basis, thou.</td>
<td>(E)</td>
</tr>
<tr>
<td>KFC</td>
<td>Feeder calf availability, thou.</td>
<td>(E)</td>
</tr>
<tr>
<td>LP</td>
<td>Labor productivity index for poultry</td>
<td>(X)</td>
</tr>
<tr>
<td>MCB</td>
<td>Farm-retail choice beef margin, c/lb.</td>
<td>(E)</td>
</tr>
<tr>
<td>MCN</td>
<td>Farm-retail chicken margin, c/lb.</td>
<td>(E)</td>
</tr>
<tr>
<td>MCOWS</td>
<td>Milk cow inventory, thou.</td>
<td>(X)</td>
</tr>
<tr>
<td>MPB</td>
<td>Farm-retail processing beef margin, c/lb.</td>
<td>(E)</td>
</tr>
<tr>
<td>MPK</td>
<td>Farm-retail pork margin, c/lb.</td>
<td>(E)</td>
</tr>
<tr>
<td>NFSHBS</td>
<td>Nonfed steer and heifer beef supply, mil. lb.</td>
<td>(E)</td>
</tr>
<tr>
<td>PBPA</td>
<td>Pork by-product allowance, c/lb.</td>
<td>(X)</td>
</tr>
<tr>
<td>PCB</td>
<td>Retail price of choice beef, c/lb.</td>
<td>(E)</td>
</tr>
<tr>
<td>PCDUM</td>
<td>Price control dummy, 1973III</td>
<td>(X)</td>
</tr>
<tr>
<td>PCN</td>
<td>Retail price of chicken, c/lb.</td>
<td>(E)</td>
</tr>
<tr>
<td>PF</td>
<td>Cattle placed on feed, 23 states, thou.</td>
<td>(E)</td>
</tr>
<tr>
<td>PCB</td>
<td>Retail price ground beef, c/lb.</td>
<td>(E)</td>
</tr>
<tr>
<td>PKINV</td>
<td>Ending stocks of pork, mil. lb.</td>
<td>(E)</td>
</tr>
<tr>
<td>PKM</td>
<td>Pork imports, mil. lb.</td>
<td>(X)</td>
</tr>
<tr>
<td>PKS</td>
<td>Pork production, mil. lb.</td>
<td>(E)</td>
</tr>
<tr>
<td>PKX</td>
<td>Pork exports, mil. lb.</td>
<td>(X)</td>
</tr>
<tr>
<td>PPEX</td>
<td>Farm price index</td>
<td>(X)</td>
</tr>
<tr>
<td>PPK</td>
<td>Pork retail price, c/lb.</td>
<td>(E)</td>
</tr>
<tr>
<td>PTB</td>
<td>Retail price of table beef, c/lb.</td>
<td>(E)</td>
</tr>
<tr>
<td>Q2</td>
<td>Dummy for quarter 2</td>
<td>(X)</td>
</tr>
<tr>
<td>Q3</td>
<td>Dummy for quarter 3</td>
<td>(X)</td>
</tr>
<tr>
<td>Q4</td>
<td>Dummy for quarter 4</td>
<td>(X)</td>
</tr>
<tr>
<td>RBCP</td>
<td>Real price of utility cows, $/100 lb.</td>
<td>(E)</td>
</tr>
<tr>
<td>RBSP</td>
<td>Real price of feeder steers, $/100 lb.</td>
<td>(E)</td>
</tr>
<tr>
<td>RBSPA</td>
<td>Four quarter moving average of RBSP, $/100 lb.</td>
<td>(E)</td>
</tr>
<tr>
<td>RCEDR</td>
<td>Real corn diversion rate, $/bu.</td>
<td>(X)</td>
</tr>
<tr>
<td>RCESP</td>
<td>Real corn effective support price, $/bu.</td>
<td>(X)</td>
</tr>
</tbody>
</table>
Table 6.2 (continued)

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Unit</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFCNP</td>
<td>Real price of broilers, c/lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>RFPPK</td>
<td>Real farm price of pork, $/100 lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>RFSP</td>
<td>Real price of choice steers, $/100 lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>RINT</td>
<td>Expected real rate of interest, %</td>
<td>(X)</td>
<td></td>
</tr>
<tr>
<td>RPCN</td>
<td>Real retail chicken price, $/lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>RPCORN</td>
<td>Real price of corn, $/bu.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>RPGB</td>
<td>Real price of processing (ground) beef, $/lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>RPPK</td>
<td>Real retail price of pork, $/lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>RPTB</td>
<td>Real retail price of table beef, $/lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>RSBPM</td>
<td>Real soybean price in current marketing year, $/bu.</td>
<td>(X)</td>
<td></td>
</tr>
<tr>
<td>SC</td>
<td>Calf slaughter, thou.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>STP</td>
<td>Choice steer price, Omaha, $/100 lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>Quarterly time trend, one in 19601</td>
<td>(X)</td>
<td></td>
</tr>
<tr>
<td>TCOWS</td>
<td>Total cow inventory, thou.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>USPOP</td>
<td>Total U.S. population, mil.</td>
<td>(X)</td>
<td></td>
</tr>
<tr>
<td>WRBSPA</td>
<td>Expected price of feeder steers, $/100 lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>WRMP</td>
<td>Wage rate in meat packing, $/hr.</td>
<td>(X)</td>
<td></td>
</tr>
<tr>
<td>WRPP</td>
<td>Wage rate in poultry dressing, $/hr.</td>
<td>(X)</td>
<td></td>
</tr>
<tr>
<td>XCN</td>
<td>Total chicken consumption, mil. lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>XCNC</td>
<td>Per capita chicken consumption, lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>XDC</td>
<td>Total domestic corn use, mil. bu.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>XPB</td>
<td>Total processing beef consumption, mil. lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>XPBC</td>
<td>Per capita processing beef consumption, mil. lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>XPK</td>
<td>Total pork consumption, mil. lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>XPKC</td>
<td>Per capita pork consumption, lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>XTB</td>
<td>Total table beef consumption, mil. lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>XTBC</td>
<td>Per capita table beef consumption, lb.</td>
<td>(E)</td>
<td></td>
</tr>
<tr>
<td>YH</td>
<td>Corn yield per harvested acre, bu.</td>
<td>(X)</td>
<td></td>
</tr>
<tr>
<td>YZ</td>
<td>Total personal disposable income, $'000 mil.</td>
<td>(X)</td>
<td></td>
</tr>
<tr>
<td>YZC</td>
<td>Per capita personal disposable income, $'mil.</td>
<td>(X)</td>
<td></td>
</tr>
</tbody>
</table>
Model Validation

Validation of a model is the process of confirming that the model provides a reasonable representation of the relevant characteristics of the system it is intended to represent. The steps of specifying functions based upon logical postulates derived from economic theory and of verifying that the estimated functions correspond with the theory can be viewed as necessary preconditions for model validity. The final test of model validity, and the one emphasized by Friedman [1953], is the ability of the model to predict the variables which are endogenous to it.

The process of validating a model is essentially that of testing a hypothesis. Thus, while the validity of the model may be rejected at any stage in the validation process, its validity can never be proved [Silberberg, 1978, p. 9]. The best that can be done is to subject the model to a number of tests. The approach taken in this study is that advocated by Popper [1959] in a more general context, and suggested for simulation models by Naylor and Finger [1971]. If, after a number of tests have been conducted, no negative results have been found, then our confidence in the model can gradually be increased.

Using this multi-stage validation procedure, three forms of model evaluation were conducted and have been discussed in this section. These procedures are (1) historical (within-sample) simulations, (2) beyond-sample simulations (ex post forecasts), and (3) examination of the characteristic roots of the model. As previously noted, the process of validation is never complete and rejection of the model
may be based upon subsequent analysis of its predictions. Thus, the calculation of multipliers and the analysis of exogenous shocks, of the type reported in Chapter VII can be thought of as contributing to the continuing process of validating the model as well as of obtaining information about the system.

**Historical simulation**

Historical simulation involves an analysis of the performance of the model in replicating the values of the individual variables over the period which was used to estimate the model. It is clearly a less rigorous test than an ex post forecast because the characteristics of the data set used for estimation influence the estimated coefficients. Howrey and Kelejian [1971, p. 300] have, in fact, argued that this approach yields no additional information about the validity of a linear model which has been estimated and tested in terms of known distribution theory.

In practice, the true structure and distributions underlying the model are unknown and so simulation does provide some useful additional information. It clearly allows the rejection of some specifications as unsatisfactory. In fact, the rejection of some equation specifications in Chapter V was based upon the results of such simulation experiments.

In a dynamic model such as the one estimated in this study, the simulation procedure used may be either static or dynamic. A static simulation involves the calculation of predictions given information
about past values of the endogenous variables. In a dynamic simulation, by contrast, the model uses the predicted values of the lagged endogenous variables. Dynamic simulation clearly allows for a much greater degree of interdependence in determining the predictions of the model and so provides a far more stringent test of model performance than does static simulation. Only the dynamic simulation approach will be considered in this section.

No single statistic is available to evaluate the simulation performance of an entire model. However, a number of summary statistics are available for evaluating the predictions of individual variables. Kost [1980] provides an excellent review of the measures available for model validation by simulation. Once the performance of the model in predicting individual variables has been summarized, subjective judgements about the model can be made based upon the perceived importance of particular variables.

Two of the most commonly used, and most useful, measures for evaluating simulation performance are the Root Mean Square (RMS) error of simulation and the Root Mean Square percent error. These two statistics are defined [Kost, 1980, p. 3] as:

\[
\text{RMS error} = \sqrt{\frac{1}{T} \sum_{t=1}^{T} (y_t^s - y_t^a)^2} \quad \text{and} \quad \text{(6.1)}
\]

\[
\text{RMS percent error} = \sqrt{\frac{1}{T} \sum_{t=1}^{T} \left( \frac{y_t^s - y_t^a}{y_t^a} \right)^2} \quad \text{(6.2)}
\]
Where:

\( T \) is the number of periods for the simulation,

\( Y_t^s \) is the simulated value of \( Y_t \), and

\( Y_t^a \) is the actual value of \( Y_t \).

These measures, together with some graphical analysis of the predicted and actual values have been used in the evaluation of this model.

The values of both the RMS error and RMS percentage error from a within-sample simulation are presented, for most variables of the model, in Table 6.3. In order to evaluate the dynamic performance of the model over a reasonably extended period, the model was simulated for the period from 1965I to 1979IV. Because of nonlinearities introduced by the annual crop equations, the simulation was performed using Newton's nonlinear methods with the SIMNLIN procedure of SAS/ETS [SAS, 1980].

Only the errors for the real price variables have been reported in Table 6.3. Deflation by an exogenous variable has an equal effect on both the numerator and the denominator of (6.2) and so the RMS percentage error is unaffected by the use of a price deflator. For the same reason, the conversion of meat consumption into per capita terms has no effect on the RMS percentage error and only the per capita variables have been reported. Apart from the variables omitted for the reasons given above, the error statistics have been reported for all of the variables of the model. The variables are reported in approximately the same order as the equations of Table 6.1.
Table 6.3. Forecasting accuracy of the model, 1965I - 1979IV

<table>
<thead>
<tr>
<th>Variable</th>
<th>RMS error</th>
<th>RMS error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(percentage)</td>
</tr>
<tr>
<td>XTBC</td>
<td>0.956</td>
<td>6.17</td>
</tr>
<tr>
<td>XPBC</td>
<td>0.371</td>
<td>3.05</td>
</tr>
<tr>
<td>XPKC</td>
<td>1.29</td>
<td>7.91</td>
</tr>
<tr>
<td>XCNC</td>
<td>0.348</td>
<td>3.82</td>
</tr>
<tr>
<td>RPGB</td>
<td>0.054</td>
<td>9.67</td>
</tr>
<tr>
<td>RPPK</td>
<td>0.081</td>
<td>11.12</td>
</tr>
<tr>
<td>RPCN</td>
<td>0.035</td>
<td>8.87</td>
</tr>
<tr>
<td>PCB</td>
<td>11.17</td>
<td>7.44</td>
</tr>
<tr>
<td>MCB</td>
<td>6.83</td>
<td>6.58</td>
</tr>
<tr>
<td>MPB</td>
<td>5.46</td>
<td>8.89</td>
</tr>
<tr>
<td>MPK</td>
<td>5.56</td>
<td>7.54</td>
</tr>
<tr>
<td>MCN</td>
<td>2.34</td>
<td>6.75</td>
</tr>
<tr>
<td>BINV</td>
<td>43.66</td>
<td>13.55</td>
</tr>
<tr>
<td>PKINV</td>
<td>48.30</td>
<td>21.4</td>
</tr>
<tr>
<td>RFSP</td>
<td>6.19</td>
<td>10.6</td>
</tr>
<tr>
<td>RBCP</td>
<td>6.28</td>
<td>16.2</td>
</tr>
<tr>
<td>RFPJKP</td>
<td>10.83</td>
<td>21.0</td>
</tr>
<tr>
<td>RFCNP</td>
<td>4.49</td>
<td>13.7</td>
</tr>
<tr>
<td>FSHBS</td>
<td>305.2</td>
<td>8.08</td>
</tr>
<tr>
<td>NFSHBS</td>
<td>122.2</td>
<td>97.0</td>
</tr>
<tr>
<td>CBS</td>
<td>84.0</td>
<td>8.48</td>
</tr>
<tr>
<td>BBS</td>
<td>12.5</td>
<td>10.5</td>
</tr>
<tr>
<td>PF</td>
<td>650.1</td>
<td>11.5</td>
</tr>
<tr>
<td>RBSP</td>
<td>7.07</td>
<td>13.2</td>
</tr>
<tr>
<td>SC</td>
<td>94.8</td>
<td>8.76</td>
</tr>
<tr>
<td>KC</td>
<td>795.1</td>
<td>1.72</td>
</tr>
<tr>
<td>KFC</td>
<td>790.4</td>
<td>2.03</td>
</tr>
<tr>
<td>BCOWS</td>
<td>842.1</td>
<td>2.09</td>
</tr>
</tbody>
</table>
Table 6.3 (continued)

<table>
<thead>
<tr>
<th>Variable</th>
<th>RMS error</th>
<th>RMS error (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCOWS</td>
<td>842.1</td>
<td>1.62</td>
</tr>
<tr>
<td>HBR</td>
<td>550.5</td>
<td>7.14</td>
</tr>
<tr>
<td>HMKT</td>
<td>3229.2</td>
<td>7.98</td>
</tr>
<tr>
<td>PKS</td>
<td>275.2</td>
<td>8.12</td>
</tr>
<tr>
<td>CHPDN</td>
<td>68.6</td>
<td>3.50</td>
</tr>
<tr>
<td>ICT</td>
<td>243.2</td>
<td>15.8</td>
</tr>
<tr>
<td>RPCORN</td>
<td>0.49</td>
<td>19.21</td>
</tr>
<tr>
<td>XDC</td>
<td>92.1</td>
<td>10.2</td>
</tr>
<tr>
<td>COSPRUS</td>
<td>84.5</td>
<td>1.57</td>
</tr>
<tr>
<td>ACP</td>
<td>0.64</td>
<td>0.93</td>
</tr>
<tr>
<td>AU</td>
<td>1640.5</td>
<td>4.18</td>
</tr>
<tr>
<td>RBSPA</td>
<td>4.97</td>
<td>9.20</td>
</tr>
<tr>
<td>WRBSPA</td>
<td>4.03</td>
<td>7.10</td>
</tr>
</tbody>
</table>

The estimated errors were generally regarded as being quite satisfactory for dynamic simulation of a model covering an industry of this complexity. The level of error in the meat consumption variables was lowest for processing beef, and highest for pork. It must be remembered that the pork data series used for this simulation is only approximate prior to 1970 and this may have exaggerated the error on the pork variables.

The meat price variables had higher errors than the corresponding quantity variables. The fact that none of the behavioral equations was normalized on price during the estimation phase may have contributed
to the higher errors on prices [Heien, Matthews, and Womack, 1973]. Although a theoretical rationale for price-dependent demand equations has been proposed [Heien, 1977], the quantity-dependent form was used in this study because the theory of the consumer is best developed for this case.

Error statistics have been reported for the nominal price variable PCB, since it does not enter the model in real terms. This variable is a weighted average of PTB and PGB and has a slightly lower average than either of its components. The error statistics for the farm-retail margin variables seem quite satisfactory, given the somewhat ad-hoc nature of their specification. The errors on the meat inventory equations are rather high, and particularly so on the pork inventory equation.

The errors on the farm-price variables are noticeably higher than at the retail level. Given the difficulty reported in finding satisfactory specifications for the pork supply equations, the high error on the farm pork price gives rise to some concern about this component of the model. Revising the specification of these equations and re-estimating them, when a longer data series becomes available, would appear likely to be worthwhile.

Of the four beef supply equations, three have reasonably low percentage errors. The very high RMS percentage error on the NFSHBS variable (97 percent) reflects the residual nature of this component, the limitations of the data used to estimate it and its relatively small mean value. The problem appears much less serious when the absolute RMS errors are examined. The RMS error for this variable
is only 40 percent of that for FSHBS, even though FSHBS has a much lower percentage error. The level of table beef consumption is a linear combination of the FSHBS and NFSHBS variables and has a relatively low RMS percentage error. Thus, the extremely large relative variability of NFSHBS does not appear to have had serious adverse effects on the remainder of the model.

The errors on both the placements on feed (PF) and the feeder steer price (RBSP) variables are both moderately large. However, these errors do not appear unreasonable in view of the specification problems associated with the RBSP equation, and the fact that these equations contain only endogenously determined causal variables.

The calf slaughter variable (SC) appears to have been explained reasonably well by the model. The standard errors on the key beef cow inventory (BCOWS) and calf crop (KC) variables are particularly low. The inventory of feeder calves (KFC) also has quite low errors. Given the crucial importance of the cow inventory and calf supply variables in the model, these low errors are reassuring.

The hog inventory and pork supply variables all have moderately high errors, although their values do not seem unreasonable for a dynamic simulation. The chicken production variable has a very low percentage error.

The errors on each of the corn market demand and price variables are relatively high, while the corn supply variables appear to have been predicted very accurately. Since the animal units variable was predicted quite accurately, the source of the relatively large errors
in the corn market variables appears likely to lie within the specification of the corn demand equations.

Since there is no absolute standard by which to gauge simulation RMS errors, it is desirable to evaluate these errors in relation to some alternative source of forecasts. Arzac and Wilkinson [1979a, p. 303] used a simple fourth-order autoregressive model for a comparison. Since many of their variables are comparable to those appearing in this model, their published RMS errors could provide a suitable basis for comparison of the two models.

In order to compare the two models, the model developed for this study was simulated dynamically to produce forecasts for the 1965I - 1975IV period used by Arzac and Wilkinson, [1979a]. They presented their error statistics as the RMS error as a percentage of the mean, and this statistic is presented for comparable variables from the two models in Table 6.4.

The model presented in this study appears to have generated better forecasts than the Arzac and Wilkinson [1979a] model in a number of areas. At the retail price level, our model had lower errors for all meat prices except pork. The improvement in the forecast errors was particularly marked for the price of processing quality beef, PGB. There was also an improvement in the errors for the quantity of beef consumed in two of the four cases, with a dramatic improvement in the forecast errors for lower quality beef.
Table 6.4. Comparison of the forecasting accuracy of the model used in this study and the Arzac and Wilkinson\textsuperscript{a} model, 1965I - 1975IV

<table>
<thead>
<tr>
<th>Variable name</th>
<th>RMS error as percentage of mean</th>
<th>Arzac and Wilkinson variable</th>
<th>RMS error as percentage of mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCB</td>
<td>7.9</td>
<td>PR1</td>
<td>10.4</td>
</tr>
<tr>
<td>PGB</td>
<td>9.9</td>
<td>PR2</td>
<td>16.8</td>
</tr>
<tr>
<td>PPK</td>
<td>12.9</td>
<td>PR3</td>
<td>10.9</td>
</tr>
<tr>
<td>PCN</td>
<td>10.6</td>
<td>PR4</td>
<td>12.8</td>
</tr>
<tr>
<td>XTB</td>
<td>6.7</td>
<td>XD1\textsuperscript{b}</td>
<td>5.4</td>
</tr>
<tr>
<td>XPB</td>
<td>3.2</td>
<td>XD2\textsuperscript{b}</td>
<td>20.3</td>
</tr>
<tr>
<td>XPK</td>
<td>8.0</td>
<td>XD3</td>
<td>8.0</td>
</tr>
<tr>
<td>XCN</td>
<td>4.0</td>
<td>XD4</td>
<td>4.5</td>
</tr>
<tr>
<td>STP</td>
<td>11.9</td>
<td>PF1</td>
<td>13.3</td>
</tr>
<tr>
<td>CWP</td>
<td>14.7</td>
<td>PF2</td>
<td>19.6</td>
</tr>
<tr>
<td>HOP</td>
<td>24.1</td>
<td>PF3</td>
<td>15.2</td>
</tr>
<tr>
<td>CHFP</td>
<td>15.8</td>
<td>PF4</td>
<td>18.1</td>
</tr>
<tr>
<td>FSHBS</td>
<td>8.7</td>
<td>XS1</td>
<td>5.6</td>
</tr>
<tr>
<td>NFSHBS</td>
<td>25.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CBS</td>
<td>9.7</td>
<td>XS2\textsuperscript{b}</td>
<td>23.1</td>
</tr>
<tr>
<td>BBS</td>
<td>9.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PKS</td>
<td>8.3</td>
<td>XS3</td>
<td>7.8</td>
</tr>
<tr>
<td>CHPDN</td>
<td>3.9</td>
<td>XS4</td>
<td>3.2</td>
</tr>
<tr>
<td>COSPRUS</td>
<td>3.2</td>
<td>XSC</td>
<td>3.3</td>
</tr>
<tr>
<td>ACP</td>
<td>2.0</td>
<td>AP1</td>
<td>2.9</td>
</tr>
<tr>
<td>SC</td>
<td>8.8</td>
<td>SC</td>
<td>24.0</td>
</tr>
<tr>
<td>PF</td>
<td>10.9</td>
<td>IP</td>
<td>7.1</td>
</tr>
</tbody>
</table>

\textsuperscript{a}See Arzac and Wilkinson [1979a, p. 303].

\textsuperscript{b}These variables differ in definition because Arzac and Wilkinson used a fed/nonfed beef categorization rather than the table/processing beef division used in this study.
Table 6.4 (continued)

<table>
<thead>
<tr>
<th>Variable name in this study</th>
<th>RMS errors as percentage of mean</th>
<th>Arzac and Wilkinson variable</th>
<th>RMS error as percentage of mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBSP</td>
<td>11.8</td>
<td>PF5</td>
<td>20.5</td>
</tr>
<tr>
<td>HBR</td>
<td>8.0</td>
<td>KH</td>
<td>6.2</td>
</tr>
<tr>
<td>HMKT</td>
<td>8.3</td>
<td>IH</td>
<td>5.2</td>
</tr>
<tr>
<td>BCOWS</td>
<td>2.4</td>
<td>KB</td>
<td>4.1</td>
</tr>
<tr>
<td>KC</td>
<td>1.3</td>
<td>KC</td>
<td>4.4</td>
</tr>
<tr>
<td>XDC</td>
<td>7.5</td>
<td>XDC</td>
<td>9.3</td>
</tr>
<tr>
<td>ICT</td>
<td>10.3</td>
<td>ICC</td>
<td>14.6</td>
</tr>
<tr>
<td>RPCORN</td>
<td>18.0</td>
<td>PGL</td>
<td>13.8</td>
</tr>
</tbody>
</table>

At the farm level, our model yields noticeably better forecasts for three of the four prices. However, its performance in forecasting the price of hogs is considerably worse.

Comparison of the meat supply equations is particularly interesting. The disaggregation of nonfed beef in this study reveals wide disparities in the errors of its components. The two major components of total nonfed beef production, CBS and BBS, were predicted reasonably well, while NFSHBS had a relatively large error. In our model, NFSHBS is primarily allocated to table beef supply, whereas this meat was all included under nonfed beef in the Arzac and Wilkinson model. Despite the large error on NFSHBS, its inclusion in the table beef supply category has not resulted in large errors for the latter variable. By

1Interestingly, the RMS as a percentage of the mean statistic shows a much lower error for NFSHBS than the RMS percentage error (25.6 versus 109.5). The RMS percentage error is clearly sensitive to extreme values in this case.
contrast, inclusion of this class of beef with cow and bull to have resulted in large errors on the PR2 and XD2 variables of the Arzac and Wilkinson model.

Our model appears to have predicted the price of feeder steers (RBSP) with considerably greater accuracy than the Arzac and Wilkinson model. On the other hand, our forecast error for the number of cattle placed on feed was slightly higher.

The predictions for breeding hog inventories and market hog inventories generated by this model were inferior to those generated by the Arzac and Wilkinson model. However, it must be remembered that our errors for these variables cover five nonsample years for which the data are not strictly comparable. This model performed noticeably better than the Arzac and Wilkinson model in predicting the crucial cow inventory and calf crop variables.

Turning to the corn market variables, this model produced noticeably better forecasts of both corn consumption and inventory demand. However, the forecasts for the price of corn were somewhat worse, possibly because none of the equations were normalized on price in the estimation process.

Overall, comparison of the errors from this model with those from the Arzac and Wilkinson model suggests that the use of the table/processing beef disaggregation has probably helped to improve the predictive performance of the model. This and other respecifications included in the model have resulted in a considerable improvement in the forecast errors for many of the key meat price and quantity variables.
of the model. For the 25 variables which could be directly compared, 15 were predicted more accurately by our model. The comparison does, however, suggest some areas of weakness particularly in the hog/pork component of the model, and in explaining the price of corn.

Plots of the actual and predicted values from the model frequently provide useful additional information about the simulation performance of the model. Plots covering the period 1965I - 1980IV for three key variables of the model are presented in Figures 5.1, 5.2, and 5.3.

From Figure 5.1, it appears that the model has tracked the inventory of beef cows very well, during both the expansion and contraction stages of the cycle. The turning points also appear to have been predicted remarkably well. The RMS error on the real price of processing beef (RPGB) was considerably higher than for BCOWS and this higher level of error is reflected in Figure 5.2. While the basic cyclical pattern appears to have been reproduced, there are persistent under and over-predictions for this variable which suggest that further experimentation with the specification, or correction for autocorrelation, might be justified. At the very least, some procedure such as the use of "add" factors [Intriligator, 1978, p. 516] would probably be needed to obtain satisfactory forecasts for this variable. The pattern of the forecasts for RBCP, in Figure 5.3, is similar to that for RPGB in Figure 5.2. In both cases, serious errors have been caused by a delay in predicting the most recent downturn in prices and by overpredictions in subsequent periods. However, these errors are clearly far more serious for RBCP than for RPGB.
Figure 6.1. Actual and predicted values for the inventory of beef cows, 1965I - 1980IV
Figure 6.2. Actual and predicted values for the real price of processing beef, 1965I - 1980IV.
Figure 5.3. Actual and predicted values for the real prices of beef cow, 1965I - 1980IV
The final, and least satisfactory simulation plot is that for the real price of corn (Figure 5.4). In a number of years, the predictions indicate an excessive degree of seasonal variation in this price. This problem might possibly be reduced by the use of a nonlinear functional form in the stocks equation, as suggested by Sharples and Holland [1981], or by allowing the structure of the market relationships to change from quarter to quarter as was done by Subotnik and Houck [1979]. Unfortunately, none of the simpler nonlinear functional forms investigated in this study proved to be satisfactory. The Subotnik and Houck approach was viewed as too complex for satisfactory inclusion in a relatively large model such as the one developed in this study.

**Beyond-sample forecasts**

In order to allow testing of the forecasting performance of the model outside the sample period, data for the four quarters of 1980 were not included in the estimation of the model equations. As a test of the model's performance in forecasting outside the sample period, forecasts were generated for the period 1980I - 1980IV. These forecasts were then used to calculate the beyond-sample RMS error statistics which have been reported in Table 6.5, following the format of Table 6.3.

In general, the error statistics reported in Table 6.5 are higher than those presented in Table 6.3. This is to be expected since the beyond-sample simulation is a much more rigorous test of the model.
Figure 6.4. Actual and predicted values for the real price of corn, 1965I - 1980IV
Table 6.5. Forecast accuracy of the model in beyond-sample forecasting, 1980I - 1980IV

<table>
<thead>
<tr>
<th>Variable</th>
<th>RMS error</th>
<th>RMS error (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>XTBC</td>
<td>1.07</td>
<td>7.24</td>
</tr>
<tr>
<td>XPBC</td>
<td>0.33</td>
<td>3.09</td>
</tr>
<tr>
<td>XPKC</td>
<td>1.21</td>
<td>6.51</td>
</tr>
<tr>
<td>XCNC</td>
<td>0.41</td>
<td>3.50</td>
</tr>
<tr>
<td>RPTB</td>
<td>0.14</td>
<td>13.43</td>
</tr>
<tr>
<td>RPGB</td>
<td>0.058</td>
<td>10.17</td>
</tr>
<tr>
<td>RPPK</td>
<td>0.041</td>
<td>7.68</td>
</tr>
<tr>
<td>RPCN</td>
<td>0.055</td>
<td>18.53</td>
</tr>
<tr>
<td>PCB</td>
<td>31.02</td>
<td>12.95</td>
</tr>
<tr>
<td>MCB</td>
<td>16.64</td>
<td>9.69</td>
</tr>
<tr>
<td>MPB</td>
<td>5.84</td>
<td>6.00</td>
</tr>
<tr>
<td>MPK</td>
<td>6.24</td>
<td>6.43</td>
</tr>
<tr>
<td>MCN</td>
<td>30.72</td>
<td>41.89</td>
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<tr>
<td>BINV</td>
<td>64.76</td>
<td>26.07</td>
</tr>
<tr>
<td>PKINV</td>
<td>43.52</td>
<td>15.29</td>
</tr>
<tr>
<td>RFSP</td>
<td>11.42</td>
<td>21.73</td>
</tr>
<tr>
<td>RBCP</td>
<td>15.31</td>
<td>44.59</td>
</tr>
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<td>RFPPK</td>
<td>4.05</td>
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</tr>
<tr>
<td>RFCNP</td>
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<td>25.53</td>
</tr>
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<td>FSHBS</td>
<td>399.97</td>
<td>9.94</td>
</tr>
<tr>
<td>NFSHBS</td>
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<td>224.1</td>
</tr>
<tr>
<td>CBS</td>
<td>38.16</td>
<td>4.31</td>
</tr>
<tr>
<td>BBS</td>
<td>24.41</td>
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</tr>
<tr>
<td>PF</td>
<td>991.25</td>
<td>16.67</td>
</tr>
<tr>
<td>RBSP</td>
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<td>21.64</td>
</tr>
<tr>
<td>SC</td>
<td>49.96</td>
<td>7.69</td>
</tr>
<tr>
<td>KC</td>
<td>731.98</td>
<td>1.56</td>
</tr>
</tbody>
</table>
Table 6.5 (continued)

<table>
<thead>
<tr>
<th>Variable</th>
<th>RMS error</th>
<th>RMS error (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KFC</td>
<td>74.25</td>
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</tr>
<tr>
<td>BCOWS</td>
<td>706.52</td>
<td>1.81</td>
</tr>
<tr>
<td>TCOWS</td>
<td>710.43</td>
<td>1.42</td>
</tr>
<tr>
<td>HBR</td>
<td>319.98</td>
<td>4.18</td>
</tr>
<tr>
<td>HMKT</td>
<td>1641.13</td>
<td>3.51</td>
</tr>
<tr>
<td>PKS</td>
<td>285.32</td>
<td>6.74</td>
</tr>
<tr>
<td>CHPDN</td>
<td>132.56</td>
<td>4.74</td>
</tr>
<tr>
<td>ICT</td>
<td>368.69</td>
<td>11.14</td>
</tr>
<tr>
<td>RPCORN</td>
<td>0.209</td>
<td>9.48</td>
</tr>
<tr>
<td>XDC</td>
<td>178.13</td>
<td>11.59</td>
</tr>
</tbody>
</table>

However, in most cases, the prediction errors remain in a reasonably acceptable range. In particular, the quantities of meat consumed, and the cow and calf inventory levels, appear to have been predicted very well.

The very high levels of prediction errors on some variables require closer examination, however. NFSHBS has an extremely large RMS percentage error, even though its RMS error is lower than in the long-run simulation presented in Table 6.3. Examination of the predicted and actual values suggests that the alarmingly high percentage error statistic is due to one observation where the actual value of NFSHBS is very close to zero. Again, the absolute RMS error on this variable is much lower than that on the FSHBS variable.
The relatively high error statistics for RBCP present a different problem. In this case, examination of the predicted and actual values made it clear that the problem was one of consistent overprediction, a pattern which is clearly evident in Figure 6.3. This pattern is relatively serious for structural analysis since it implies some degree of error in the structural estimates. Paradoxically, it may be less serious for forecasting because of the consistent nature of this bias over reasonably extended periods of time.

While the beyond-sample forecasts reported in this section have revealed some weaknesses in the model, it must be remembered that the vast majority of the variables were forecasted satisfactorily. The use of an individual year is, of course, arbitrary and may well have resulted in misleadingly high error statistics for some variables. This problem is, to some extent, inevitable in any use of simulation for model validation. The alternative approach of calculating the characteristic roots of the model, to which we now turn, deals directly with the estimated structure of the model, and so is independent of any particular set of data observations.

The characteristic roots of the model

For any set of values for the exogenous variables, it seems reasonable to assume the existence of a unique set of long-run
equilibrium values of the endogenous variables. In a static model, it is assumed that these stationary values are always achieved. In a dynamic system, however, it may take an extended period of time for long-run equilibrium to be achieved following a change in the exogenous variables.

The stability properties of the system involve the dynamic path of adjustment of the endogenous variables. The definition of stability used in economics has been defined by Samuelson [1947, p. 261] as "...if from any initial conditions all the variables approach their equilibrium values in the limit as time becomes infinite."

Stability is an extremely important property of a model. If the model is unstable, then the deviations of the endogenous variables from their equilibrium values will increase, rather than decrease through time. As a result, the model will never reach long-run equilibrium and the values of its variables may tend to infinity. Clearly, a market form of organization is not likely to survive if that is the true nature of the system which results from use of the market as a coordinating mechanism. Since the system modeled in this study

---

1The term long-run equilibrium has been used to refer to the stationary values of the endogenous variables. In fact, the entire model developed in this study is an equilibrium model, and the individual time period solutions are short-run equilibrium values [Bowden, 1978, p. 19]. The use of true disequilibrium models was discussed in Chapter IV.

2In their analysis of the Klein-Goldberger model, Theil and Boot [1962] raised the fascinating question of whether the U.S. economy as a whole was unstable. They were unable to reject the possibility that the system was unstable in the absence of stabilization policy.
has relied primarily on market signals to coordinate activity for a long time, it appears that the system is almost certainly inherently stable, even if it is subject to various cyclical influences. The characteristic roots (or eigenvalues) of a linear model provide a means of determining whether a dynamic, deterministic model is stable, and whether its deterministic component will generate cyclical behavior. Chow [1975, p. 25] has demonstrated that the values of the deviations of the endogenous variables from long-run equilibrium can be written as a linear combination of the individual characteristic roots raised to the power $t$, i.e.,

$$y_{i,t} = \sum_{j=1}^{n} k_{i,j} \cdot \lambda_j^t$$

Where:

- $y_{i,t}$ is the value of the deviation of $y_i$ from equilibrium at time $t$,
- $k_{i,j}$ is the coefficient for variable $i$ on characteristic root $j$,
- $\lambda_j$ is characteristic root $j$.

Clearly, if any $\lambda_j$ is greater than one in absolute value, then the absolute values of the $y$'s will grow larger without limits. For stability, all of the roots must therefore be less than unity in absolute value. If the roots are less than unity in absolute value, but complex, they may generate damped cyclical behavior.
The method of calculating the characteristic roots for this model will be discussed prior to presentation of the characteristic roots of this model. A linear econometric model with g structural relations can be represented for time t as:

\[ GY_t + GY_t^L + BX_t = V_t \]  

(6.3)

Where:

- \( G \) is a \( g \times g \) matrix of structural coefficients on the endogenous variables,
- \( C \) is a \( g \times b \) matrix of structural coefficients on the \( b \) lagged endogenous variables,
- \( B \) is a \( g \times k \) matrix of coefficients on the \( k \) exogenous variables of the model,
- \( Y_t \) is a \( g \times 1 \) vector of endogenous variables,
- \( Y_t^L \) is a \( b \times 1 \) vector of lagged endogenous variables,
- \( X_t \) is a \( k \times 1 \) vector of exogenous variables in the model, and
- \( V_t \) is a \( g \times 1 \) vector of error terms.

The model in its present form is nonhomogeneous and stochastic. Since our objective is to investigate the dynamic properties of the deterministic system, we must reduce the model to its homogeneous, deterministic form [Chiang, 1974, ch. 16]. To do this, we must set the error vector to its expected value of zero and delete the term
BX_t, which is associated with only the particular solution of the model. The resulting homogeneous system is:

\[ G_y + C_y^L = 0 \]  \hspace{1cm} (6.4)

Where:

\[ y_t = y_t - \bar{Y} \] and \( \bar{Y} \) is the particular solution.

This specification is quite general in the sense that \( y_t^L \) may include lags of any order and need not have the same dimensions as \( y_t \). Conceptually, the system can be solved in this form to yield estimates of the characteristic roots, characteristic vectors, and the complementary solution. However, the problem will be computationally more tractable if the equation system is first converted to a system containing only first order lags.

One approach to obtaining a first order system [Chow, 1975, p. 22] involves the calculation of the reduced form of (6.4) as a first step. This results in:

\[ y_t = -G^{-1}C_y^L = \pi y_t^L \]

Where:

\( \pi \) is a \( g \times b \) matrix of reduced form coefficients for the lagged endogenous variables.

Chow then suggests partitioning the reduced form matrix by the order of the lags included in it and setting up an augmented coefficient matrix.

\footnote{As in the case of single equations, the general solution, if desired, could be obtained by adding the particular solution to the complementary solution obtained from the homogeneous form [Gandolfo, 1971, p. 255].}
matrix for the first order system. Partitioning \( \pi \) yields

\[
y_t = \pi_1 y_{t-1} + \pi_2 y_{t-2} + \ldots + \pi_m y_{t-m}
\]

Chow's augmented matrix equation is then:

\[
\begin{bmatrix}
y_t \\
y_{t-1} \\
\vdots \\
y_{t-m}
\end{bmatrix} = 
\begin{bmatrix}
\pi_1 & \pi_2 & \ldots & \pi_m \\
I & 0 & \ldots & 0 \\
0 & I & \ldots & 0 \\
\vdots & \vdots & \ddots & \vdots \\
0 & 0 & \ldots & I \\
\end{bmatrix} 
\begin{bmatrix}
y_{t-1} \\
y_{t-2} \\
\vdots \\
y_{t-m-1}
\end{bmatrix}
\]

This system is of order \( g \times m \) where \( m \) is the order of the longest lag in the system. Given the relatively long lags occurring in the estimated model, this approach would lead to an extremely large (224 x 224), albeit sparse, matrix of coefficients. Reeves [1979, p. 166] points out that the use of Baumol's [1970, p. 332] artificial variable approach will usually result in a much smaller coefficient matrix. Baumol's approach consists of adding an additional equation and an additional variable to the structural system for each lag period greater than one. As an example of Baumol's approach, the scalar equation

\[
q_t = aq_{t-1} + bq_{t-2}
\]

involving a second order lag would become the following first-order system of two equations:
\[ q = a q_{t-1} + b q_t^* \]

\[ q_t^* = q_{t-1} \]

Because of the dimensionality problem, Baumol's approach was used to convert the structural system into a first-order system of 73 equations. The reduced form was then calculated as:

\[ y_t^* = \pi^* y_{t-1} \]

Where:

- \( y_t^* \) is a \( g + d \) vector of endogenous variables,
- \( \pi^* \) is a \( (g + d) \times (g + d) \) matrix of coefficients,
- \( y_{t-1}^* \) is a \( (g + d) \) vector of first-order lagged endogenous variables, and
- \( d \) is the number of artificial variables created.

In this reduced form, the variables included in \( y_t^* \) and \( y_{t-1}^* \) were arranged in the same order and columns of zeros were used where necessary to make the \( \pi^* \) matrix square.

Using standard techniques for the analysis of first order difference equations [Chiang, 1974, p. 580], we introduce trial solutions of the form:

\[ y_t^i = a_i \lambda^t \]

Where:

- \( y_t^i \) is the value of variable \( i \) at time \( t \),
- \( a_i \) is an undetermined constant, and
- \( \lambda \) is another constant equal to a root of the characteristic equation of the system.
Substituting the trial solution into the first order reduced form
leads to:

\[
\begin{bmatrix}
  a_1 \\
  \vdots \\
  \vdots \\
  g+d
\end{bmatrix} \cdot \lambda^t = \begin{bmatrix}
  \pi^* \\
  \vdots \\
  \vdots \\
  a_{g+d}
\end{bmatrix} \cdot \begin{bmatrix}
  a_1 \\
  \vdots \\
  \vdots \\
  g+d
\end{bmatrix}
\]

Cancelling the $\lambda^{t-1}$ term from both sides and rewriting the vector

\((a_1, \ldots, a_{g+d})\) as \(a\) leads us to the matrix equation:

\[
\pi^* a - \lambda a = 0
\]

which can equivalently be written:

\[
\pi^* a - \lambda I a = 0
\]

Where:

- \(I\) is an identity matrix of order \((g+d)\).

This equation rearranges to:

\[
(\pi^* - \lambda I) \cdot a = 0
\]

For this equation to hold for nontrivial values of \(a\), the matrix

\((\pi^* - \lambda I)\)

must be singular and, hence, \(\left|\pi^* - \lambda I\right|\) must equal zero. The
solutions of the characteristic equation defined by equating this
determinant to zero are the characteristic roots of the matrix \(\pi^*\).

While algebraic solutions to higher order characteristic equations are
not feasible, the characteristic roots can be approximated to any
desired degree by numerical methods [Baumol, 1970, p. 231]. For this
study, the characteristic roots were estimated using the EIGRF subroutine in the IMSL Fortran subroutine library [IMSL, 1982].

For calculation of the characteristic roots, the system had to be reduced slightly. The corn area planted and corn production equations enter only once per year and this represented a serious nonlinearity from the point of view of analytical investigation of the structure of the model. Since these equations were not interdependent with the model, their exclusion will not affect its dynamic properties. Accordingly, they were excluded from the model for calculation of the characteristic roots. The nonlinearities associated with price deflation and calculation of per capita meat consumption were removed by setting population and the price deflators at their 1979 average values. The model analyzed used the corn inventory equation in the absence of the Farmer Owned Reserve.

The calculated values of all the characteristic roots with a modulus greater than 0.1 are given in Table 6.6. The details of the method used to compute these roots are given in Appendix B. For those roots which are pairs of complex conjugates, the modulus and the period of the associated cycle [Baumol, 1970, p. 210] have also been presented in the table.

All of the characteristic roots in Table 6.6 have a modulus of less than one, with none close to one. This provides a necessary and sufficient condition for stability of the deterministic model [Theil and Boot, 1962]. It also allows us to make some qualitative inferences about the behavior of the deterministic system.
Table 6.6. The characteristic roots of the homogeneous version of the model

<table>
<thead>
<tr>
<th>Type of root</th>
<th>Characteristic root</th>
<th>Modulus</th>
<th>Length of corresponding cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real</td>
<td>0.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.84</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.46</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complex</td>
<td>0.92 ± 0.14</td>
<td>0.93</td>
<td>40.9</td>
</tr>
<tr>
<td></td>
<td>-0.38 ± 0.78</td>
<td>0.86</td>
<td>5.6</td>
</tr>
<tr>
<td></td>
<td>-0.04 ± 0.85</td>
<td>0.85</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>0.59 ± 0.60</td>
<td>0.84</td>
<td>7.9</td>
</tr>
<tr>
<td></td>
<td>0.18 ± 0.76</td>
<td>0.78</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td>0.70 ± 0.33</td>
<td>0.77</td>
<td>14.3</td>
</tr>
<tr>
<td></td>
<td>0.68 ± 0.37</td>
<td>0.77</td>
<td>12.6</td>
</tr>
</tbody>
</table>

The dominant root of the model, which will determine the long-run behavior of the system, has a modulus of 0.93 and is associated with a cycle of 41 quarters duration. This cycle length corresponds closely to the cattle cycle of 10 years duration observed by Simpson.
However, even the component of the solution associated with this root will virtually have vanished after 40 quarters and so the model requires the introduction of continuing shocks for cycles to be perpetuated.

Several pairs of complex roots with moduli between 0.78 and 0.86 have periods of between one and two years. These probably reflect some combination of seasonal influences, spurious short-term cyclical properties and, possibly, short-term cyclical behavior in the poultry industry. Two pairs of complex roots with moduli of 0.77 are associated with cycles of between three and four years duration. One or both of these may be associated with the observed cyclical behavior of the hog industry. The periods of these two cyclical components corresponds quite closely to the cycles of 12.8 and 16 quarters observed by Spreen and Shonkwiler [1981] in their analysis of hog slaughter data.

Each of the positive real roots of the model will contribute a convergent component to the dynamic behavior of the system. Even the largest of these roots, 0.87, will decay reasonably rapidly and will have virtually disappeared after five years. The negative real roots will each contribute a fluctuating component to the solution, being alternatively positive and negative in alternate quarters. All of the negative roots are relatively small, and will rapidly vanish.

The characteristic roots of this model appear to be very satisfactory in relation to the roots reported in other studies. After arbitrary adjustment of a coefficient in his beef cow inventory equation, the dominant cyclical element in Freebairn's [1972, p. 232]
model was provided by a pair of complex roots with modulus 0.97 and a periodicity of 5.7 years. This cyclical period corresponds to neither the hog nor the cattle cycle. Reeves' model [1979, p. 268] included a pair of complex roots with a modulus of 0.995, and a cycle period of 4.0 years. Such a cycle will persist almost indefinitely and may have been associated with the spurious cyclical problems reported in Reeves' simulation analysis.

Clearly, examination of the characteristic roots of this model suggests that the deterministic component of this model displays the type of dynamic behavior actually observed in the system. While the actual behavior of the system will also depend upon the values of the stochastic error terms, the fact that the characteristic roots are all less than one means that the multivariate time series generated by the model will be covariance stationary [Chow, 1975, p. 54]. This suggests that the full, stochastic system will also be stable, although the periodicities of the cyclical behavior observed in the stochastic case may differ from those suggested by the deterministic system [Adelman and Adelman, 1959]. It should be possible to calculate the autocovariance matrix associated with the model using the estimated coefficient matrix [Chow, 1975, p. 54]. Unfortunately, this procedure involves either calculation and manipulation of all of the eigenvectors of the model or the approximate summation of an infinite series. Because of the size of the model, it was believed that calculation of

1The time series referred to here are the series of deviations from long-run equilibrium values.
of the autocovariance function would be prohibitively expensive and so this step was not undertaken.

Based on the three approaches to validation considered in this chapter, the model was tentatively accepted as a useful representation of the system. The multiplier analysis and simulations discussed in the next chapter will indirectly provide some further tests of the validity of the model. However, since we have conditionally accepted the model, their main purpose is to allow us to make inferences about the behavior of the system, rather than of the model itself.
CHAPTER VII. MULTIPLIERS FOR BEEF IMPORTS AND THE EXCESS DEMAND FOR BEEF

A great advantage of a disaggregated structural model of the type developed in this study is the flexibility of the model for use in policy analysis. In some cases, a policy change can be represented by a change in one (or more) of the structural coefficients of the model. In other cases, a particular policy approach converts a formerly endogenous variable into a policy instrument. Either type of change can be incorporated once the structural model has been estimated.

The U.S. feed-livestock subsector includes several cases of policies which allow formerly endogenous variables to be treated as policy instruments, e.g., meat imports, and (in some circumstances) the price of corn. The effects of the Farmer-Owned Reserve (FOR) were considered in Chapter V by the related technique of changes in some of the coefficients of the model.

The discussion in this chapter is based upon the use of dynamic multipliers of the type developed by Theil and Boot [1962]. In the first section, the impact of a change in the level of beef imports on key variables in the feed-livestock sector will be examined. In the second section, the multiplier technique will be used to consider the effects of various variables upon the demand for imported beef.

Before proceeding to the multiplier analysis, it will be worthwhile to provide a brief explanation of the algebra of the multipliers used.
Using the notation defined for Equation (6.3), the deterministic part of the model can be written as

\[ GY_t + CY_{t-1} + BX_t = 0 \]

(7.1)

Inverting \( G \) and premultiplying both sides of (7.1) allows us to obtain the reduced form of the model

\[ Y_t = DY_{t-1} + \pi X_t \]

(7.2)

Where:

- \( D = - G^{-1}C \), and
- \( \pi = G^{-1}B \)

By backward substitution, this can be transformed to

\[ Y_t = D^2Y_{t-2} + D\pi X_{t-1} + \pi X_t \]

(7.3)

The matrix \( \pi \) in (7.3) gives the effect of a change in the exogenous variables on the endogenous variables in the current period. The matrix product, \( D\pi \), termed an interim multiplier, gives the effect of changes in the exogenous variables during the previous period, upon values of the endogenous variables in the current period. \( D\pi \) is known as the first-period interim multiplier for a policy change. Interim multipliers for any desired order of lag (e.g., \( D^2\pi \), \( D^3\pi \),...) can be calculated by repeated substitution. Addition of the interim multipliers

\[ \text{The formulation used here is less general than that used in Theil and Boot [1962], which permitted lagged exogenous variables to enter the system. When lagged exogenous variables enter the system, their effect can always be incorporated by defining an artificial endogenous variable equal to the exogenous variable of interest, and incorporating the lag of this quasi-endogenous variable in the model.} \]
for any subperiod yields the interim multipliers for a policy change sustained for the length of the subperiod.

If a policy change is assumed to be permanent, then its ultimate effect is the sum of all of the interim multipliers, i.e.

\[ T = \pi + \sum_{t=1}^{\infty} D^t \pi \]  

(7.4)

Where:

- \( T \) is the total multiplier for the policy change.

As long as the roots of the matrix \( D \) are all less than unity in absolute value (as they were found to be for this model in the previous chapter) then the infinite series in (7.4) will converge [Theil and Boot, 1962, p. 139]. In this case, assuming the matrix \((I-D)\) is invertible, the total multipliers can be calculated explicitly from the formula for the infinite sum in (7.4).

\[ T = (I-D)^{-1} \pi \]

All three types of multipliers outlined above, the impact, interim, and total multipliers, will be used extensively in the remainder of this chapter.

Multipliers for the Model With Exogenous Beef Imports

Since the introduction of the Meat Import Act of 1964, the level of meat imports into the United States has been a policy variable of considerable interest [USITC, 1977a, 1977b]. A number of studies have analyzed the effects of changes in this policy variable (e.g., Houck, 1974;
Freebairn and Rausser, 1975; Woods, 1975. Under the 1979 law, the level of imports is no longer subject to discretionary control in all years but it is still subject to presidential discretion under some circumstances [Conable, 1980]. In principle, the level of imports is also a control variable in the sense that the law governing the volume of imports could be changed.

Since control of the level of beef imports is still of policy relevance, and because these multipliers provide an opportunity for comparisons with other models, the first set of multipliers to be considered are those for beef imports. Most of the models considered in this section are calculated on the assumption of a freely operating corn market, without either government intervention to maintain the price of corn, or the operation of the FOR program. However, some multipliers have also been calculated for the use of corn price as a policy instrument. Beef import multipliers have been presented in Table 7.1 for the effects of an increase of 400 million pounds annually, or 100 million pounds per quarter. This is approximately 17 percent of the peak annual import level of 2,405 million pounds in 1979 and almost a quarter of average imports during the 1962-1979 sample period used in this study. To keep the size of the table manageable, the multipliers have been aggregated to a yearly basis, except for the initial period, or impact, multipliers which refer to the effect of the change in the first quarter. Since beef imports are a flow variable, the effects of a quarterly increase of 100 million pounds, and
Table 7.1 Impact, interim and total multipliers for an increase of 400 million pounds annually in the level of beef imports

<table>
<thead>
<tr>
<th>Retail prices</th>
<th>Impact (quarterly)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTB, c/lb.</td>
<td>0.09</td>
<td>2.11</td>
<td>-0.07</td>
<td>-0.23</td>
<td>-0.68</td>
<td>-0.78</td>
<td>-0.64</td>
<td>-1.07</td>
</tr>
<tr>
<td>PGB, c/lb.</td>
<td>-2.84</td>
<td>-3.09</td>
<td>-0.38</td>
<td>-0.52</td>
<td>-0.57</td>
<td>-0.57</td>
<td>-0.42</td>
<td>-5.62</td>
</tr>
<tr>
<td>PPK, c/lb.</td>
<td>-1.11</td>
<td>-0.99</td>
<td>0.17</td>
<td>-0.33</td>
<td>-0.20</td>
<td>-0.05</td>
<td>0.01</td>
<td>-1.24</td>
</tr>
<tr>
<td>PCN, c/lb.</td>
<td>-0.58</td>
<td>-0.23</td>
<td>-0.10</td>
<td>-0.13</td>
<td>-0.10</td>
<td>-0.07</td>
<td>-0.03</td>
<td>-0.59</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Farm prices</th>
<th>Impact (quarterly)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>STP, $/100 lbs.</td>
<td>-0.32</td>
<td>0.34</td>
<td>-0.21</td>
<td>-0.14</td>
<td>-0.26</td>
<td>-0.29</td>
<td>-0.23</td>
<td>-0.84</td>
</tr>
<tr>
<td>CWP, $/100 lbs.</td>
<td>-2.17</td>
<td>-2.37</td>
<td>-0.29</td>
<td>-0.40</td>
<td>-0.44</td>
<td>-0.44</td>
<td>-0.32</td>
<td>-4.31</td>
</tr>
<tr>
<td>HOP, $/100 lbs.</td>
<td>-0.65</td>
<td>-0.59</td>
<td>0.10</td>
<td>-0.20</td>
<td>-0.12</td>
<td>-0.03</td>
<td>0.01</td>
<td>-0.73</td>
</tr>
<tr>
<td>CHFP, $/100 lbs.</td>
<td>-0.36</td>
<td>-0.12</td>
<td>-0.07</td>
<td>-0.07</td>
<td>-0.05</td>
<td>-0.03</td>
<td>-0.02</td>
<td>-0.31</td>
</tr>
<tr>
<td>BSP c, $/100</td>
<td>-0.21</td>
<td>0.35</td>
<td>-0.25</td>
<td>-0.23</td>
<td>-0.31</td>
<td>-0.36</td>
<td>-0.28</td>
<td>-1.10</td>
</tr>
</tbody>
</table>

\(^a\)The interim multipliers given refer to the effect of an increase in beef imports of 100 million pounds per quarter sustained for four quarters. The multipliers for the year 1 includes the impact effect noted for the first quarter.

\(^b\)All prices have been expressed in 1979 dollars.

\(^c\)Corresponds to the real price of feeders, RBSP, expressed in 1979 dollars.
Table 7.1 (continued)

<table>
<thead>
<tr>
<th>Impact Year (quarterly)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCORN^d</td>
<td>0</td>
<td>-1.48</td>
<td>-0.60</td>
<td>-0.23</td>
<td>0.08</td>
<td>0.13</td>
<td>0.17</td>
</tr>
<tr>
<td>Beef supplies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FSHBS, mil. lb./qtr.</td>
<td>0</td>
<td>-44.6</td>
<td>7.8</td>
<td>1.8</td>
<td>-0.07</td>
<td>5.4</td>
<td>5.5</td>
</tr>
<tr>
<td>NFSHBS, mil. lb./qtr.</td>
<td>-10.8</td>
<td>4.3</td>
<td>-2.4</td>
<td>5.1</td>
<td>2.3</td>
<td>4.1</td>
<td>2.6</td>
</tr>
<tr>
<td>CBS, mil. lb./qtr.</td>
<td>-27.0</td>
<td>0.3</td>
<td>4.6</td>
<td>3.9</td>
<td>4.6</td>
<td>3.4</td>
<td>-10.5</td>
</tr>
<tr>
<td>BBS, mil. lb./qtr.</td>
<td>-7.2</td>
<td>0.4</td>
<td>0.6</td>
<td>0.7</td>
<td>0.6</td>
<td>0.4</td>
<td>-4.6</td>
</tr>
<tr>
<td>XTB, mil. lb./qtr.</td>
<td>-30.9</td>
<td>4.1</td>
<td>3.6</td>
<td>6.2</td>
<td>7.3</td>
<td>6.2</td>
<td>-1.9</td>
</tr>
<tr>
<td>XPB, mil. lb./qtr.</td>
<td>39.9</td>
<td>50.6</td>
<td>6.5</td>
<td>5.3</td>
<td>6.6</td>
<td>7.5</td>
<td>5.7</td>
</tr>
<tr>
<td>Cow inventories</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BCOWS, thou.</td>
<td>37.4</td>
<td>146.3</td>
<td>148.3</td>
<td>151.2</td>
<td>131.2</td>
<td>93.8</td>
<td>50.6</td>
</tr>
</tbody>
</table>

^d Corresponds to the real price of corn expressed in cents at 1979 dollars.
an annual increase of 400 million pounds are the same. The estimated effects on retail meat prices are considered first, followed by discussion of the other multipliers.

Multipliers of beef imports for retail meat prices

From Table 7.1, it can be seen that the initial-quarter impact of an increase of 100 million pounds of beef imports (per quarter) is a reduction of 2.84 cents per pound in the retail price of processing beef. This impact is much smaller than the 11.19 cents per pound impact reported by Arzac and Wilkinson\(^1\) [1979a, p. 304]. At least two factors contribute to this differential: (1) In this model, cow beef supplies can respond to the endogenous cow beef price within the current quarter; and (2) This model includes an inventory equation for processing beef. The supply response factor is clearly the more important of the two. The impact multipliers for NFSHBS, CBS and BBS reveal a supply impact of \(-48.1\) million pounds per quarter in the production of these classes of beef. This immediate supply response is sufficiently large that the impact effect of a change in imports is smaller than the long-run (or total) effect. The inclusion of the beef inventory equation also has a minor effect. When this equation is removed from the model, the impact multiplier increases from \(-2.84\) to \(-3.55\).

The dynamic multipliers for the price of processing beef reveal a somewhat uneven pattern of adjustment to a permanent increase in the

\(^1\) Their published estimate of 8.30 \(\) was expressed in 1975 prices. The estimate of 11.19 \(\) was obtained by transforming this estimate to reflect changes in the Consumer Price Index between 1975 and 1979.
level of imports. The price falls substantially in the first year, and then falls relatively slowly from years two to six. The annual multipliers presented in Table 7.1 can be added to obtain the cumulative effects of a sustained change. When this is done for the PGB multipliers, the sum for six years is seen to be -5.55 cents per pound. Since the total multiplier for a change in imports is -5.62 cents per pound, it appears that most of the adjustment to a permanent change in imports, including domestic supply adjustment, takes place in the first six years.

The total multipliers for retail meat prices obtained with this model can be compared with those reported in earlier studies. For this comparison, the total multipliers obtained by Freebairn and Rausser [1975, p. 686] and Arzac and Wilkinson [1979a, p. 304] have been converted to 1979 prices and to a 400 million/pound annual change in the import level. The three sets of multipliers are presented in Table 7.2.

The total multiplier for the price of processing beef is slightly lower in this study than in either of the two previous studies, although it is likely that the difference would not be statistically significant if standard errors for these estimates were available. Part of this difference is probably due to the use of symmetry restrictions on the demand equations in this model. As noted in Chapter V, imposition of these restrictions generally reduced the size of the estimated substitution effects, which are involved in calculation of the effects of an exogenous change in quantity on price [Houck, 1965]. To assess the extent to which the difference in results can be attributed to this
Table 7.2. Comparison of total multipliers for retail meat prices of a 400 million pound annual increase in beef imports

<table>
<thead>
<tr>
<th></th>
<th>Freebairn and Rausser&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Arzac and Wilkinson&lt;sup&gt;a&lt;/sup&gt;</th>
<th>This study</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCB&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-4.55</td>
<td>-0.43</td>
<td>-2.12</td>
</tr>
<tr>
<td>PGB</td>
<td>-7.95</td>
<td>-6.15</td>
<td>-5.62</td>
</tr>
<tr>
<td>PPK</td>
<td>-0.70</td>
<td>-5.02</td>
<td>-1.23</td>
</tr>
<tr>
<td>PCN</td>
<td>-1.07</td>
<td>-3.45</td>
<td>-0.59</td>
</tr>
</tbody>
</table>

<sup>a</sup>Freebairn and Rausser's 1972 prices were converted to 1979 equivalents using a ratio of 1.736 derived from the change in the CPU variable. A conversion factor of 1.3487 was applied to Arzac and Wilkinson's 1975 prices.

<sup>b</sup>The PCB variable in this study (see Appendix A) is a weighted average of the price of table and processing beef in the proportions occurring in a choice beef carcass. It corresponds to the price of fed beef in the other two models.

change in specification, the model was reformulated using demand estimates calculated in the same way as those used in the model, except for the absence of the symmetry restriction.

Use of the unrestricted demand equations resulted in total multipliers of -3.24, -6.26, -2.73, and -0.83 for PCB, PGB, PPK, and PCN, respectively. The use of the restricted demand equations thus seems to have contributed to the generally smaller total multipliers (and the particularly small multipliers for other meat) observed in this study. However, the restricted estimates are preferred on the basis of: a priori theoretical considerations; accordance of the coefficient
estimates with expectations; and performance in simulation of the model. The use of the information contained in these restrictions also avoided the need for the type of arbitrary price aggregation procedures used by Freebairn and Rausser [1975, p. 679], which may have affected the reliability of their cross-price effects.

The total multipliers for the price of processing quality beef can be used to obtain an estimate of the long-run price flexibility of beef imports at the sample means. Using the long-run multiplier derived with deflated prices, a price flexibility of -0.20 is obtained for the effect of import quantity changes on the price of processing beef. This implies that a 1 percent reduction in the quantity of beef imports would raise the price of processing quality beef by only one-fifth of 1 percent in the long run. When considering a change in the total quantity of U.S. processing beef, the estimated flexibility becomes much larger, because a 1 percent change involves a much larger quantity of meat. In this case, the price flexibility is -1.15, implying that a 1 percent reduction in the quantity supplied would lead to a long-run price increase of slightly more than 1 percent.

The long-run multiplier can be used to provide an estimate of the effect of complete elimination of meat imports. Reduction of imports by their sample average level of 419.85 million pounds per quarter is estimated to lead to an increase of 22.5 cents/pound\(^1\) in the retail price of processing quality beef. This would be a reduction of 19\(^1\)Expressed in 1979 prices.
percent from the sample average price of 117.9 cents/pound\(^1\) for processing beef, and so is consistent with the price flexibility of -0.20 noted earlier. In interpreting this result, it must be remembered that the model is only a local, linear approximation to the structure of the system and so is strictly valid only in the range of observations with which it was estimated. Global changes, such as complete elimination of imports, are outside this range and so their estimated effects need to be interpreted with great caution.

The price flexibility estimates presented here take into account the effect of changes in imports on the domestic supply of beef. Since these changes in the supply of beef are likely to partly offset changes in the level of imports, the estimates presented here should be lower than "short-run" estimates based only on the demand effects. Thus, it is to be expected that the price flexibility obtained in this study (-0.20) is considerably smaller than Houck's [1974, p. 71] short-run estimate that beef imports hold processed meat prices 35 to 50 percent below the levels that would exist in their absence.

Houck's estimate was based on the analytical "short-run" period in which supply does not respond to changes in the level of imports. The multipliers presented in Table 7.1 suggest that this corresponds to an extremely short period of calendar time. Even within one quarter, it appears that the effects of a reduction in imports would be partially offset by an increase in domestic supply. In fact, the short-run

\(^1\)Expressed in 1979 prices.
within quarter) price increase resulting from a reduction in beef imports would be smaller than the long-run effect.

The total multipliers for PCB, PPK, and PCN reported in Table 7.2 reveal wide disparities between the three studies. The estimates for this study fall between those from the other studies for PCB and PPK while the PCN estimate is smaller in absolute value than the other two. Arzac and Wilkinson's PPK and PCN multipliers are very large, although part of this may be attributed to their very large corn price multiplier, to be discussed in the next section.

One final comment on the effect of imports on retail meat prices is needed. Our model, like Freebairn and Rausser's [1975, p. 686] suggests that an increase in imports will lead to a rise in the long-run inventory of beef cows. In addition, it predicts an increase in the supply of beef from nonfed steers and heifers. For reasons to be discussed later, it is believed that these multipliers reflect an aspect of the specification of the model. They indicate that the model is over-predicting domestic beef supply after an increase in beef imports, and so is probably over-estimating the negative effect of beef imports on domestic beef prices to some degree.

Multipliers of beef imports for other variables

While the effects of changes in beef imports on retail meat prices have been given the most attention, it is useful to consider their effects on other variables within the model. The multipliers for farm level prices of livestock, and of corn, were given in Table 7.1. From
this table, it is evident that an increase in beef imports leads, in most cases, to a somewhat smaller decline in the farm price of livestock.

The long-run impact of a 400 million pound annual increase in imports is estimated to be -0.84 dollars per 100 pounds for fed steers, -4.31 dollars per 100 pounds for cows, -0.73 dollars per 100 pounds for hogs, and -0.31 cents per pound for chickens. Compared to the sample average levels\(^1\) of 64.4, 42.3, 51.6, and 33.87, respectively, these are changes of -1.3 percent, -10.2 percent, -1.4 percent, and -0.9 percent, respectively. Clearly, the model suggests that the effects of beef imports on the prices of slaughter livestock, other than cows, are relatively slight. For cows, the predicted long-run decline in price is relatively large and corresponds to a price flexibility of -0.43. The effect reported here is only slightly larger than the effect of -3.78 dollars per 100 pounds reported by Freebairn and Rausser [1975, p. 687] but considerably larger than the -1.83 dollars per 100 pounds reported by Arzac and Wilkinson [1979a, p. 304].\(^2\) The large price depressing effect for cows in this model and the Freebairn and Rausser model have probably contributed to the positive long-run multipliers for beef cow inventory in these models.

The large estimated long-run effect on the price of cows will have an adverse effect on producers of cow beef. However, it must be remembered that most cow herds are maintained for the production of

\(^1\)All prices expressed in 1979 dollars using the Index of Prices Paid by Farmers (PPEX).

\(^2\)Both of these prices were converted to 1979 values using the change in the consumer price index.
feeder calves and the estimated long-run effect on the price of feeders is much smaller. The long-run effect of $-1.10 per 100 pounds for feeders is $-1.73$ percent of the sample average price\(^1\) of $63.00 per 100 pounds and corresponds to a price flexibility of only $-0.074$. While a fall in the price of cull cows reduces the revenue obtained by cow herd owners from this source, it also reduces the opportunity cost of maintaining a cow herd. Thus, the overall negative impact of imports on owners of cow-calf herds is likely to be much less severe than the simple cow-beef price multiplier would suggest.

The multipliers of beef imports for the price of corn in this model are very much smaller than the corresponding multipliers reported by Arzac and Wilkinson [1979a, p. 304]. Their long-run multiplier, converted to a 400 million pound change, and updated to 1979 prices,\(^2\) is $-20.5$ cents per bushel. The corresponding estimate for this study is only $-1.62$ cents per bushel. The result reported in this study suggests that the incidence of a change in beef imports falls almost entirely on the meat subsector, with almost no spillover onto the feed-grain subsector. At our sample means, the results of this study correspond to a flexibility of corn prices, with respect to beef imports, of $-0.02$. By contrast, the Arzac and Wilkinson estimate produces a flexibility of $-0.1$, suggesting that beef imports have a proportional effect on corn prices which is approximately half as large as their effect on

\(^1\)Expressed in 1979 dollars.

\(^2\)The change in the Consumer Price Index (CPI) was used to update these variables.
processing beef prices. The greater reduction in corn prices predicted by the Arzac and Wilkinson model may also have contributed to the larger negative long-run multipliers predicted for hog and chicken prices in their model.

The multipliers for beef supplies reported in Table 7.1, are all negative, except for a small positive effect on NFSHBS. The reduction in meat supplies tends to dampen the fall in meat prices. In the long-run, the multipliers for FSHBS, CBS, and BBS remain negative and that for NFSHBS remains positive. The positive multiplier for NFSHBS is believed to be a spurious result of the specification of this variable as a residual component and the predicted increase in the inventory of beef cows. The CBS multiplier would probably also have a larger negative value of the inventory of beef cows were not predicted to increase. Despite these effects, total domestic beef production is predicted to decline overall.

The positive total multiplier for the inventory of beef cows is cause for some concern. Like the positive multiplier reported by Freebairn and Rausser [1975, p. 686] it is associated with a marked reduction in cow price, which lowers the cost of holding cow inventories. Despite the rise in the cow inventory, the model predicts a reduction in the supply of cow beef which clearly implies the adoption of a much lower rate of culling from the cow herd. This result may be simply due to a lack of statistical precision in the estimates, as suggested

1 Their total multiplier of -6.15, presented in Table 7.2 corresponds to a flexibility, at our sample means, of -0.22.
by Freebairn and Rausser [1975, p. 687]. More likely, it reflects the omission of the most important cost in maintaining a cow herd, the cost of roughage feed.

This model, along with most other recent models of the U.S. livestock sector, implicitly assumes that the supply of pasture (and other roughage feeds) used by beef cows is perfectly elastic. Although data on the quantity and price of pasture are obviously difficult to obtain, one potential approach for future studies might be to use the price of hay as a proxy for the price of all roughage feeds and to include this variable in the beef cow inventory equation in some form. At a late stage in the analysis, an attempt was made to estimate an equation for the price of hay, and to incorporate this factor in the beef cow inventory equation. The annual hay price equation obtained is reported as Equation (7.5).

\[
RPHAY = 31.85 + 0.0011 \cdot TCOWS - 0.21 \cdot QHAY
\]

\[
(1.48) \quad (2.94) \quad (-1.35)
\]

\[
(R^2 = 0.33, DW = 1.47, OLS, 1960-1981)
\]

Where:

- RPHAY is the price of hay [USDA, 1982b, p. 267] deflated by PPEX to 1977 dollars, $/ton, and
- QHAY is total U.S. hay production, thou./tons [USDA, 1982b, p.267].

While this equation explains only a small proportion of the total variation in the price of hay, it suggests that the size of the cow inventory does have a significant influence on the price of hay (and
presumably of other roughage feeds as well). Because the Durbin-Watson statistic lay in the indeterminate range, the equation was reestimated by autoregressive least squares under the assumption of first order autoregressive residuals. The autoregressive parameter was not significantly greater than zero, but the TCOWS variable was still significant after this transformation of the variables. Unfortunately, attempts to include the price of hay in the beef cow inventory equation proved to be unsuccessful, and so the attempt to include roughage prices had to be abandoned.

Incorporation of the cost of pasture, or its supply, in the specification of models dealing with beef cow and nonfed steer and heifer beef production seems a very desirable step in the construction of future livestock subsector models. Unfortunately, the problems of data availability for such a specification remain extreme. The fact that only one recent model of the livestock subsector [Gruber and Heady, 1968] has included this factor despite its obvious importance, is indicative of the data problems associated with its use. However, the apparent adverse effects of its exclusion suggest that development of a method of incorporating it should be a high priority in future research.

**Multipliers of other exogenous variables**

Several variables other than beef import levels can usefully be thought of as control variables in the system [Arzac and Wilkinson, 1979b]. These variables include the level of corn stocks, the level
of corn exports, and the effective support price variables for corn plantings. In addition, the level of consumer income is a variable, subject to some degree of government control, which exerts a marked influence on the livestock-feed subsector. In addition, the price of corn can be treated as a control variable in many years; whenever the market price of corn is near the corn loan rate. Selected multipliers for the effects of changes in corn exports, consumer incomes, and the price of corn are given in Table 7.3

The multipliers presented in Table 7.3 reveal wide differences between the timing and magnitude of responses to impulses from different exogenous variables. The multipliers for an increase in corn exports suggest a substantial long-run increase in the price of all of the meats, and of corn, in long-run equilibrium. Of the variables considered, only the inventory of beef cows is reduced by the increase in corn exports, and this decline in the cow inventory is probably the major factor contributing to the rise in the price of processing beef.

The large rise in the price of pork following an increase in corn exports is probably due to the importance of the price of corn in hog inventory decisions. Substitution effects between pork and ground beef at the level of consumer demand probably also contributed to the relatively large positive long-run multiplier observed for the price of processing beef.

When considering the multipliers for corn exports, it must be remembered that these multipliers correspond to an analytical "short-run" in which the production of corn is unresponsive to market price. Incorporating corn acreage supply response, either through market price
Table 7.3. Impact, one-year, and total multipliers\textsuperscript{a} for specified changes in selected policy variables

<table>
<thead>
<tr>
<th>Endogenous variables</th>
<th>Corn exports 100 mil. bu. increase</th>
<th>Consumer incomes $100/capita.increase</th>
<th>Corn price $1 per bu. increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Impact</td>
<td>Interim\textsuperscript{b}</td>
<td>Total</td>
</tr>
<tr>
<td>PTB, c/lb.</td>
<td>-0.23</td>
<td>0.37</td>
<td>7.46</td>
</tr>
<tr>
<td>PGB, c/lb.</td>
<td>-0.34</td>
<td>-0.41</td>
<td>12.31</td>
</tr>
<tr>
<td>PPK, c/lb.</td>
<td>-0.14</td>
<td>2.71</td>
<td>22.6</td>
</tr>
<tr>
<td>PCN, c/lb.</td>
<td>-0.09</td>
<td>2.88</td>
<td>7.86</td>
</tr>
<tr>
<td>PCORN, c/bu.</td>
<td>48.8</td>
<td>67.9</td>
<td>89.4</td>
</tr>
<tr>
<td>BCOWS, thou.</td>
<td>-6.97</td>
<td>-108.54</td>
<td>-2666.1</td>
</tr>
</tbody>
</table>

\textsuperscript{a}To obtain these multipliers, the price of corn was made exogenous and one equation (Equation 49 in Table 6.1) was dropped from the model. An artificial variable, RPCORNA, was introduced and set equal to RPCORN. The lag of this endogenous variable then entered the model as a lagged endogenous variable.

\textsuperscript{b}In this table, the interim multipliers refer to the effects of the policy change after one year.
effects or some type of policy behavioral function, \(^1\) would reduce the very large multipliers observed for corn price.

The multipliers for a $100 increase in consumer incomes suggest that such an increase would lead to a long-run increase in the retail prices of all meats, the price of corn, and in the inventory of beef cows. The rise in price for processing quality beef is very small, despite the existence of a positive income effect in this equation. It appears that the larger positive income effect in the table beef equation has called forth a sufficiently large increase in processing beef supply to satisfy the smaller rise in this component of demand. An increase in table beef supplies increases processing beef supply because of the joint nature of these products in fed beef production, and because it requires a larger cow herd to provide more feeders.

The third set of multipliers presented in Table 7.3 refer to the policy situation where the price of corn is exogenous. To obtain these multipliers, the model was altered as discussed in footnote (a) of Table 7.3. The increase in the price of corn has small negative impact multipliers for the first quarter, presumably associated with inventory liquidation decisions. However, all of the long-run price multipliers are positive, as would be expected. The rise in meat prices is associated with marked falls in the production of both fed and nonfed beef, and a decline in the inventory of beef cows. These multipliers are broadly consistent with those of Arzac and Wilkinson.

\[^1\] Houck and Ryan [1972] reported a reasonably strong relationship between the policy determined effective support price and the lagged market price of corn.
[1979a], but in marked contrast to those reported by Ospina and Shumway [1981] who reported long-run increases in the supply of low quality beef following an increase in the price of corn.

The Demand for Imported Beef

Viewed from a U.S. perspective, most of the crucial policy questions regarding beef imports are concerned with the effects of changes in beef import levels on U.S. prices. From the perspective of the import supplying countries, however, the level of demand for imported beef is an important issue for beef producers and agricultural policymakers. The model developed for this study can be used to estimate some effects of changes in U.S. economic factors upon the demand for imported beef.

When the level of meat imports falls below the trigger level established under the Meat Import Act of 1979, the U.S. demand for beef can be expressed as a market-determined excess demand function. The nature of this excess demand function can be investigated with the model by setting the price of beef imports (RPGB) as an exogenous variable and making the level of imports endogenous to the system.

The Meat Import Act of 1979 restricts the long-run level of imports to a prespecified proportion of total U.S. beef production. While the countercyclical factor in Equation (2.3) causes the share of imports to vary about its long-run value, this factor must average close to unity over an extended period. There seems no reason why the level of U.S. beef production and the level of excess demand for beef should respond in the same way to changes in the exogenous variables. Thus, it is of interest to consider the effects of key exogenous variables
on the long-run behavior of the import quota. This has been done using a simple extension of the linear model analyzed to date.

The Meat Import Act of 1979 also introduces some complex short-run dynamic effects into the system. Some exploration of these effects has been undertaken by Reeves [1979] and Simpson [1981] and so this study has emphasized the long-run aspects of the quota which do not appear to have been analyzed previously. Some analysis of the short-run behavior of the model incorporating the quota formula has been undertaken but time constraints prevented the inclusion of these results in this study. It is hoped that these results will provide the basis for subsequent studies.

**Import demand in the absence of quotas**

The import demand function generated by the model developed in this study will be effective only when the level of imports it generates falls below the level of imports allowed under the import law. Consideration of the effects of changes in the exogenous variables of the system is, however, of interest even when the quantity demanded is expected to exceed the quota limit. In this situation, a change in one of the exogenous variables may cause the level of demand to fall below the limit and, hence, cause the market demand function to become effective.

The multipliers for the price of ground beef, and a number of the exogenous variables of the model are presented in Table 7.4. In interpreting Table 7.4, it must be remembered that each multiplier refers to a change in the quarterly level of imports and so
<table>
<thead>
<tr>
<th>Year</th>
<th>Increase of 10¢ in processing beef price (PGB)</th>
<th>Increase of $100 in consumer incomes (Y2C)</th>
<th>Increase of 100 mil. bu. in corn exports (EC)</th>
<th>Increase of 100 mil. bu. in govt. corn stocks (ICG)</th>
<th>Continuation of down trend in meat demand for 10 periods (T)</th>
<th>Increase of $1/hr. in meat packing wage (WRMP)</th>
<th>Increase of $1/bu. in corn prices</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-320.5</td>
<td>142.6</td>
<td>-12.0</td>
<td>1.4</td>
<td>-198.6</td>
<td>26.1</td>
<td>-10.0</td>
</tr>
<tr>
<td>2</td>
<td>41.4</td>
<td>-10.0</td>
<td>86.2</td>
<td>24.0</td>
<td>34.8</td>
<td>-4.3</td>
<td>136.2</td>
</tr>
<tr>
<td>3</td>
<td>43.1</td>
<td>-48.4</td>
<td>48.9</td>
<td>-6.8</td>
<td>70.8</td>
<td>29.6</td>
<td>36.0</td>
</tr>
<tr>
<td>4</td>
<td>50.7</td>
<td>-71.0</td>
<td>52.5</td>
<td>2.2</td>
<td>106.1</td>
<td>53.8</td>
<td>63.1</td>
</tr>
<tr>
<td>5</td>
<td>42.4</td>
<td>-61.3</td>
<td>58.6</td>
<td>1.5</td>
<td>94.3</td>
<td>49.4</td>
<td>68.1</td>
</tr>
</tbody>
</table>

| Total multiplier | -177.8 | 0.07 | 219.2 | 0 | 32.6 | 118.2 | 255.0 |

\(^a\)All price effects in the table are expressed in 1979 prices.

\(^b\)The annual multipliers, rather than quarterly interim multipliers, were used for reasons of presentation. Each one represents the effect of a policy change sustained for four periods on the quarterly flow of imports. They, thus, strictly refer to the change in the fourth quarter of each year following the policy change.

\(^c\)The effects of changes in both the price of corn and its lag were incorporated as discussed for Table 7.3.
should be compared with a sample average level of 419.8 million pounds/quarter or a 1979 peak level of 601.25 million pounds/quarter. Since imported beef has been treated as equal in quality to domestic processing quality beef, a change in the price of processing beef considered in the table is synonymous with a change in the price of imported beef. Treatment of this price as exogenous does not imply that it is a policy variable in this case. The approach does, however, provide useful insights into the nature of the excess demand function.

From the first column of Table 7.4, it is clear that an increase in the price of processing quality beef would lead to a very large initial reduction in the quantity of beef imported. The very large initial effect is due to an initial liquidation of nonfed cattle. As inventories are restored, the level of imports would rise in subsequent periods. The total multiplier corresponds to a price elasticity of -5.0 at the sample means. Although Houck [1965] has demonstrated that this need not always be the case, this result is exactly the inverse of the flexibility of -0.20 noted earlier for changes in the quantity of beef imports.

An increase in consumer disposable income has a substantial positive initial effect on the demand for meat imports. However, the subsequent-period effects are negative, and the long-run effect is to leave the level of beef imports almost unchanged. This surprising result seems to be partly due to a large increase in fed beef production which, under our assumption, contributes a considerable portion of the total supply of processing quality beef. The other contributing factor
to the rise in domestic processing beef supply is an increase in the
domestic cow herd induced by higher profitability of feeder steer
production.

An increase of 100 million bushels in corn exports is relatively
large in relation to the sample average level of 248 million bushels.
The estimated multipliers suggest that an exogenous increase in corn
exports of this magnitude would have a very large, positive long-run
effect on the demand for imported beef. The initial, negative impact
on imported beef demand is due to the initial liquidation of herds
as the increase in exports drives up the price of corn. Again, the
multiplier for corn exports is, in an analytical sense, a short-run
estimate since it does not allow for acreage or yield response within
the United States. Thus, the dramatic increase in corn exports during
the 1970s (from 130 million bushels/quarter in 1971 to 586 million
bushels/quarter in 1979) did not cause a massive increase in the demand
for imported beef because its effect on corn price was largely offset
by increases in the area planted and the yield of corn.

The dynamic pattern of response to an increase in U.S. government
corn stocks is particularly interesting. The effect in the first year
includes both positive and negative quarterly impulses, but the overall
effect is a slight increase in meat import demand, as shown in Table 7.4.
Clearly, the increase in corn stocks has its maximum effect on imports
in the second year. In subsequent years, the effect tends to taper off.
Ultimately, the level of stocks adjusts to its new higher equilibrium
level and the long-run effect on both corn prices and beef import
demand is essentially zero.

The trend variable for shifts in consumer demand is obviously
not a policy instrument. It is, however, of interest to consider what
would be the effects of a continuation of this trend. In addition,
the level of consumer demand, can be affected to some extent by changes
in advertising policy [Lee, Schraufnagel, and Heady, 1982] which might
be used to offset the apparent downtrend in demand. The multipliers
presented in Table 7.4 refer to a sustained reduction in beef and pork
consumption equal to that which is estimated to have occurred every
ten quarters during the sample period. The initial impact of such a
fall in consumer demand is, as expected, a reduction in the level of
beef imports. This reduction in beef imports is associated with both
the direct effect through consumer demand and some inventory liquidation.
In subsequent years, however, the effect of the sustained drop
in consumer demand for table beef, and for pork appears to have a
positive influence on the demand for meat imports. This surprising
positive effect seems to arise because the fall in table beef demand
reduces the size of the cow herd and, hence, the supply of cow and
bull beef. In addition, the quantity of fed steer and heifer beef
produced declines and this reduces the supply of processing quality
beef derived from the lower quality cuts on these carcasses.

An increase in the level of U.S. meat packing wage rates appears
to exert a large, positive, influence on the demand for imported meat.
Since this wage rate is probably serving as a proxy for the level of
wage rates throughout the marketing chain, it is likely that the estimated effect over-estimates the effect of a change in meat packing wage rates alone. However, it does suggest that the level of marketing costs, has a very marked impact upon the competitive position of U.S. relative to imported meat.

The final exogenous variable considered in Table 7.4 is that for a change in the real price of corn. An increase of $1 per bushel (at 1979 prices) leads to an initial decrease in import demand as livestock inventories are liquidated. In subsequent periods, the demand for imported beef increases, as domestic livestock production declines. The total effect of a sustained increase in the price of corn is an increase in beef import demand of 255.0 million pounds per quarter, or over half the sample average level of imports.

The long-run behavior of the import quota

As noted earlier in this chapter, the long-run level of imports under the Meat Import Act of 1979 is determined as a share of total U.S. production. Thus, in a long-run setting, the determinants of the total level of U.S. beef production become the determinants of the import quota. In this section, we will consider the effects of changes in key exogenous variables on the long-run quota level, and contrast these changes with the effects on the excess demand for beef discussed in the previous section.

To investigate the effects of changes in the exogenous variables on the long-run level of imports under the meat import law, the quota
was expressed as a specified share (7.8 percent) of total U.S. beef production. Since this simple method of making the import quota endogenous misrepresents the short-run dynamics of the import quota, only the long-run multipliers are of any relevance. Accordingly, only the long-run multipliers for key exogenous variables have been presented in Table 7.5. Since both the level of imports, and their price are of interest to import suppliers, the multipliers have been presented for each of these variables.

Table 7.5. Long-run multipliers for beef imports and processing beef price where imports are a fixed share of total production^a

<table>
<thead>
<tr>
<th></th>
<th>Beef import quota (mil. lb./qtr.)</th>
<th>Price of processing beef (¢/lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase of $100 in consumer incomes</td>
<td>8.36</td>
<td>-1.08</td>
</tr>
<tr>
<td>Increase of $1 in the price of corn</td>
<td>-5.41</td>
<td>1.41</td>
</tr>
<tr>
<td>Increase of $1/hr. in packing plant wage rates</td>
<td>-10.19</td>
<td>8.06</td>
</tr>
<tr>
<td>Permanent demand decrease equal to 10 qtrs. downtrend</td>
<td>-12.4</td>
<td>0.02</td>
</tr>
</tbody>
</table>

^aThe model used in the preparation of this table takes the price of corn as exogenous as discussed in the footnotes to Table 7.3. All price effects refer to changes expressed in 1979 dollars.

Table 7.5 reveals some very interesting contrasts between the long-run behavior of the import quota and the excess demand for meat considered in Table 7.4. While an increase in consumer incomes was seen to have virtually no impact on the long-run excess demand for beef in Table 7.4, it has a sizeable positive effect on the level of the import.
quota. Calculated at the sample means, the long-run elasticity of the import quota with respect to consumer incomes, is 1.26. In the presence of the import quota, increases in consumer incomes are seen to have a negative long-run effect on the price of processing beef. The elasticity of price with respect to consumer incomes is, however, relatively small with a value of -0.58 at the sample means. This somewhat surprising effect is due to an increase in supplies of this quality of beef from both domestic and foreign sources interacting with a relatively low income elasticity for this product.

The large effect of consumer incomes on the long-run import quota means that, with rising incomes, the import quota will tend to increase relative to the level of U.S. excess demand for imported beef. As the size of the quota increases relative to the level of excess demand, the chances that the quota will be a binding constraint in any year are clearly reduced. In this way, rising U.S. consumer incomes confer an indirect benefit on the suppliers of imported beef, even though they do not appear to increase the level of excess demand for meat.

An increase in the price of corn has the opposite effect of an increase in consumer incomes. It leads to a slight reduction (elasticity of -0.04) in imports as total U.S. beef production declines. At the same time, it leads to a slightly larger increase in the price of imported beef (elasticity of 0.35). Since an increase in the price of corn was seen in Table 7.4 to lead to a large increase in U.S. excess demand for beef, it is clear that an increase in corn prices increases
the long-run likelihood that the import quota will be a binding con-
straint in any year.

The increase in U.S. domestic marketing costs represented by an
increase of $1/hour in packing plant wages is seen to reduce the level
of the import quota, whereas it was earlier shown to substantially
increase the excess demand for imported beef.

Continuation of the estimated downward trend in consumption of
table beef and pork for ten quarters reduces the long-run import quota,
but has virtually no effect on the price of processing quality beef.
This contrasts with the relatively large long-run increase in the
excess demand for beef noted in Table 7.4.

Comparison of the long-run multipliers for the beef import quota
has revealed some very interesting reversals of effects. An increase
in consumer incomes, which has very little effect on the long-run excess
demand for imported beef, is seen to have a substantial positive effect
on the import quota. Conversely, an increase in the price of corn,
which greatly increases the excess demand for beef, causes a reduction
in the long-run level of the import quota. Since there is no reason
to expect the real price of corn to rise in the long run, but one hopes
that the level of consumer incomes will continue to rise, it seems
likely that the meat import quotas will tend to be a binding constraint
less frequently in the long run. On the other hand, a continuation of
the apparent downtrend in high quality beef consumption could tend to
narrow the gap between the quota and the level of excess demand.
CHAPTER VIII. THE EFFECTS OF ALTERNATIVE METHODS OF DISAGGREGATING BEEF CONSUMPTION

Beef is a highly heterogeneous commodity and its aggregation into a single commodity for statistical analysis may result in serious errors. Colman [1966] demonstrated the existence of substantial differences between the demand elasticities for high grade and processing quality beef, and most subsequent studies have disaggregated total beef consumption into two classes [e.g. Woods, 1975; Freebairn and Rausser, 1975; Bain, 1977; Arzac and Wilkinson, 1979a; Reeves, 1979].

The relevant distinction between high and low quality beef is based primarily upon its end use characteristics. Thus, Colman [1966, p. 11] defined low-grade beef as "...it is processed in some form and mechanically tenderized or used as stewing beef." Clearly, some portion of even the highest quality carcass falls into this category. While recognizing this [Houck, 1974, p. 61; Bain, 1977, p. 16], most authors have made their distinction between high- and low-quality beef on the basis of whether it was obtained from fed or nonfed carcasses. Since between 20 and 25 percent of fed carcass beef is used for processing [Ryan, 1980; American Meat Institute, 1980b, p. 2] and fed beef production accounts for around seventy percent of total U.S. beef production, this classification clearly omits an important component of the total supply of processing quality beef.
Ryan [1980] has recently argued that the omission of this component of total processing quality beef may cause serious overestimation of the effects of beef imports on U.S. meat prices. This argument is extremely important because, if correct, it affects the validity of the results obtained from almost all of the studies conducted to date.

In the rest of this chapter, we will first consider the nature of the potential bias considered by Ryan. Then, to provide an indication of the direction and magnitude of the bias, we will compare estimates of the demand for imported beef obtained using the same data and methodology, except for the beef disaggregation procedure.

Ryan [1980, p. 61] illustrated the nature of the potential bias using a simple single variable regression specification of the form

\[ P = A_0 - B_1(Q_1 + Q_2) + v \]  (8.1)

Where:

- \( P \) is an nx1 vector of hamburger beef prices;
- \( Q_1 \) is an nx1 vector of cow beef plus imported beef quantities;
- \( Q_2 \) is an nx1 vector of low quality steer and heifer beef cuts;
- \( v \) is a vector of error terms.

Ryan then considered the case where the quantity \( Q_2 \) is omitted from this equation and estimates are obtained using the relationship

\[ P = a_0 - b_1Q_1 + u \]  (8.2)

The omission of \( Q_2 \) from (8.2) can be viewed as a type of specification error [Johnston, 1972, p. 169]. Using this framework,
Ryan [1980] demonstrated that estimates of the parameter $b_1$ obtained using $b_1$ in equation (8.2) are likely to be biased upwards in absolute value. For this reason, he argued, most previous studies had probably overestimated the price depressing effects of changes in the level of imported beef.

While this argument is indicative of the serious specification problems which can arise from seemingly reasonable disaggregation procedures, it is far from conclusive regarding the direction of the bias. Models of the livestock subsector have not generally excluded $Q_2$ from their equations, but have classified it with the higher quality cuts elsewhere in their models. Denoting the supply of higher quality cuts obtained from steers and heifers as $Q_3$, the model investigated by analysts using the fed/nonfed distinction is more nearly

$$ P = c - dQ_1 - e(Q_2 + Q_3) \quad (8.3) $$

Whereas, the true model should be

$$ P = F - G(Q_1 + Q_2) - HQ_3 \quad (8.4) $$

The problem with equation (8.3) is essentially one of specifying incorrect restrictions on the parameters. Instead of imposing the correct restriction that the coefficient of $Q_2$ must equal that of $Q_1$, the analyst using (8.3) has applied the restriction that the coefficient of $Q_2$ must equal the coefficient of $Q_3$. Since the bias arising from the use of an incorrect restriction depends upon all of
the variables in the model [Johnston, 1972, p. 158] it becomes difficult to obtain a qualitative indication of the nature of the bias.

In addition to his consideration of the nature of this bias, Ryan also compared several empirical studies of the effects of changes in the demand for imported beef. His comparison suggested that the use of a table/processing distinction resulted in a smaller estimate of the effects of imports on beef prices than alternative approaches such as the fed/nonfed approach. Unfortunately, the comparison involved models of widely different coverage and periodicity and these differences, rather than the meat disaggregation procedures may have resulted in the observed differences in results. In order to assess the empirical effect of the misspecification, it seems desirable to compare models which are alike in other respects. In order to make such a comparison both short-run and long-run effects will be discussed in the following two sections for models which differ only in their method of disaggregating total beef supplies.

**Short-Run Comparisons**

In order to make the comparison between the two disaggregation procedures, one econometric model of the U.S. livestock-feed subsector was developed using the table/processing beef distinction suggested by Ryan [1980] and another was developed using the fed/nonfed approach. The production equations disaggregated the supply of beef into fed steer and heifer beef supply, nonfed steer and heifer beef supply, cow
beef supply and bull beef supply. These quantities were then related via identities to the fed/nonfed and table/processing quantities for use in the retail demand equations. The only differences between the behavioral equations of the two models were in the retail demand equations. All of the other differences between the models were brought about by changes in the definitional identities. In particular, the fed/nonfed model differed from the model discussed earlier in this study in that high quality beef was defined as equal to total fed beef production, minus beef exports and the USDA's price series for choice beef was used instead of the constructed series for the price of table beef. In the remainder of this section we will consider the short-run effect of changes in quantity upon the price of processing quality beef, using the demand equations estimated for these two models.

The retail demand equations for the table/processing beef model have been presented in Table 5.1. The retail demand equations for the fed/nonfed model are presented in Table 8.1. Both of these equations were estimated subject to the cross-equation restrictions implied by the symmetry property from demand theory [Fisher, 1979].

---

1 It was not possible to obtain a satisfactory beef inventory equation for the fed/nonfed model and so this equation was also dropped from both models. This change made virtually no difference to the long-run multipliers of the table/processing beef model.

2 The choice beef price series includes all cuts from a choice beef carcass. The table beef series was constructed by removing the estimated value of processing quality beef from this price series. See Appendix A for details.
The retail demand equations for the fed/nonfed model presented in Table 8.1 differ in several important respects from the table/processing beef equations presented in Table 5.1. The estimated own-price coefficient for nonfed beef (-42.08) is much larger in absolute value than that for processing beef (-16.65). If an estimate of the effect of changes in the quantity of processing beef were to be obtained merely by taking the inverse of these coefficients, then the fed/nonfed model would suggest a much smaller (absolute) effect of changes in the quantity of low quality beef. However, as Houck [1965] has demonstrated, the effect of a change in quantity involves the whole matrix of own and cross-price effects, and the cross-price effects are generally larger in the fed/nonfed model.

In order to obtain an estimate of the effect of changes in the per capita quantity of processing quality beef, the demand systems presented in Tables 5.1 and 8.1 were inverted to obtain a system with exogenous quantities and endogenous prices. From the table/processing beef model, the effect of an increase of one pound per capita in the supply of processing quality beef on its own price is estimated to be -16.83 cents. From the fed/nonfed model, the corresponding estimate for an increase in the supply of nonfed beef is estimated to be -10.06 cents. These two results correspond to price flexibilities, at the sample means, of -1.66 and -0.81 respectively.

1These estimates have been converted from the 1967 base used for the consumer price index to a 1979 price level using a factor of 2.1745 obtained from the increase in the CPI over the period.
Table 8.1. 3SLS estimates of the fed/nonfed meat demand functions subject to the symmetry constraint\(^{a}\)

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>Normalized variables</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>XFBC</td>
<td>XNFBC</td>
<td>XPKC</td>
</tr>
<tr>
<td>Intercept</td>
<td>-9.37</td>
<td>3.43</td>
<td>20.54</td>
</tr>
<tr>
<td></td>
<td>(-2.78)</td>
<td>(1.89)</td>
<td>(12.02)</td>
</tr>
<tr>
<td>RPCB</td>
<td>-17.64</td>
<td>16.71</td>
<td>-5.22</td>
</tr>
<tr>
<td></td>
<td>(-5.23)</td>
<td>(4.65)</td>
<td>(-3.89)</td>
</tr>
<tr>
<td>RPPB</td>
<td>16.71</td>
<td>-42.08</td>
<td>12.58</td>
</tr>
<tr>
<td></td>
<td>(4.62)</td>
<td>(-9.46)</td>
<td>(7.92)</td>
</tr>
<tr>
<td>RPPK</td>
<td>-5.22</td>
<td>12.58</td>
<td>-16.74</td>
</tr>
<tr>
<td></td>
<td>(-3.86)</td>
<td>(7.92)</td>
<td>(-17.44)</td>
</tr>
<tr>
<td>RPCN</td>
<td>1.43</td>
<td>1.43</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>(0.86)</td>
<td>(0.74)</td>
<td>(1.02)</td>
</tr>
<tr>
<td>YZC</td>
<td>15.37</td>
<td>1.26</td>
<td>2.81</td>
</tr>
<tr>
<td></td>
<td>(11.24)</td>
<td>(2.73)</td>
<td>(3.56)</td>
</tr>
<tr>
<td>PCDUM</td>
<td>-1.55</td>
<td>-0.94</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>(-1.57)</td>
<td>(0.92)</td>
<td>----</td>
</tr>
<tr>
<td>T</td>
<td>-0.16</td>
<td>----</td>
<td>-0.06</td>
</tr>
<tr>
<td></td>
<td>(-7.24)</td>
<td>----</td>
<td>(-5.35)</td>
</tr>
<tr>
<td>Q2</td>
<td>-0.47</td>
<td>0.52</td>
<td>-0.56</td>
</tr>
<tr>
<td></td>
<td>(-1.66)</td>
<td>(1.66)</td>
<td>(-3.58)</td>
</tr>
<tr>
<td>Q3</td>
<td>-0.75</td>
<td>1.62</td>
<td>-0.44</td>
</tr>
<tr>
<td></td>
<td>(-2.59)</td>
<td>(5.09)</td>
<td>(-2.84)</td>
</tr>
<tr>
<td>Q4</td>
<td>-1.08</td>
<td>1.34</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>(-3.82)</td>
<td>(4.29)</td>
<td>(6.33)</td>
</tr>
</tbody>
</table>

\(^{a}\)The following variables have not previously been defined: XFBC = per capita supply of fed beef, less beef exports, lb. XNFBC = per capita consumption of nonfed beef, i.e., NFSHBS + CBS + BBS + BM - ABINV, expressed in lb. RPCB = the real price of choice beef (c/lb.).

\(^{b}\)Figures in parentheses are t-statistics for H\(_{0}: \) Coeff = 0.
These results suggest that, if anything, the effect of adopting a table/processing beef demand disaggregation is to increase the estimated short-run impact of changes in the quantity of processing beef, rather than to decrease it as suggested by Ryan [1980]. Because the imposition of the symmetry restrictions as suggested by Court [1967] and Fisher [1979] has not been the usual procedure in modeling the U.S. livestock subsector, it was considered worthwhile to investigate whether this factor had contributed to the estimated differences in results. Accordingly, the two demand systems were reestimated in the same manner except for the absence of the symmetry restriction. The resulting estimates of the effect of an increase of one pound in low quality beef supplies were -28.46 cents for the table/processing beef model and -11.46 cents for the fed/nonfed model. Clearly, the estimated effect of a change in the supply of low quality beef was smaller when the fed/nonfed model was used than when the table/processing beef model was used, whether the symmetry restrictions were imposed or not.

All of the comparisons made to date have referred to the analytical short-run period in which supply does not adjust to the change in quantity. Since this short run appears to correspond to an extremely short period of calendar time in this market, it is probably of greater interest to consider the long-run effects of changes in imports on the price of processing quality beef after domestic supply has fully adjusted to the change.
Long-Run Comparisons

While the table/processing distinction is not relevant on the beef supply side of the model, the complex interactions between the supply and demand sides of the model may result in different effects of a change in beef imports when the supply side is included. For instance, if table and processing beef are strong substitutes, the fall in price of processing beef following an increase in imports will cause a relatively large fall in the price of table beef. In a table/processing beef model, any subsequent fall in the production of fed beef causes an additional fall in the supply of processing beef because the table and processing beef are joint products in production. In a fed/nonfed model, by contrast, this effect is ignored.

The long-run effect of a change in the level of beef imports was calculated using the total multipliers for the two alternative models. The long-run effects of an increase of 100 million pounds per quarter in beef imports were estimated for the table/processing model and the fed/nonfed model, both with and without the symmetry restrictions, and the results have been presented in Table 8.2.

Table 8.2. Total multipliers of an increase of 100 million pounds per quarter in beef imports for the price of low quality beef

<table>
<thead>
<tr>
<th></th>
<th>With symmetry restrictions</th>
<th>Without symmetry restrictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table/processing model</td>
<td>-5.62</td>
<td>-6.26</td>
</tr>
<tr>
<td>Fed/nonfed model</td>
<td>-3.33</td>
<td>-3.50</td>
</tr>
</tbody>
</table>
From Table 8.2, it is clear that the use of the table/processing beef disaggregation procedure resulted in considerably smaller estimates for the effects of a change in beef imports. As noted in Chapter VII, the long-run multiplier of -5.62 obtained using the preferred model developed for this study is reasonably consistent with the results of earlier studies, even though those studies used a fed/nonfed beef distinction. The results of Table 8.2, and the earlier section of this Chapter, suggest that we would have obtained a considerably lower estimate of the effects of beef imports if we had followed the same procedure as the earlier studies.

Although the apparent discrepancy between our fed/nonfed results and those obtained by earlier authors requires some caution in the interpretation of these results, it is clear that the comparison reported here provides no support for Ryan's suggestion that the fed/nonfed procedure leads to overestimates of the effects of beef imports. The results, in fact, suggest that it may result in underestimation of the effect.

All of the preceding analysis has considered only the effect of changes in the level of imports on the U.S. price. From the perspective of the import supplying countries however, the level of U.S. excess demand for beef is also of importance. Although the market excess demand for beef is not relevant when the import quota is a binding constraint, it has been relevant in the majority of years, when the
quota has been nonbinding. It seems likely that the estimated level of U.S. demand for imported beef will be sensitive to the disaggregation procedure used and so some long-run multipliers for this variable have been calculated.\(^1\) The long-run multipliers for a $100 increase in per capita consumer incomes, and for a 100 million bushel per quarter increase in corn exports have been given in Table 8.3.

Table 8.3. Total multipliers for the level of U.S. excess demand for meat

<table>
<thead>
<tr>
<th></th>
<th>Table/processing model</th>
<th>Fed/nonfed model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase of $100 in consumer incomes(^a)</td>
<td>0.07</td>
<td>11.10</td>
</tr>
<tr>
<td>Increase of 100 million bushels per quarter in corn exports</td>
<td>219.2</td>
<td>116.2</td>
</tr>
</tbody>
</table>

\(^a\)Effect refers to a change of $100 in per capita consumer disposable income at 1979 prices.

The results reported in Table 8.3 reveal some interesting differences between the two models in the response of long-run import demand to changes in the exogenous variables. The table/processing beef model predicts that a long-run increase in the level of consumer incomes will have almost no effect on the excess demand for beef. This estimate apparently arises because the increase in demand for high quality beef

\(^1\)The excess demand multipliers were obtained by fixing the price of low quality beef and treating the level of imports as endogenous.
generates a larger supply of its joint product, the lower quality cuts from fed carcasses, and this additional supply satisfies the smaller increase in processing quality beef demand. In the fed/nonfed beef model, by contrast, some increase in the demand for imports is predicted because the model ignores the effect of this increase in processing beef supply.

The effects of the increase in corn exports also reveal an important difference between the two models. The rise in the price of corn associated with this increase in exports leads to markedly different predictions from the two models. In this case, a larger increase in import demand would be expected from the table/processing beef model since it takes into account the reduction in processing beef supply following a decline in cattle feeding. However, examination of the other multipliers for this model reveals that only about ten percent of the difference between these two multipliers can be attributed to this factor. A large part of the remainder appears to be due to a large fall in pork supplies in the table/processing model, a difference which could not be predicted as an effect of the disaggregation procedure.

Clearly, Ryan [1980] has made an important contribution by pointing out that the use of a fed/nonfed beef disaggregation is a potentially serious misspecification and may lead to biased parameter estimates for the U.S. livestock subsector. The results of this study
suggest that the consequent bias in the price effects of meat imports is, if anything, in the opposite direction to that predicted by Ryan. The results do, however, suggest that the bias resulting from use of the fed/nonfed specification may be substantial, both for evaluating the impact of imports on the U.S. beef market and for assessing the effect of exogenous variables on the level of U.S. excess demand for beef.
CHAPTER IX. SUMMARY AND CONCLUSIONS

In this study, we set out to develop a model of the U.S. livestock-feed subsector and to use this model to investigate the impact of particular policy variables upon the U.S. livestock-feed subsector and upon the demand for imported beef.

In Chapter II, the system to be modeled was first delineated and then analyzed and described to provide a basis for the specification of the model. In Chapter III, we reviewed a number of previous models, and some of the relevant theoretical literature on modeling methods. Chapter IV was devoted exclusively to the estimation problems introduced by the limited-dependent variable nature of the import quota. After reviewing the alternative approaches to this problem, the simplest possible approach to overcoming it was chosen, that of choosing a time period sufficiently short (quarterly) that the level of imports could reasonably be viewed as predetermined.

A medium sized quarterly econometric model was specified using a similar basic structure to the model developed by Arzac and Wilkinson [1979a], with a number of substantial modifications. The major modifications to the specification involved changes in the method of disaggregating beef supply and demand, the imposition of symmetry restrictions at the retail demand level, and the use of deflated prices on both the supply and the demand side. Although the data used were in most cases similar to those used by Arzac and Wilkinson [1979a], and the sample periods included a large degree of overlap, the
estimated equations frequently differed substantially even where the same initial specifications had been adopted.

The model validation procedure included within-sample prediction tests, a beyond-sample prediction test, and calculation of the characteristic roots of the model. The model performed satisfactorily on all of these tests. In within-sample dynamic prediction, the model was found to generate better predictions than the Arzac and Wilkinson model for over half of the variables on which the two models could be compared. The characteristic roots were all stable, and there were a number of cyclical elements. The dominant root corresponded to a cycle approximately equal in length to the cattle cycle while two other pairs of roots corresponded to the observed length of the hog cycle.

Impact, interim and long-run multipliers were calculated for the effect of a change in the level of imports on key variables of the livestock feed subsector. Despite the differences in the method of analysis, the multipliers for the effects of changes in beef imports on the price of low quality beef were broadly comparable with those obtained in earlier studies. Like the Freebairn and Rausser [1975] model, this model predicted that an increase in imports would have the paradoxical effect of increasing the long-run beef cow inventory. It was argued that this result probably followed from the omission of roughage feed costs from the model and that the inclusion of this important factor in future livestock models would be desirable.

The structure of the U.S. livestock-feed subsector, and the level of its exogenous variables was also viewed as the source of U.S.
excess demand for beef. When the import quota is nonbinding, this excess demand becomes the effective market demand and the level of imports can be viewed as depending upon their own price and the levels of key exogenous variables of the system, such as consumer disposable income and the level of corn exports. A sustained increase in the level of corn exports, or the price of corn, was found to lead to a large increase in the level of excess demand for beef. On the other hand, changes in consumer incomes were found to have virtually no effect on the level of excess demand for beef.

While it was not possible to include an analysis of the short-run behavior of the beef import quota, some consideration was given to its long-run determinants. It was observed that the long-run level of the import quota was a constant share of total U.S. production. The response of the long-run quota level to changes in the exogenous variables of the model was also investigated using multiplier techniques. It was found that an increase in U.S. consumer incomes would have a strong, positive long-run effect on the level of the import quota, even though it would leave the level of excess demand for beef virtually unchanged. Conversely, an increase in the price of corn was found to cause a reduction in the long-run quota level, even though it increases the excess demand for beef. The interaction of these, and other, exogenous factors will determine whether the quota becomes more or less frequently a binding constraint on the market.

The effects of using a table/processing beef disaggregation procedure rather than the conventional fed/nonfed beef classification were
compared in Chapter IX. While use of the fed/nonfed approach is likely to lead to bias in estimates of the price effects of beef imports, the direction of this bias does not appear to be evident a priori. The results of the empirical comparisons made in the chapter suggested that the bias may be downwards, rather than upwards as was suggested by Ryan [1980]. The disaggregation procedure used also appears to be important when considering the demand for imported beef.

Most of the resources available for this study were devoted to the construction of a satisfactory model of the U.S. livestock feed subsector. The resulting model is a very general tool of analysis and the range of issues addressed in this study is only a small subset of the possibilities for application of the model to policy issues. The model could provide a framework for future analyses of many U.S. agricultural policy issues.
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Hildreth, C. and F. G. Jarrett  

Houck, J. P.  

Houck, J. P. and M. E. Ryan  

Houck, J. P. and A. Subotnik  

House of Representatives

Houthakker, H. and L. Taylor

Howrey, E. P. and H. H. Kelejian

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Reutlinger, S.

Rhodes, V. J. and W. L. Davis

Roberts, R. and E. O. Heady

Rogers, G. B., L. A. Voss, W. L. Hensen, and H. B. Jones

Ryan, M. E. and M. E. Abel
Ryan, T. J.

Samuelson, P. A.

Sargent, T. J.

SAS

Schatzer, R. J. and E. O. Heady

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<th>Reference</th>
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Finally, I would like to thank my wife Kris who provided affection and support without which this study could never have been completed, and also helped with the editing and proofreading.
APPENDIX A: DEFINITIONS AND SOURCES OF DATA USED IN THE MODEL

The model contains 55 endogenous variables and 34 exogenous variables. Some of these data series were obtained directly from various secondary sources while others have been derived by transforming input variables in order to obtain data corresponding to the particular economic concept of interest. Almost all the data used are quarterly, even where this required interpolation of the original series, since the simulation routine used is designed to handle systems with only one periodicity [SAS, 1980].

Definitions and sources of the variables actually appearing in the model are given in Table A.1. Where the series is available in published form, a reference to this source is given in the table. The details of the derivation of all other variables from their original series and the rationale for these derivations are given later in this Appendix. The definitions and sources of the input variables used to create the derived variable set are given in Table A.2.

Many quarterly series are only published in fragments of a few quarters at a time. Most of the historical series used were obtained via a telephone link to the OASIS data base maintained by the Economic Research Service of USDA [Bell, et al., 1978]. This service provided historical series for most variables from 1960 to 1980 and greatly
reduced the time needed for data collection. The OASIS variable names and logical groups for all variables obtained from OASIS are given in Table A.4. Even where variables were obtained from OASIS, a reference is given to published sources in order to facilitate verification and updating of the data.
Table A.1. Definitions and sources of variables appearing in the model

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Units of measure</th>
<th>Definition</th>
<th>Published source</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACP</td>
<td>thou. ac.</td>
<td>Area planted to com, U.S.</td>
<td>FdS-281, p. 25</td>
</tr>
<tr>
<td>AU</td>
<td>thou.</td>
<td>Grain consuming animal units</td>
<td>Derived</td>
</tr>
<tr>
<td>BBS</td>
<td>mil. lb.</td>
<td>Supply of beef from bulls, carcass wt.</td>
<td>Derived</td>
</tr>
<tr>
<td>BCOWS</td>
<td>thou.</td>
<td>Opening inventory of beef cows and heifers that have calved, interpolated to a quarterly sequence from annual and semiannual data</td>
<td>CATTLE (1-82), p.3</td>
</tr>
<tr>
<td>BINV</td>
<td>mil. lb.</td>
<td>Beef ending cold storage stocks, carcass wt.</td>
<td>LMStat, p. 155</td>
</tr>
<tr>
<td>CBS</td>
<td>mil. lb.</td>
<td>Production of cow beef, carcass wt.</td>
<td>Derived</td>
</tr>
<tr>
<td>CHFP</td>
<td>c/lb.</td>
<td>Farm liveweight price of broilers</td>
<td>PES-312, p. 16</td>
</tr>
<tr>
<td>CHPDN</td>
<td>mil. lb.</td>
<td>Total production of broiler meat, ready to cook weight</td>
<td>PES-312, p. 16</td>
</tr>
</tbody>
</table>

The following notation is used to identify some of the standard data sources used:

- AGSTAT - Agricultural Statistics, [USDA]
- CATTLE - Cattle [USDA]
- FdS - Feed Outlook and Situation [USDA]
- LMS - Livestock and Meat Outlook and Situation [USDA]
- PES - Poultry and Egg Outlook and Situation [USDA]
- SCB - Survey of Current Business [Bureau of Economic Analysis]
- LMStat - Livestock and Meat Statistics [USDA]

In many cases, the cited reference will not include all the observations included in the model. However, it will enable the reader to trace the series back to earlier, comparable series or to extend it forward. The number attached to any symbol indicates the volume number.
<table>
<thead>
<tr>
<th>Variable name</th>
<th>Units of measure</th>
<th>Definition</th>
<th>Published source</th>
</tr>
</thead>
<tbody>
<tr>
<td>CWP</td>
<td>$/100 lb.</td>
<td>Price of utility cows at Omaha, liveweight basis</td>
<td>LMS-244, p. 13</td>
</tr>
<tr>
<td>FSHBS</td>
<td>mil. 1b.</td>
<td>Production of beef from fed beef steers and heifers, carcass wt.</td>
<td>Derived</td>
</tr>
<tr>
<td>HBR</td>
<td>thou.</td>
<td>Inventory of breeding hogs, 14 states, March 1, June 1, September 1, December 1 for 1970 --</td>
<td>LMS-244, p. 26</td>
</tr>
<tr>
<td>HMKT</td>
<td>thou.</td>
<td>Inventory of market hogs, 14 states, March 1, June 1, September 1, December 1 for 1970 --</td>
<td>LMS-244, p. 26</td>
</tr>
<tr>
<td>HOP</td>
<td>$/100 lb.</td>
<td>Price of barrows and gilts, 7 markets, liveweight</td>
<td>LMS-244, p. 24</td>
</tr>
<tr>
<td>ICT</td>
<td>mil. bu.</td>
<td>Total ending stocks of corn, adjusted to 3 months quarters</td>
<td>FdS-284 as adjusted</td>
</tr>
<tr>
<td>KC</td>
<td>thou.</td>
<td>Estimated quarterly calf crop</td>
<td>Derived</td>
</tr>
<tr>
<td>KFC</td>
<td>thou.</td>
<td>Estimated supply of feeder calves</td>
<td>Derived</td>
</tr>
<tr>
<td>MCB</td>
<td>¢/lb.</td>
<td>Farm-retail margin for choice beef</td>
<td>Derived</td>
</tr>
<tr>
<td>MCN</td>
<td>¢/lb.</td>
<td>Farm-retail margin for chicken</td>
<td>Derived</td>
</tr>
<tr>
<td>MPB</td>
<td>¢/lb.</td>
<td>Farm-retail margin for processing beef</td>
<td>Derived</td>
</tr>
<tr>
<td>MPK</td>
<td>¢/lb.</td>
<td>Farm-retail margin for pork</td>
<td>Derived</td>
</tr>
<tr>
<td>NFSHBS</td>
<td>mil. 1b.</td>
<td>Production of beef from nonfed steers and heifers</td>
<td>Derived</td>
</tr>
<tr>
<td>PCB</td>
<td>¢/lb.</td>
<td>Retail price of choice beef, retail weight basis</td>
<td>LMS-244, p. 33</td>
</tr>
<tr>
<td>PCN</td>
<td>¢/lb.</td>
<td>Retail price of frying chicken, ready to cook</td>
<td>PES-312, p. 6</td>
</tr>
<tr>
<td>Variables name</td>
<td>Units of measure</td>
<td>Definition</td>
<td>Published source</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------</td>
<td>------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>PF</td>
<td>thou.</td>
<td>Placements of cattle on feed, 23 states</td>
<td>LMS-244, p. 14</td>
</tr>
<tr>
<td>PGB</td>
<td>¢/lb.</td>
<td>Retail price of ground beef, retail weight basis</td>
<td>Derived</td>
</tr>
<tr>
<td>PKINV</td>
<td>mil. 1b.</td>
<td>Ending cold storage stocks of pork, carcass weight equivalent</td>
<td>LMS-244, p. 30</td>
</tr>
<tr>
<td>PKS</td>
<td>mil. 1b.</td>
<td>Commercial production of pork, carcass wt.</td>
<td>LMS-244, p. 21</td>
</tr>
<tr>
<td>PPK</td>
<td>¢/lb.</td>
<td>Retail price of pork, retail weight</td>
<td>LMS-244, p. 21</td>
</tr>
<tr>
<td>PTB</td>
<td>¢/lb.</td>
<td>Retail price of table quality beef, retail weight</td>
<td>Derived</td>
</tr>
<tr>
<td>RBCP</td>
<td>$/100 lb.</td>
<td>Price of beef cows (CWP) deflated by PPEX to 1977 values, liveweight</td>
<td>LMS-244, p. 13</td>
</tr>
<tr>
<td>RBSF&lt;sup&gt;b&lt;/sup&gt;</td>
<td>$/100 lb.</td>
<td>Average price of feeder steers at Kansas City, deflated by PPEX to 1977 values, liveweight</td>
<td>LMStat, p. 123 or LMS-244, p. 38</td>
</tr>
<tr>
<td>RFCNP</td>
<td>¢/lb.</td>
<td>Farm price of broilers, liveweight, (CHFP) deflated by PPEX to 1977 values</td>
<td>PES-312, p. 16</td>
</tr>
<tr>
<td>RFPPK</td>
<td>$/100 lb.</td>
<td>Price of barrows and gilts, 7 markets (MOP) deflated by PPEX to 1977 values</td>
<td>LMS-244, p. 24</td>
</tr>
<tr>
<td>RFSP</td>
<td>$/100 lb.</td>
<td>Price of choice steers, 900-1100 lbs. at Omaha (STP) deflated by PPEX to 1977 values</td>
<td>LMStat, p. 124</td>
</tr>
<tr>
<td>RPCN</td>
<td>$/lb.</td>
<td>Retail price of frying chicken, ready to cook (PCN), deflated by CPU to 1967 values</td>
<td>PES-312, p. 16</td>
</tr>
</tbody>
</table>

<sup>b</sup>For definitions of RBSPA and WRBSPA, see Table 6.1.
<table>
<thead>
<tr>
<th>Variable name</th>
<th>Units of measure</th>
<th>Definition</th>
<th>Published source</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPCORN</td>
<td>$/bu.</td>
<td>Corn price received by farmers, calendar qtrs. deflated by PPEX to 1977 values</td>
<td>FdS-284, p. 31</td>
</tr>
<tr>
<td>RPPGB</td>
<td>$/lb.</td>
<td>Retail price of ground beef (PGB) deflated by CPU to 1967 values</td>
<td>Derived</td>
</tr>
<tr>
<td>RPCPK</td>
<td>$/lb.</td>
<td>Retail price of pork, retail wt. (PPK) deflated by CPU to 1967 values</td>
<td>LMS-244, p. 21</td>
</tr>
<tr>
<td>RPTPB</td>
<td>$/lb.</td>
<td>Retail price of table beef (PTB) deflated by CPU to 1967 values</td>
<td>Derived</td>
</tr>
<tr>
<td>SC</td>
<td>$/100 lb.</td>
<td>Price of choice slaughter steers (900-1100 lb.) at Omaha</td>
<td>LMS-244, p. 13</td>
</tr>
<tr>
<td>TCOWS</td>
<td>thou.</td>
<td>Total opening inventory of cows, interpolated to obtain a quarterly series</td>
<td>LMS-244, p. 10</td>
</tr>
<tr>
<td>XCN</td>
<td>mil. lb.</td>
<td>U.S. consumption of young chicken, ready to cook weight</td>
<td>Derived</td>
</tr>
<tr>
<td>XCNC</td>
<td>lb./capita</td>
<td>U.S. per capita consumption of young chicken</td>
<td>Derived</td>
</tr>
<tr>
<td>XDC</td>
<td>mil. bu.</td>
<td>U.S. total domestic use of corn adjusted to 3 month quarters</td>
<td>Derived</td>
</tr>
<tr>
<td>XPB</td>
<td>mil. lb.</td>
<td>U.S. total consumption of processing quality beef, carcass wt.</td>
<td>Derived</td>
</tr>
<tr>
<td>XPB2C</td>
<td>lb./capita</td>
<td>U.S. per capita consumption of processing quality beef, carcass wt.</td>
<td>Derived</td>
</tr>
<tr>
<td>XPK</td>
<td>mil. lb.</td>
<td>U.S. consumption of commercially produced pork, carcass wt.</td>
<td>Derived</td>
</tr>
<tr>
<td>XPK2C</td>
<td>lb./capita</td>
<td>U.S. per capita consumption of pork, carcass wt.</td>
<td>Derived</td>
</tr>
<tr>
<td>Variable name</td>
<td>Units of measure</td>
<td>Definition</td>
<td>Published source</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------</td>
<td>------------</td>
<td>------------------</td>
</tr>
<tr>
<td>XTB</td>
<td>mil. lb.</td>
<td>U.S. consumption of table quality beef, carcass wt.</td>
<td>Derived</td>
</tr>
<tr>
<td>XTBC</td>
<td>lb./capita</td>
<td>U.S. per capita consumption of table quality beef, carcass wt.</td>
<td>Derived</td>
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II. Exogenous variables of the model

<table>
<thead>
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<th>Variable name</th>
<th>Units of measure</th>
<th>Definition</th>
<th>Published source</th>
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<tbody>
<tr>
<td>BBPA</td>
<td>$/lb.$</td>
<td>Beef by-product allowance (carcass plus farm allowance)</td>
<td>LMS-244, p. 33</td>
</tr>
<tr>
<td>BX</td>
<td>mil. lb.</td>
<td>Exports of beef, carcass wt.</td>
<td>LMS-244, p. 30</td>
</tr>
<tr>
<td>BM</td>
<td>mil. lb.</td>
<td>Imports of beef, carcass wt.</td>
<td>LMS-244, p. 30</td>
</tr>
<tr>
<td>CHX</td>
<td>mil. lb.</td>
<td>Young chicken exports and shipments</td>
<td>PES-312, p. 18</td>
</tr>
<tr>
<td>CPU</td>
<td>index</td>
<td>Consumer price index, all items, all urban consumers, 1967 = 100</td>
<td>[SCB, Vol. 62, No. 1, p. S-6]</td>
</tr>
<tr>
<td>CHINV</td>
<td>mil. lb.</td>
<td>Ending stocks of young chicken</td>
<td>PES-312, p. 18</td>
</tr>
<tr>
<td>DUM5560</td>
<td>0-1</td>
<td>Dummy variable for the market disruptions from 1973.3 to 1974.4</td>
<td>Derived</td>
</tr>
<tr>
<td>DUMM66</td>
<td>0-1</td>
<td>Dummy variable for the change in the method of calculating the effective support price (RCESP) and effective diversion rate (RCEDR) variables in 1966 and afterwards</td>
<td>Derived</td>
</tr>
<tr>
<td>EC</td>
<td>mil. bu.</td>
<td>U.S. corn exports, adjusted to 3 month calendar qtrs.</td>
<td>Derived</td>
</tr>
<tr>
<td>Variable name</td>
<td>Units of measure</td>
<td>Definition</td>
<td>Published source</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------</td>
<td>------------</td>
<td>------------------</td>
</tr>
<tr>
<td>FCIM</td>
<td>thou.</td>
<td>Imports of feeder cattle 200-699 lbs., annual value used in all quarters of the year</td>
<td>LMS-244, p. 32</td>
</tr>
<tr>
<td>FORDUM</td>
<td>0-1</td>
<td>Dummy variable for the effects of the Farmer-Owned Reserve Program—Unity in 1977.4 and after</td>
<td>Derived</td>
</tr>
<tr>
<td>GCFP</td>
<td>mil. bu.</td>
<td>Conversion factor from mil. lbs. of chicken production to thousand grain consuming animal units</td>
<td>Derived</td>
</tr>
<tr>
<td>ICG</td>
<td>thou.</td>
<td>Ending government owned inventory of corn</td>
<td>Derived</td>
</tr>
<tr>
<td>ID</td>
<td>index</td>
<td>Dairy heifer replacements 500 lbs. and over, January 1 number applied to whole year</td>
<td>CATTLE (1-82), p. 3</td>
</tr>
<tr>
<td>LP</td>
<td>index</td>
<td>Index of output per hour of labor used for farm work in poultry, annual value applied in all quarters</td>
<td>AGSTAT, 1979, p. 442</td>
</tr>
<tr>
<td>MCOWS</td>
<td>thou.</td>
<td>Milk cows and heifers that have calved, annual and semiannual series</td>
<td>CATTLE (1-82), p. 3</td>
</tr>
<tr>
<td>PBPA</td>
<td>¢/lb.</td>
<td>By-product allowance for pork</td>
<td>LMS-244, p. 26</td>
</tr>
<tr>
<td>PCDUM</td>
<td>0-1</td>
<td>Dummy variable for the effects of price controls in 1973, quarter 3</td>
<td>Derived</td>
</tr>
<tr>
<td>PKM</td>
<td>mil. lb.</td>
<td>Imports of pork, carcass wt.</td>
<td>LMS-244, p. 30</td>
</tr>
<tr>
<td>PKX</td>
<td>mil. lb.</td>
<td>Exports and shipments of pork, carcass wt.</td>
<td>LMS-244, p. 31</td>
</tr>
<tr>
<td>PPEX</td>
<td>index</td>
<td>Index of prices paid by farmers excluding prices of feed and feeder cattle</td>
<td>Derived</td>
</tr>
<tr>
<td>Q2</td>
<td>0-1</td>
<td>Dummy variable for quarter 2 of the calendar year, 1 in quarter 2, zero elsewhere</td>
<td>Derived</td>
</tr>
</tbody>
</table>
Table A.1 (continued)

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Units of measure</th>
<th>Definition</th>
<th>Published source</th>
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</thead>
<tbody>
<tr>
<td>Q3</td>
<td>0-1</td>
<td>Dummy variable for quarter 3 of the calendar year</td>
<td>Derived</td>
</tr>
<tr>
<td>Q4</td>
<td>0-1</td>
<td>Dummy variable for quarter 4 of the calendar year</td>
<td>Derived</td>
</tr>
<tr>
<td>RCEDR</td>
<td>$/bu.</td>
<td>Real corn effective diversion rate</td>
<td>Derived</td>
</tr>
<tr>
<td>RCESP</td>
<td>$/bu.</td>
<td>Real corn effective support price</td>
<td>Derived</td>
</tr>
<tr>
<td>RINT</td>
<td>%</td>
<td>Estimated one-period ahead real rate of interest</td>
<td>Derived</td>
</tr>
<tr>
<td>RSBPM</td>
<td>$/bu.</td>
<td>Price received by farmers for soybeans, average for the quarter of planting and three previous quarters, deflated by PPEX</td>
<td>Derived</td>
</tr>
<tr>
<td>T</td>
<td>integer</td>
<td>Time trend variable for quarters, 1 in 1960.1, 2 in 1960.2, etc.</td>
<td>Derived</td>
</tr>
<tr>
<td>YH</td>
<td>bu./ac.</td>
<td>Corn yield per harvested acre</td>
<td>FdS-281, p. 25</td>
</tr>
<tr>
<td>YZC</td>
<td>$ thou.</td>
<td>Average per capita personal disposable income (YZ divided by USPOP)</td>
<td>SCB, Vol. 62, No. 1, p. 12</td>
</tr>
</tbody>
</table>
Generation of the Derived Variables Appearing in the Model

Many of the variables appearing in the model were not taken directly from published sources but, rather, were transformed in order to obtain a series which more closely reflected the economic concept of interest. In some cases (e.g., AU), the variable derivation is contained within the model, while in others, the transformation process was used to obtain the input data. The purpose of this section is to set out the procedures used to derive the variables and to outline the rationale for these procedures in all cases where the transformation was more complex than simple price deflation. Where a variable used in deriving a particular series has not appeared in the model, and hence in Table A.1, its definition and published source is given in Table A.2.

**Derived endogenous variables**

The AU variable was used to aggregate inventory numbers for various types of grain consuming animals into a single variable, Grain Consuming Animal Units, which could be used in the corn demand equation.

No variable for the inventory of cattle on feed is included in the model and so this component of the index was based upon lagged placements of cattle on feed. For the years 1970-1980, the average ratio of the beginning number of cattle on feed to placements on feed in the previous two quarters was found to be [USDA, 1981b, p. 44]:
Table A.2. Definitions and sources of variables used to generate other variables but which do not themselves appear in the model

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Units of measure</th>
<th>Definitions</th>
<th>Published source^</th>
</tr>
</thead>
<tbody>
<tr>
<td>BESCPUS</td>
<td>mil. lb.</td>
<td>Total commercial beef production</td>
<td>LMS-244, p. 12</td>
</tr>
<tr>
<td>CCLCIJUS</td>
<td>thou.</td>
<td>Beef cows and heifers that have calved, January 1</td>
<td>CATTLE 1-82, p. 5</td>
</tr>
<tr>
<td>CMCIJUS</td>
<td>thou.</td>
<td>Milk cows and heifers that have calved, January 1</td>
<td>CATTLE 1-82, p. 5</td>
</tr>
<tr>
<td>CONENUS</td>
<td>mil. bu.</td>
<td>Ending government-owned stocks of corn, USDA calendar quarters</td>
<td>FdS-284, p. 27</td>
</tr>
<tr>
<td>COUDTUS</td>
<td>mil. bu.</td>
<td>Corn, total domestic disappearance, USDA calendar quarters</td>
<td>FdS-284, p. 27</td>
</tr>
<tr>
<td>CPUBVHA</td>
<td>index</td>
<td>Retail price index for ground beef other than canned</td>
<td>[Bureau of Labor Statistics, 1982a]</td>
</tr>
</tbody>
</table>

^Sources follow the notation used in Table A.1 with the addition of:

AGP - Agricultural Prices Annual Summary [USDA]
EI - Economic Indicators [Council of Economic Advisers]
FOS - Fats and Oils Outlook and Situation [USDA]
LSL - Livestock Slaughter: Annual Summary 1981 [USDA].
<table>
<thead>
<tr>
<th>Variable name</th>
<th>Units of measure</th>
<th>Definitions</th>
<th>Published source</th>
</tr>
</thead>
<tbody>
<tr>
<td>COUXTUS</td>
<td>mil. bu.</td>
<td>Corn exports, USDA, calendar quarters</td>
<td>Fds-284, p. 27</td>
</tr>
<tr>
<td>CVSNBUS</td>
<td>thou.</td>
<td>U.S. calf crop</td>
<td>LMS-244, p. 7</td>
</tr>
<tr>
<td>CWKCNUS</td>
<td>thou.</td>
<td>Commercial slaughter of cows (used number slaughtered under F.I. divided by proportion of total cattle under F.I.)</td>
<td>[LSL, 1982, pp. 4 and 10]</td>
</tr>
<tr>
<td>CWKGAUS</td>
<td>lb.</td>
<td>Average dressed weight of cows slaughtered under F.I.</td>
<td>[LSL, 1982, p. 5]</td>
</tr>
<tr>
<td>FCDRWT</td>
<td>lb.</td>
<td>Average dressed weight of fed cattle (derived using average weight of Prime, Choice, and Good USDA grades)</td>
<td>[Crom, 1981]</td>
</tr>
<tr>
<td>FCM39ST</td>
<td>thou.</td>
<td>Fed cattle marketings in 39 selected states</td>
<td>[Crom, 1981]</td>
</tr>
<tr>
<td>INT3</td>
<td>%</td>
<td>Average prime rate of interest charged by banks</td>
<td>[Council of Economic Advisers, 1982, p. 30]</td>
</tr>
<tr>
<td>PP7PF</td>
<td>index</td>
<td>Prices paid by farmers for feed</td>
<td>AGP, p. 16</td>
</tr>
<tr>
<td>PP7PI</td>
<td>index</td>
<td>Prices paid by farmers for all production items</td>
<td>AGP, p. 16</td>
</tr>
<tr>
<td>PP7PL</td>
<td>index</td>
<td>Prices paid by farmers for feeder livestock</td>
<td>AGP, p. 17</td>
</tr>
<tr>
<td>PP7WR</td>
<td>index</td>
<td>Wage rates paid by farmers</td>
<td>AGP, p. 22</td>
</tr>
<tr>
<td>SBP</td>
<td>$/bu.</td>
<td>U.S. average price received by farmers for soybeans</td>
<td>FOS-302, p. 20</td>
</tr>
<tr>
<td>STPMKKC</td>
<td>$/100 lb.</td>
<td>Price of feeder steers, all weights and grades Kansas City</td>
<td>LMS-244, p. 38</td>
</tr>
</tbody>
</table>
A conversion factor of 0.87 was used to provide an estimate of the cattle on feed inventory from data on placements lagged one and two quarters. A conversion factor from the USDA's Livestock-Feed Relationships: Supplement for 1974 [Allen and Devers, 1975, p. 48] was then used to relate estimated inventory to grain consuming animals units. The cattle on feed component, $A_{U_c}$, of the AU variable was thus defined as:

$$A_{U_c} = 0.87 \times 1.5286 \times (PF_{t-1} + PF_{t-2})$$
$$= 1.33 \times (PF_{t-1} + PF_{t-2})$$

The inventory of milk cows was converted to animal units using a conversion factor of 1.05 [Allen and Devers, 1975, p. 48]. Similarly, the inventory of market hogs was multiplied by a factor of 0.2291 obtained from the same source.

Because there has been a very rapid improvement in feed conversion efficiency within the broiler industry, a single conversion factor from broiler meat to animal units was not believed to be appropriate. Accordingly, technological advance in poultry feed conversion was
specified as a linear function of time.

Using annual data for 1960 to 1978, the quantity of poultry feed (lbs.) required for 100 lbs. of meat produced [USDA, 1980a] was regressed against a linear time trend. The estimated equation was:

\[ \text{PFCR} = 410.95 - 5.67 \, T \]

Where:

- \( \text{PFCR} \) = poultry feed conversion ratio
- \( T \) = time in years

This conversion factor was converted to time in quarters by dividing the coefficient on \( T \) by four. It was then converted to the quantity required per million pounds of poultry meat by multiplying by 10,000. This figure was then converted into animal units by dividing by 4880 [USDA, 1974, p. 90]. Finally, the estimate was divided by 1000 to obtain thousand animal units.

The final factor obtained was:

\[ \text{GCFP} = 0.84 - 0.002904 \, TQ \]

Where:

- \( TQ \) = time in quarters

GCFP = grain consumption factor for poultry

The resulting definition of AU as it appears in the model is:

\[ \text{AU} = 1.33 \times (\text{PF}_{t-1} + \text{PF}_{t-2}) + 1.05 \times \text{MCOWS} + 0.2291 \times \text{HMKT} + \text{GCFP} \times \text{CHPDN} \]
BBS: Supply of beef from bulls, car. wt., mil. lb.

\[ BBS = BLKCNUS \times BLKGAUS/1000 \]

CBS: Supply of beef from cows, car. wt., mil. lb.

\[ CBS = CWKCNUS \times CWKGAUS/1000 \]

CS: Total supply of corn, mil. bu.

\[ CS = ICT_{t-1} + COSPRUS \]

DBCOWS: Change in inventory of beef cows during quarter

\[ DBCOWS = BCOWSF - BCOWS \]

Where: \( BCOWSF = \) ending inventory of cows in a quarter

FSHBS: Fed steer and heifer beef production, car. wt., mil. lb.

\[ FSHBS = FCM39ST \times FCDRWT/1000 \]

KC: Estimated quarterly calf crop, thou.

Since the simulation procedures in SAS [SAS, 1980] require that all data used be of the same periodicity, it was necessary to estimate the calf crop on a quarterly basis. No data on U.S. calvings appear to be available on a quarterly basis and bi-annual estimates have only become available since 1977 [USDA, 1982c, p. 5]. The estimates reported in Cattle suggest that approximately 70% of calves are born in the first
half of the year [USDA, 1982c] and industry specialists indicated that most of these calves are born in the period from March 1-May 30.

In the absence of any reliable figures over the sample period, the quarterly calf crop was estimated crudely by applying the annual calving percentage to the cow inventory in the particular quarter. Thus:

\[ KG = \frac{CVSNBUS}{(BCCIJUS + GMIJUS)} \times TCOWS \]

KFC: Estimated supply of year-old feeders, thou.

\[ KFC = K_{t-4} + FCIM - SC_{t-1} - SC_{t-2} - SC_{t-3} - SC_{t-4} \]

This equation makes use of the fact that KG is on an annual basis. It then adjusts for dairy replacements, feeder calf imports and prior calf slaughter.

MGB: Farm-retail margin for choice beef, $/lb.

\[ MGB = FTB - STP \]

All of the margin variables are expressed in nominal terms and their corresponding equations are also estimated in nominal terms.

MCB: Farm-retail margin for chicken, $/lb.

\[ MCB = PCN - CHFP \]

MPB: Farm-retail margin for processing beef, $/lb.
\[ MPB = PGB - CWP \]

MPK: Farm-retail margin for pork

\[ MPK = PPK - HOP \]

NFSHBS: Production of beef from nonfed steers and heifers, mil.lb.

Published data to disaggregate beef production data down from total commercial production to its components were not directly available. Nonfed steer and heifer beef production was calculated as a residual from total commercial beef production.

\[ NFSHBS = BESCPUS - FSHBS - CBS - BBS \]

PGB: Retail price of ground beef, c/lb.

Because the USDA's long-standing and very useful series on the retail price of ground beef was discontinued during 1981, this series was computed using the price index for hamburger prepared by the Bureau of Labor Statistics. This price index, CPUBVHA, refers to "ground beef other than canned" and includes all ground beef, e.g., regular hamburger, patties, ground chuck and ground round. The formula used to derive PGB was:

\[ PGB = CPUBVHA \times 0.5225 \]

This formula converted CPUBVHA from an index with base 100 in 1967 into a price series with an average of 52.25 in 1967, so that the
new series would have the same value in 1967 as the USDA's ground beef series [USDA, 1979b, p. 26]. Since the CPUBVHA price index is still being prepared and published, it is possible to update this series whereas the USDA's series on ground beef prices was last published in the Livestock and Meat Outlook and Situation of May 1981 (p. 24). The computed price series for PGB and the USDA series were very closely related during the sample period. Only after the CPUBVHA index was altered in 1978 to include more than just regular hamburger, did the two series diverge to any extent. Even then, the divergence was only a matter of a few cents per pound.

PTB: Retail price of table beef, ¢/lb.

Following Ryan [1980], total beef consumption at retail was divided into two classes: (1) table quality beef and (2) processing quality beef. Since no published data are available for these two classes of beef, it was necessary to derive estimates of both the quantities and prices of these two commodities.

The proportion of low quality, processing beef in each fed carcass was assumed to be 0.232, following Ryan [1980, p. 63] and so the weighted average price of a choice beef carcass would be:

$$PCB = 0.232 \times PGB + 0.768 \times PTB$$

and so:

$$PTB = \frac{PCB - 0.232 \times PGB}{0.768}$$

Where PGB is assumed to be a reasonable proxy for the price of
those portions of the fed carcass, e.g., flanks, briskets and some trimmings, which are processed.

RPGB: Real retail price of ground beef, \$/lb.

\[ \text{RPGB} = \frac{\text{PGB}}{\text{CPU}} \]

The use of CPU which has a base of 100 converts RPGB into \$/lb. instead of c/lb. as for PGB. This leads to demand function parameter estimates of more convenient magnitude.

RPTB: Real retail price of table beef, \$/lb.

\[ \text{RPTB} = \frac{\text{PTB}}{\text{CPU}} \]

XCN: U.S. consumption of young chicken, mil.lb.

\[ \text{XCN} = \text{CHPDN} - \text{CHX} + \text{CHINV} - \text{CHINV} \]

XCNC: U.S. per capita consumption of young chicken

\[ \text{XCNC} = \frac{\text{XCN}}{\text{USPOP}} \]

XDC: U.S. total domestic use of corn adjusted to 3 month quarters.

Since 1975, U.S. quarterly data on feed grain inventory and consumption have referred to quarters of unequal length. In order to obtain satisfactory estimates of corn consumption and inventory demand, it was felt necessary to convert these data to quarters of equal length.

The crop year quarters used in the USDA's Feed Situation (1982d
p.27) are October-December, January-March, April-May and June-September. Thus, the second and third "quarters" of the calendar year are of two and four months respectively. These quarters were adjusted to yield data "as if" the quarters were of three months duration. This introduces some error because price may differ substantially between June and the remaining months of the second calendar quarter. However, this approach was felt preferable to retaining "quarters" of uneven duration in the corn sector of the model. Domestic corn demand, corn exports, total corn inventory and government corn inventory were all modified as follows:

If $Qtr = 2$ then $XDC = COUTUS \times 1.5$
If $Qtr = 3$ then $XDC = COUTUS - 0.5 \times COUTUS_{t-1}$
If $Qtr = 1$ or $Qtr = 4$ then $XDC = COUTUS$

If $Qtr = 2$ then $EC = COXTUS \times 1.5$
If $Qtr = 3$ then $EC = COXTUS - 0.5 \times COXTUS_{t-1}$
If $Qtr = 1$ or $Qtr = 4$ then $EC = COXTUS$

$DGOINV = CONEUS - CONEUS_{t-1}$
If $Qtr = 2$ then $ICG = CONEUS + 0.5 \times DGOINV$
ELSE $ICG = CONEUS$

If $ICG$ less than or equal to zero, then set $ICG$ equal to zero.
If $Qtr = 2$ then $ICT = COCOTUS_{t-1} - XDC - EC$
If Qtr not equal to 2 then \( \text{ICT} = \text{COCOTUS} \)

\( \text{XPB} \): U.S. total consumption of processing quality beef, mil.lb.

In estimating total consumption of processing quality beef, it was assumed that the beef produced from nonfed steers and heifers was primarily used for table quality beef. This treatment differs from the Fed/Nonfed dichotomy used in many studies [e.g., Freebairn and Rausser, 1975; Bain, 1977] but is consistent with the approach of Ryan [1980]. By the use of identities, it has been possible to combine the two approaches identified by Bain [1977, p. 16]: the end-use approach of distinguishing high and low quality beef and the production approach of distinguishing between fed and nonfed beef.

Ryan [1980, p. 61] argues that most of the beef produced from non-fed steers and heifers when grass finishing was common (during 1974, 1975 and 1976) appeared as table cuts in retail stores. Rhodes and Davis [1976] describe the merchandising procedures used to sell this lighter beef as table cuts. It appears that this product has demand characteristics which are nearer to those of table cuts from fed beef than to processing quality beef.

Cow beef, bull beef, imported beef and beef inventories were all treated as being of processing quality.

The equation used to derive the consumption of processing beef was:

\[
\text{XPB} = 0.232 \times (\text{FSHBS} + \text{NFSHBS}) + \text{CBS} + \text{BBS} + \text{BINV}_{t-1} - \text{BINV} + \text{BM}
\]
XPBC: U.S. per capita consumption of processing quality beef, lb.

\[ XPBC = \frac{XPB}{USPOP} \]

XPK: U.S. consumption of commercially produced pork, mil. lb.

\[ XPK = PKX + PKM + PKINV_{t-1} - PKINV - PKX \]

XPKC: U.S. per capita consumption of pork, lb.

\[ XPKC = \frac{XPK}{USPOP} \]

XTB: U.S. consumption of table quality beef, mil. lb.

Since 76.8 percent of beef produced from both fed and nonfeed steers and heifers was assumed to be used for table quality beef, this variable was defined as:

\[ XTB = 0.768 \times FSHBS + 0.768 \times NFSHBS - BX \]

XTBC: U.S. per capita consumption of table quality beef, lb.

\[ XTBC = \frac{XTB}{USPOP} \]

**Derived Exogenous variables**

DUM5560: Dummy variable for the extreme market disruptions during 1973.3 to 1974.4

This variable takes on the value one during the period from 1973.3 to 1974.4, inclusive. It is zero in all other quarters.
DUM66: Dummy variable for the change in method of calculating the corn price variables.

This variable takes on the value of unity for 1966 and all subsequent years. It is zero prior to 1966.

EC: U.S. corn exports adjusted to 3 month quarters, mil. bu.

The adjustment process for this variable is given under XDC in the endogenous variables section.

GCFP: Conversion factor from mil. lb. of chicken production to thousand grain consuming animal units.

The derivation of this variable was given with the AU endogenous variable.

ICG: Ending government inventory of corn, mil. bu.

Derived with the XDC variable - see the endogenous variables section.

PPEX: Index of prices paid by farmers excluding prices of feed and feeder livestock, index, base 100 in 1977.

Given the rapid rates of inflation prevailing over the latter half of the sample period, it was felt that the use of nominal variables in the production equations would not be satisfactory. Thus, it became necessary to introduce a variable which would represent the price of those inputs whose price is exogenous to the feed grain-livestock sector. Both the Consumer Price Index and the Implicit Price Deflator for GNP were considered but rejected as too general. When plotted, they
did not appear to reflect price changes for agricultural inputs sufficiently closely, particularly over the volatile 1973-1975 period.

Arzac and Wilkinson [1979a, p. 299] chose to use nominal prices of corn and the various meats in their supply equations, without any consideration of the exogenously determined price of other inputs. Their justification for this approach was the lack of a suitable, generally available price index, and the relatively moderate inflation in most of their 1957-1975 sample period [1979a, p. 299]. Unfortunately inflation was much more serious in the 1962-1979 sample period used in this study. The consumer price index (CPU) increased from 90.1 in 1962 I to 227.6 in 1979 IV or by a factor of 2.53. As a result, it was felt necessary to develop an index of exogenous farm costs for this study.

The index of Prices Paid by Farmers for Production Items, PP7PI, was the published index most closely related to the concept of interest in this study [USDA, 1979a, p. 30]. This index is a component of the overall index of Prices Paid by Farmers. Unfortunately, PP7PI includes Feed and Feeder Livestock Prices whose prices are endogenous to the feed grain-livestock model and excludes Farm Wage Rates which are an important cost to farmers. Interest and taxes are not included in PP7PI but are included in the total Parity Index of Prices Paid by Farmers. Since the effects of interest rates and taxes on production decisions are unlike the effects of input price changes, they were excluded from the new PPEX index. Farm Wage Rates, PP7WR, were, however, included in the index used.
PP7PI is a fixed-weight index with weights as given in Table A.3 [USDA, 1979a, p. 30].

Table A.3. Weights used in the index of prices paid by farmers for production items (PP7PI)

<table>
<thead>
<tr>
<th>Percentage of total parity index of prices paid by farmers (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
</tr>
<tr>
<td>Feeder livestock</td>
</tr>
<tr>
<td>Seed</td>
</tr>
<tr>
<td>Fertilizer</td>
</tr>
<tr>
<td>Agricultural chemicals</td>
</tr>
<tr>
<td>Fuels and energy</td>
</tr>
<tr>
<td>Farm and motor supplies</td>
</tr>
<tr>
<td>Autos and trucks</td>
</tr>
<tr>
<td>Tractors and S.P. machinery</td>
</tr>
<tr>
<td>Other machinery</td>
</tr>
<tr>
<td>Building and fencing</td>
</tr>
<tr>
<td>Farm services and cash rent</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

The Farm Wage Rate Index, PP7WR, is a separate index making up a total of 5.2 percent of the weight in the total Parity Index of Prices Paid by Farmers.

To compute the new index, PPEX, the endogenous Feed and Feeder Livestock components were first removed from the PP7PI index. This resulted in:
\[ PP1 = \frac{(PP7PI - 0.20486 \times PP7PF - 0.203125 \times PP7PL)}{0.592} \]
\[ = 1.689 \times PP7PI - 0.346 \times PP7PF - 0.3431 \times PP7PL \]

Where:
- PP7PF = the price index for feed and
- PP7PL = the price index for feeder livestock

The intermediate index, PP1, was then combined with the Farm Wage Rates index, PP7WR using their relative weights in the total Parity Index of Prices Paid by Farmers. Thus

\[ PPEX = \frac{5.2 \times PP7WR + 34.1 \times PP1}{39.3} \]
\[ = 0.1323 \times PP7WR + 0.8677 \times PP1 \]

Substituting in this equation for the index PP1 yields the direct estimating equation\(^1\)

\[ PPEX = 0.13285 \times PP7WR + 1.47155 \times PP7PI \]
\[ - 0.30146 \times PP7PF - 0.29893 \times PP7PL \]

The weights used in the current Prices Paid Index for all periods since January 1965 are those derived from the 1971-73 Expenditure Survey [USDA, 1979a, p. 29]. Thus, the index PPEX should be adjusted exactly for all sample-period years except 1962, 1963 and 1964. In those years, price movements were relatively slight and so the process

\(^1\)The weights were also multiplied by a factor of 1.004132 to obtain a base of exactly 100 in 1977.
of deflating makes only a slight difference in any event. It is believed that PPEX should be a good measure of the exogenously determined price of inputs other than feed and feeder livestock.

RCEDR: Real corn effective diversion rate, $/bu.

This variable and the corn effective support price, RCESP, were calculated using the methodology suggested by Houck, et al. [1976] and Houck and Subotnik [1969]. The variable used corresponds to DPC** in the Houck et al. study [1976, pp. 12-13] which provides a description of the derivation of this variable. A listing of the data used up to 1977 is given in Gallagher [1978, p. 14]. The method of calculating the variable and examples for 1978 and 1979 will be detailed here.

The basic calculation of the nominal diversion rate, CEDR involves averaging the diversion rate payable on the minimum area which could be diverted and the rate applicable at the maximum allowed diversion [Houck et al. 1976]. Thus:

$$CEDR = \frac{1}{2} \left( \frac{D_{\text{min}}}{A_o} \right) PR_1 + \frac{1}{2} \left( \frac{D_{\text{max}}}{A_o} \right) PR_2$$

Where:

- $PR_1$ = diversion payment rate for levels of diversion near the minimum requirement;
- $PR_2$ = diversion payment for levels of diversion near the maximum allowable;
- $D_{\text{min}}$ = minimum acreage diversion requirement;
- $A_o$ = base acreage for a particular farm
\[ D_{\text{max}} = \text{maximum acreage diversion requirement}. \]

After 1966, price support payments were applied only to a specified proportion of the base area for any farm. The effective price variables used were redefined for this later period to include the support payments as part of the incentive to divert at least the minimum area required for program participation. This change in the definition of the variables used required the addition of a dummy variable to the acreage demand equation.

The calculation of CEDR for 1978 and 1979 follows the procedure used by Gallagher [1981]. In these years, an acreage diversion program was in effect, in addition to the required acreage set-aside for program participation [Fulton, 1981, p. 22]. The diversion payment calculation takes into account two options available to farmers: (1) partial compliance, in which the farmer makes only those reductions necessary to be in the program, and (2) full compliance in which the maximum permissible acreage diversion is made.

In 1978, a 10 percent set aside was in effect and setting aside an area equal to 10 percent of the area planted provided target price protection on 80 percent of planted acreage. No explicit diversion payment was made in this case, since the diversion payment in this Partial Compliance case is considered to be the opportunity cost of not reducing plantings. The target price provides for a maximum deficiency payment of

\[ D_p = P_T - P_L = 2.10 - 2.00 = 0.10 \]
Where:

\[ D_P = \text{the deficiency payment/bu.}, \]
\[ P_T = \text{target price per bu.}, \] and
\[ P_L = \text{loan rate per bu.}. \]

The revenue per acre not planted was therefore given by:

\[ \frac{R_F}{A_P} = D_P \times Y_b \times 0.8 \times \frac{A_P}{A_D} \]

Where:

\[ R_F = \text{revenue from not planting} \]
\[ A_p = \text{acreage diverted}, \]
\[ Y_b = \text{established farm yield per acre}, \] and
\[ A_P = \text{acreage planted}. \]

Expressing this in per bushel terms yields:

\[ PR = D_P \times 0.8 \times \frac{A_P}{A_D} = 0.1 \times 0.8 \times 10 = \$0.80/\text{bu}. \]

Where:

\[ PR = \text{the per bushel diversion payment rate in \$ per bu.} \]

In 1978, a 10 percent set aside was required for program participation with limited compliance and so the Effective Diversion Rate was

\[ DR_1 = w \times PR_1 = \frac{A_D}{A_T} \times \frac{A_P}{A_D} = 0.091 \times 0.80 \]
\[ = \$0.073/\text{bu}. \]

Where:
\( \text{DP}_1 \) = the partial compliance diversion payment rate, \\
\( \text{w} \) = the proportion of area diverted (= 0.1 ac set aside per 1.0 ac. planted), and \\
\( \text{A}_T \) = total area (= \( \text{A}_D + \text{A}_p \)).

In the Full Compliance case, an additional area equal to 10 percent of the area planted was diverted, leading to a total reduction equal to 20% of the area planted, i.e., 2 acres in 12 had to be diverted. This option provided target price coverage on 100 percent of planted acreage plus a direct cash payment of $0.20 per bushel on planted acreage.

The returns from full compliance consisted of the direct cash component plus the opportunity cost of nonparticipation. Total revenue from participation was given by:

\[ R = \text{D}^*_p \cdot \text{Y}_b \cdot \text{A}_p + \text{D}_p \cdot \text{Y}_b \cdot \text{A}_p \]

Where:

\( \text{D}^*_p \) = direct cash payment on a planted acreage basis ($0.20)

\( \text{D}_p \) = expected deficiency payment on planted acreage ($0.10)

On a per bushel basis:

\[ \text{PR}_2 = (\text{D}^*_p + \text{D}_p) \cdot \frac{\text{A}_p}{\text{A}_D} = (0.2 + 0.1) \cdot 5 \]

Thus,

\[ \text{PR}_2 = 0.30 \times 5 = 1.50/\text{bu.} \]

Calculating \( \text{DP}_2 \) by considering the reduction in area possible under the diversion program yields:
\[ DP_2 = w \cdot PR_2 = \frac{A_D}{A_T} \cdot PR_2 = \frac{0.2}{1.2} \cdot PR_2 = \$0.25/\text{bu.} \]

The final diversion payment (CEDR) used was obtained by averaging the two options:

\[ CEDR_{78} = \frac{1}{2} \cdot DP_1 + \frac{1}{2} \cdot DP_2 = \$0.162/\text{bu.} \]

For the 1979 crop, the program conditions were the same as for 1978, except that the values of the Target Price, Loan Rate and Diversion Payments were altered. Thus, for a 10 percent set aside:

\[ DP_1 = P_T - P_L = \$2.20 - 2.10 = \$0.10/\text{bu.} \]
\[ PR_1 = \frac{D^*}{P_R} \cdot 0.8 \cdot \frac{A_P}{A_D} = 10 \cdot 0.8 \cdot 10.0 = \$0.8/\text{bu.} \]
\[ DP_1 = w \cdot \frac{A_D}{A_T} \cdot PR_1 = 0.091 \cdot 0.8 = \$0.073/\text{bu.} \]

For a 20 percent set aside:

\[ PR_2 = (DP^* + D) \cdot \frac{A_P}{A_D} = (0.1 + 0.1) \cdot 5 = \$1.00 \]
\[ DP_2 = w \cdot PR_2 = \frac{0.2}{1.2} \cdot 1.00 = \$0.167/\text{bu.} \]

The value of CEDR was again obtained by taking the simple average of \( DP_1 \) and \( DP_2 \). Thus:

\[ CEDR_{79} = \frac{1}{2} \cdot (0.073) + \frac{1}{2} \cdot (0.167) = 0.12 \]

The value of RCEDR was then obtained by deflating (CEDR) by the index of prices paid by farmers (PPEX). Thus:
RCEDR = CEDR/PPEX * 100

RCESP: Real corn effective support price, $/bu.

The nominal effective support price for corn, CESP, was also calculated using the methodology developed in the series of studies beginning with Houck and Subotnik [1969] and including Houck and Ryan [1972], Ryan and Abel [1976] and Houck, et al. [1976] and Gallagher [1978].

For the sample years 1962 to 1965, price support payments were available on the area planted on farms in compliance with the conditions of the program. During this period, any direct payment made for "income support" provided an incentive to increase the area planted. Beginning in 1966, however, the price support payments ceased to be related to planted acreage [Houck et al., 1976, p. 12]. In 1966 and subsequent years, price support payments were no longer related to planted area, but instead to a fixed percentage of each farm's base area. This change altered the effect of the price support payments since it removed their price increasing effect at the margin. For 1966 and subsequent years, the price support payments and the target price protection provisions which replaced them after 1973 [Cochrane and Ryan, 1973], were included in the diversion payment variable, CEDR.

Up to the 1973 crop year, the effective support price variable was basically calculated using the following formula provided by Houck, et al. [1976, p. 13]
Where:

\[ PF = r \cdot PA = \left[ \frac{1}{2} \left( \frac{A_{\min}}{A_o} + \frac{A_{\max}}{A_o} \right) \right] PA \]

PA = announced support price for corn

\( A_o \) = base acreage for a particular farm

\( A_{\min} \) = minimum acreage allowable under the program

\( A_{\max} \) = maximum acreage allowable under the program

\( r \) = the adjustment factor reflecting the acreage restrictions in the program, equals 1.0 if no restrictions, 0.9 if 10 percent set aside, etc.

For 1974 and subsequent years, the price support payments were replaced by target price guarantees. Under these arrangements, supplementary payments are provided for producers as long as the average market price received by producers in the first five months of the marketing year falls below the pre-established target price. In this event, a payment equal to the difference between the target price and the higher of the loan level or the average market price, is made to eligible producers.

For 1974 and subsequent years, CESP was calculated by taking a weighted average of the target and loan rates. The weights reflect the fact that target price coverage is only available on 80 percent of a participant's planted acreage, unless the additional, voluntary acreage reduction is undertaken [Fulton, 1981, p. 14].
CESP = 0.8 * TP + 0.2 * LR

Where:

TP = the target price for corn provided under the feed grain program, and

LR = the loan rate provided under the program.

Finally, RCESP was obtained by deflating CESP by the farm price deflator, PPEX.

RINT: Estimated one-period-ahead real rate of interest, percent.

Given the very rapid rate of inflation observed during part of the sample period, it was felt that the nominal rate of interest would not be a suitable indicator of the real opportunity cost of capital. To overcome this problem, the RINT variable was derived to estimate the expected real rate of interest, i.e., the nominal rate of interest minus the expected rate of inflation in the CPI.

A number of approaches to obtaining an expected rate of inflation have been proposed. One such approach is to assume that expectations about the inflation rate are formed adaptively. This approach is equivalent to the assumption of rational expectations about the inflation rate only if the inflation rate can be characterized as a first order Moving Average process in the first differences [Nelson, 1975, p. 558]. An approach more consistent with the concept of rational expectations as defined by Muth [1961] is the use of a more general ARIMA process to model expectations about the rate of inflation.
In this analysis, the rate of inflation in CPU was modeled using Bo-Jenkins time-series techniques in a manner similar to Kreicher [1981]. The interest rate used was the bank prime rate, INT3. The inflation rate was first transformed into its first differences in order to obtain a stationary series. The estimated predictive equation was a third order moving-average model:

\[ w_t = 0.055 - 0.251 * e_{t-1} - 0.286 * e_{t-2} + 0.594 * e_{t-3} \]

\[ (0.17) \quad (0.093) \quad (0.0918) \quad (0.097) \]

\[ Q_{24} = 23.29 \]

Where:

- \( w_t = \text{INFL}_t - \text{INFL}_{t-1} \)
- \( e_t \) = the error term in this equation

and figures in parentheses are standard errors

This equation was used to obtain one-period ahead forecasts of the inflation rate, PIE. RINT was then calculated as the difference between INT3 and the forecast of the inflation rate

\[ \text{RINT} = \text{INT3} - \text{PIE} \]

RSBPML: Average U.S. price received by farmers for soybeans in the year up to planting, deflated by PPEX to 1977 values, $/bu.

This variable was calculated as the average of the soybean price in the current quarter and three lagged quarters, deflated by the value of PPEX in this quarter. Thus:

\[ \text{RSBPML} = (((\text{SBP} + \text{SBPL} + \text{SBPL2} + \text{SBPL3})/4)/\text{PPEX}) \times 100 \]
<table>
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<th>OASIS logical group</th>
<th>Periodicity(^d) in OASIS</th>
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\(^d\)A denotes annual data. Q denotes quarterly data. M denotes monthly data.
Table A.4 (continued)

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APPENDIX B. A METHODS NOTE ON THE CALCULATION OF EIGENVALUES FOR A LINEAR MODEL DEVELOPED IN THE SAS/ETS SYSTEM

The coefficients of a linear model developed in the SAS/ETS system are stored in a special (TYPE = EST) SAS data set [SAS, 1980, p. 124]. Since SAS procedures cannot be used to calculate the eigenvalues of anything other than a symmetric matrix [Barr, et al., 1979, p. 286] the reduced form matrix must be output from SAS for analysis using other software. The purpose of this appendix is to explain the procedure used in this study. It is hoped that this will provide guidance to other researchers wishing to calculate eigenvalues for a model developed in SAS.

Using the notation of the SAS/ET manual, the deterministic model can be written:

\[ GY_t + CY_{t-1} + BX_t = 0 \]  

(B.1)

Where:

- \( G \) is a \( p \times p \) matrix of coefficients on the \( p \) endogenous variables,
- \( Y_t \) is a \( p \times n \) matrix of current-period endogenous variables,
- \( C \) is a \( p \times q \) matrix (\( q < p \)) of coefficients on lagged endogenous variables,
- \( Y_{t-1} \) is a \( q \times n \) matrix of lagged endogenous variables.
- \( B \) is a \( p \times r \) matrix of coefficients on the \( r \) exogenous variables, and
- \( X_t \) is an \( r \times n \) matrix of the exogenous variables.
The model must already have been transformed by use of artificial variables [Baumol, 1970, p. 333] so that it contains only lags of order 1. In the SAS TYPE = EST data set used, the coefficient of the normalized variables is written as -1 so the coefficient matrix is in the same form as equation B.1. The coefficients in this special data set are named for the variables with which they are associated.

As noted in Chapter VI, we do not need to consider the $B$ matrix associated with the exogenous variables since we are only interested in the homogeneous version of the model. Therefore, for calculation of the eigenvalues, we are concerned only with matrices $G$ and $C$. The calculation of the eigenvalues involves three steps: (1) calculation of the reduced form matrix, (2) outputting this matrix onto an OS file accessible to a suitable subroutine (e.g., IMSL), and (3) calculation of the eigenvalues. For this study, the three steps were each done separately and sample programs for the analysis are given in Tables B.1, B.2, and B.3.

The first step can be performed within SAS using PROC MATRIX. The columns of the coefficient matrix corresponding to the current endogenous variables can be kept in a smaller data set and then fetched into a matrix. This matrix should automatically be square with one row for each equation, and one column for each endogenous variable. The matrix and its associated column names should be printed out to inspect the order of its columns, which will be crucial at a later stage.
The matrix of coefficients on the lagged dependent variables should be formed from a subset of the coefficients in a similar way. The data set will contain one row for each equation but will probably not include as many columns as there are rows. Before going into PROC MATRIX, the additional columns needed to obtain a square coefficient matrix should be added by defining a lag for each endogenous variable whose lag does not already appear in the model. These lags should be set equal to zero as has been done in Table B.1.

Once the matrices $G$ and $C$ have been obtained, PROC MATRIX can be used to solve for the reduced form matrix:

$$\pi = - G^{-1} \cdot C$$  \hspace{1cm} (B.2)

Where:

$\pi$ is the reduced form matrix for the lagged endogenous variables.

The matrix $\pi$ can be converted into a SAS data set, with column names retained from the original matrix. The order of the variables in this matrix will depend upon the arrangement of the columns of matrix $G$. The arrangement of these columns was not important in the calculation of $\pi$ because the elements of a column of $\pi$ depend upon only one column of $C$. However, the columns of $\pi$ must be arranged in the order of the variables in the original $G$ matrix in order to obtain a matrix which is arranged correctly for calculation of the relevant eigenvalues.

The arrangement of the columns of $\pi$ can be implemented with a SAS PUT statement at the time that the matrix is written out to an OS file.
Table B.1. An SAS program to calculate and output the reduced form matrix for the lagged endogenous variables

```sas
//EH73PSAS JOB 15695, WBM, MSGLEVEL=(1,1)
//SI EXEC SAS, REGION=640K
//WJEM DD DSN=W*U4327.WMDAT. THEISIS.UNIT=DISK. DISP=OLD
//SAS* SYSin DD */
* A MATRIX PROGRAM TO ANALYSE THE VERSION OF MODEL57 WITH ONLY 73 EQNS;
DATA X;
SET WJEM.MODEL57;
* SETTING UP A DATA SET CONTAINING THE REGULAR ENDOGENOUS VARIABLES:
KEEP AU BBS BCOWSF BCOWSFM BINV CBS CHFP CHPDNL CWPL FSHBS
    HBR HMKT HDP ICT KC KFC MCN MPB MPK NFSFBS PCB PCN PF PFL23
    PGB PKNV PKS PPK PTB RBSP RBSPA RBSPAL RFCNPL RFPPK RFSP
    RPCN RPCORN RPG8 RPPK RPTB SC STP TCWS WRBSPA XCN XCN:
    XDC XPB XPCX XPK XT B XTBC:
PROC TRANSPOSE OUT=X2;
PROC TRANSPOSE OUT=X3;
BY _NAME_; PROC SORT DATA=X2 OUT=X3;
PROC TRANSPOSE OUT=X4;
PROC MATRIX;
FETCH A1 DATA=X4 COLNAME =NAME1;
* BRINGING IN THE ARTIFICIAL VARIABLES:
FETCH A2 DATA=WJEM.MODEL57 (KEEP =BHRL EKFCL BKFCL2 BPFL BPFL2
    BRBSPL
    BRBSPL2 BRBSPL3 BRBSPL4 BRBSPL5 BRBSPL6 BSCL BSCL2 BSCL3
    BKCL EKCL2 BKCL3) COLNAME =NAME2;
* CREATING THE MATRIX G OF ENDOGENOUS COEFFS BY CONCATENATION:
    GM=A1][A2;;
    GN=NAME1||NAME2;
    PRINT GM COLNAME =GN;
    OUTPUT GM OUT=OATAGM COLNAME=GN;
* BRINGING IN THE REGULAR LAGGED ENDOGENOUS VARIABLES;
DATA Y1;
SET WJEM.MODEL57;
* COMMENT BCOWS IS THE LAG OF BCOWSF;
KEEP BCOWS BCOWSFHL BINVL CHFPL CHPDNL CWPL HBRL HMKT HDP
    ICTL KCL KFCL PFL PKNV PKS PPK PTB RBSP RBSPA RFCNPL RFPPK
    RPCORN RFCORN SCL
STPL;
DATA Y;
SET Y1;
```
Table B.1 (continued)

*ADDDING IN THE FO LAGS OF ALL ENDOG VBLKS TO BRING THE MATRIX TO SQUARE;
AULC0; BBGLC0; CBGLC0; CSCLC0; FSBBCLC0; MCSC0; MCNC0; MPBLC0;
NPKL0; NSBBSC0; PBC0; PCNC0; PFL22LC0; PGBLC0; PKL0;
PPCLC0; PTBL0; RBBBL0; RBBPL0; RBSPALL0; RFBP0; RFCNL0;
RPGBN0; RPBL0; RPTBL0; TCWSSL0; WRBBPL0; XCNCL0; XCNCL0;
XDBC0; XPC0; XPCBL0; XPCCL0; XTB0; XTBCL0;

PROC MATRIX;
FETCH B1 DATA =Y4 COLNAME =YNAME1;
*BRINGING IN THE COUNTERPART LAGS OF THE ARTIFICIAL VARIABLES:
FETCH B2 DATA =WJEM.MODEL57(KEEP=HBRL2 KFCL2 KFCL3 PFL2 PFL3
RBSP2 RBSP3 RBSP4 RBSP5 RBSP6 RBSP7 SCL2 SCL3 SCL4
KCL2 KCL3 KCL4) COLNAME =YNAME2;
*CREATING THE MATRIX C OF ALL LAGGED ENDOGENOUS VARIABLES IN SEQUENCE;
CM=B1||B2;
CN =YNAME1||YNAME2;
PRINT CM COLNAME =CN;
FETCH GM DATA=DATAGM;
RFORM=SOLVE (GM,CN);
RFORM= - RFORM1;
OUTPUT RFORM OUT=WJEM.RFORM COLNAME =CN;
PROC PRINT DATA=WJEM.RFORM;
//
Table B.2. An SAS program to write the reduced form matrix to an OS file

//D231 JOB UXXXX.WBM.MSGLEVEL=(1,1)
//*WEXEC SAS
//WXEM DD DSN=W.U4327.WMDAT.THEISIS,UNIT=DISK,DISP=OLD
//RFORM DD DSN=W.U4327.EIGEN,UNIT=DISK,
// VOL=SER=EHOOO1,DISP=(*,CATLG),DCB=(RECFM=FB,LRECL=400,
// BLKSIZE=6000),SPACE=(TRK,(4,2),RLSE)
//SAS.SYSIN DD *
*WRITING THE REDUCED FORM TO AN OS FILE ;
* THE ORDER OF THE LCD ENDOGENOUS VBLS IN THE PUT STATEMENT MUST
CORRESPOND WITH THE ORDER OF THE ENDOGENOUS VBLS IN THE 6 MATRIX;
DATA X;
FILE RFORM NOTITLES:
PUT (AUL BBSL BCOWSFH BINVLC BSL CFPL CHPDNL CSL CKPL
FSHBSL HBRL HMKTIL HODPL ICTL KCL KFCL MCBL MCNL
MPBL MPKL NFSHBSL PCLP PCNL PFL PFL23 PGBK PKINVL PKSL
PPKL PIBL RBGPL RBSPL RBSPLA RBSPLALL RFNPPL RSPPKL RFSPPL RPCNL
RPCORNL RPKGBL RPKKL RPKBL SCL STPL TCOFSL WRBSPL XCNCL XCNL
XDEL XPBCS XPBLC XPKCL XPKCL XTBC XTBK XTBK BLRL2 KFCL2 KFCL3
PFL2 PFL3 RBSPL2 RBSPL3 RBSPL4 RBSPL5 RBSPL6 RBSPL7 SCL2 SCL3
SCL4 KCL2 KCL3 KCL4) (E22.15);
*READING IN THE DATASET TO SEE IF IT IS OK;
DATA ECHO;
INFILE RFORM;
INPUT (LAG1-LAG73) (E22.15);
PROC PRINT DATA=ECHO;
Table B.3. A Fortran program to calculate the eigenvalues of the reduced form matrix

```fortran
//D231 JOB UXXXX, WILL, MSGLEVEL=(1, 1)
//S1 EXEC FORTGCLG, D=DOUBLE, REGION, GO=256K
//FORT, SYSIN DD *
INTEGER N, IA, IJOB, IZ, IER, VAR, LAG
REAL*8 A(73, 73), WK(73), RW(146), RZ(292)
COMPLEX*16 W(73), Z(73), Z(73, 73)
EQUIVALENCE (W(1), RW(1)), (Z(1), RZ(1))

IA = 73
IZ = 73
N = 73
IJOB = 0

C READING THE INPUT MATRIX A
DO 10 VAR = 1, 73
    READ(10, 11) (A(VAR, LAG), LAG = 1, 73)
    WRITE(6, 12) (A(VAR, LAG), LAG = 1, 73)
11 FORMAT (18(E22.15), /, 18(E22.15), /, 18(E22.15), /, 18(E22.15), /, 18(E22.15), /, 18(E22.15), /, 18(E22.15), /

C/, 1(E22.15))
10 CONTINUE

CALL EIGRF(A, N, IA, IJOB, RW, RZ, IZ, WK, IER)

DO 30 I = 1, 73
    WRITE(6, 112) W(I)
30 CONTINUE

C FORMAT (', *, 5X, 'AN EIGENVALUE-REAL THEN IMAGINARY PART', 5X, F8.5, 5X, F8.5)
112 FORMAT (', *, 5X, 'AN EIGENVALUE-REAL THEN IMAGINARY PART', 5X, F8.5, 5X, F8.5)

STOP
END
//GO. FT10F001 DD DSN=W.U4327.EIGEN,
// UNIT=DISK, VOL=SER=EH0001, DISP=SHR
```
A simple SAS program can then be used to output the $\pi$ matrix from the SAS data set to an OS file in a standard Fortran format, such as E22.15 used in the example given in Table B.2.

Finally, a numerical analysis program can be used to calculate the eigenvalues. This calculation should be done in extended precision to avoid rounding errors in approximating the roots of the characteristic polynomial. An example of a program to calculate the roots using the EIGRF subroutine of IMSL is given in Table B.3.