AN ABSTRACT OF THE THESIS OF

TIMOTHY DOUGLAS MOUNT for the M. S. in AGRICULTURAL ECONOMICS.

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Title AN ANALYSIS OF THE PRESENT AND FUTURE MARKET FOR LAMB WITH PARTICULAR REFERENCE TO OREGON.

Abstract approved ____________

The purpose of this study was to evaluate the demand and price characteristics for lamb in the US and Oregon. The primary objective was to estimate coefficients for three variables in a demand function for lamb, and these variables were the production of lamb, the production of substitute meats, and an income factor. Two secondary objectives were to determine the influence of imported mutton on the price of lamb, and to consider the future trend in the price of lamb.

The analysis consisted of two parts, the development of a single equation demand function for lamb and the formation of a structural model of the sheep industry. In both cases the price of lamb was taken as a dependent variable, and price flexibility coefficients were estimated for the other variables. The flexibility coefficient for the production of lamb was estimated to be -0.88 in the single equation
and -1.22 in the structural model. The structural flexibility was considered to be the best estimate as the validity of this coefficient did not depend on the assumption that the quantity of lamb produced was determined independently of the price. There were indications that the current price of lamb did influence the quantity produced. The conclusion reached was that the price was slightly flexible to changes in lamb production. The flexibility coefficient for the production of substitute meats was -1.11 in the single equation and -1.18 in the structural model. The high flexibility coefficient indicates that the level of production of substitute meats is important in determining the price of lamb. The flexibility coefficient for the income variable was +0.20 in the single equation and +0.42 in the structural model. Both estimates show a positive inflexible relationship with the price.

To evaluate the impact of imports on the price of lamb it was found necessary to estimate the annual production of mutton in the US, as no data give this information directly. A variable for the total quantity of mutton was included in the single equation demand function. The price decline associated with the increase of imports was estimated to be small. Although the total quantity of mutton increased by 39 percent between 1958 and 1959, over 93 percent of the decline in price was attributed to other variables.

The flexibility coefficient for the production of lamb in Oregon was estimated to be -0.54. This indicates a greater inflexibility of
the lamb price than was found for the US. A higher flexibility of the price was associated with the production of lamb in California. This indicated that California provides an important outlet for the marketing of lamb from Oregon.

The production of substitute meats and the income variable have expanded consistently throughout the period of the analysis. The net effect of these two variables was estimated from the structural model to cause a decrease in the price of lamb of $0.67/cwt each year. However, the model indicates that producers tend to reduce the size of the breeding flock in response to a decline in price. This reduction and the decrease in the size of the lamb crop that would follow are expected to partially offset the price decline. The conclusion reached is that lamb prices can only be maintained at the present level if the size of the breeding flock decreases.
AN ANALYSIS OF THE PRESENT AND FUTURE MARKET FOR LAMB WITH PARTICULAR REFERENCE TO OREGON

by

TIMOTHY DOUGLAS MOUNT

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I wish to thank all the members of the Extension Agricultural Economic Information at Oregon State University, and in particular Mrs. Elvera Horrell and Professor S. C. Marks for their cooperation in providing much of the data used in this study. I also appreciated the help received from the secretarial staff and the graduate students of the Department of Agricultural Economics in the preparation of the final draft of the thesis.
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AN ANALYSIS OF THE PRESENT AND FUTURE MARKET FOR LAMB WITH PARTICULAR REFERENCE TO OREGON

CHAPTER I

INTRODUCTION

The annual consumption of lamb in the US, which in recent years has been about five pounds per capita, is small compared with the consumption levels of other meats. The annual consumption of beef has been over 80 pounds per capita since 1954, and in 1964 reached 100 pounds per capita. Pork consumption per capita is lower than that of beef but has been consistently over 60 pounds each year (37). Lamb consumption is also relatively low when compared with certain other countries, as in the UK annual consumption is about 25 pounds per capita and in Australia and New Zealand it is over 90 pounds per capita (9, p. 50). Even so, in certain regions of the US lamb is consumed fairly extensively, and in other areas sheep production provides an important source of revenue for livestock producers. In particular, sheep production is concentrated in the western states, and in Oregon there are indications that the importance of sheep production is increasing.

Few studies in recent years have been concerned specifically with the sheep industry. Two studies for the American Sheep Producers Council, Inc. are cited in the bibliography (3; 27). The
general conclusions reached in these studies in connection with the marketing of lamb are that the availability of lamb must improve if the relative size of the sheep industry is to be maintained. There are indications that promotional programs may result in larger sales of lamb being made through the stores connected with the programs (22). In this study the characteristics of the demand for lamb in the US are investigated.

The purpose of this study is primarily to determine and evaluate the factors that influence the demand and prices of lamb in the US. Two other secondary objectives are to assess the impact of imported meat on the price of lamb and also to determine the possible future trends of lamb prices. To do this, coefficients are estimated in a single equation demand function to show the influence of three variables on the price of lamb. These variables are the production of lamb, the production of substitute meats, and an income factor, and the demand function is developed in Chapter V.

The recent increase in the quantity of mutton imported is responsible for considerable interest developing in connection with a possible decline in the price of lamb resulting from the increased imports. Data available on the production of mutton are very limited, as most information on the quantity of mutton is combined with the quantity of lamb to form a single variable. However, estimates are made of the slaughter of lambs and the slaughter of sheep, and are
used to estimate the decline in the price due to importing mutton. These estimates though are subject to limitations that are described in Chapter V.

Evidence is given in Chapter VI that questions the validity of certain assumptions that are made in the formation of the single equation demand functions. For this reason a structural model of the sheep industry is developed to provide more reliable estimates for the coefficients of the variables in the single equation model. The structural model also provides considerable information on the supply functions for the sheep industry.

The following two chapters are devoted to a discussion of the position of sheep production in the meat industry, and an analysis of the trends in production and prices for the different meats both in the US and in Oregon. Chapter IV gives an outline of the basic theory covered in the formation of a statistical model of a demand function and is concerned primarily with the problems of aggregating data.
2.1 Trends in US Meat Production

The total production of "red meat" in the US, which in this study includes beef, veal, pork, lamb and mutton, has increased considerably since 1945. However, the trends in production of each type of red meat have differed markedly from each other.

The production patterns of the four red meat industries, over the period 1945 to 1963, are illustrated in Figure I. In this graph the quantity produced is plotted on a logarithmic scale against time, so the fluctuations from year to year represent percentage and not absolute changes in production. This approach is used frequently in this study as it enables a better visual comparison to be made between the industries when assessing the importance of changes in production within each industry. Figure I shows that beef production has accounted for the majority of the increase of red meat. Pork production has also increased slightly, but veal, and lamb and mutton production have decreased from the 1945 levels. A simple linear regression of red meat production against time supports these statements, and the results of this analysis are shown in Table I. The average changes in production of all the red meats are statistically significant in the direction indicated by the sign in column 2, except for the decrease of
Figure I. Production in U.S. of Red Meat - Source - (37) Table 113-14
lamb and mutton which is not significantly different from zero. (In the remainder of this study the term "significant" will be used only to infer statistical significance.) In the cattle industry, the increase in beef production has more than offset the decrease of veal production. Production in the hog industry has also increased, but in the sheep industry no significant change in output has occurred. This situation has led to a decline in the importance of lamb and mutton in the red meat industry. Each year the proportion of the total output of red meat made up by lamb and mutton has fallen by an average of 0.065 percent a year, and this is significant at the 0.5 percent level. This emphasizes the point that lamb and mutton production has not kept up with the expansionary trends of the red meat industry since 1945.

Table I. Changes in The Production of Meat 1945-1963.

<table>
<thead>
<tr>
<th>Type of Meat</th>
<th>Av. Change/year of production million lbs</th>
<th>Calculated value of F statistic</th>
<th>Av. production per year million lbs</th>
<th>Av. production per year as % of total red meat production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>+409.56</td>
<td>82.65**</td>
<td>12,257</td>
<td>48.43</td>
</tr>
<tr>
<td>Pork</td>
<td>+ 72.97</td>
<td>7.90*</td>
<td>10,980</td>
<td>43.38</td>
</tr>
<tr>
<td>Veal</td>
<td>- 26.88</td>
<td>9.20**</td>
<td>1,323</td>
<td>5.23</td>
</tr>
<tr>
<td>Lamb &amp; Mutton</td>
<td>- 2.91</td>
<td>0.31°</td>
<td>748</td>
<td>2.96</td>
</tr>
<tr>
<td>Total Red Meat</td>
<td>+452.75</td>
<td>68.26**</td>
<td>25,308</td>
<td>100.00</td>
</tr>
</tbody>
</table>

** Significant at 0.5% level
* Significant at 1.0% level
° Not significant
In a U. S. D. A. bulletin on meat consumption (40, p. 31), a projection of the future trend in the consumption of all red meats is made based on a study by R. F. Daly in 1957. This study was extended in 1960 by the staff of Resources for the Future, Inc. to cover the period 1954 to 1980 based on 1960 prices. The conclusions from this analysis were that the consumption of all food would increase by 11 percent in this period, and in particular the consumption of red meat would increase by 16 percent. This suggests that the meat industry will take on an increasingly important position in the total production of food in the US, and that the expansionary trend of meat production will probably continue. The McKinsey Company, Inc. (27) have recommended that the policy of the American Sheep Producers Council, Inc. should be to maintain the relative size of lamb and mutton production in the red meat industry.

2.2 Production of Lamb in The US 1945-1963

The average annual production of lamb and mutton from 1945 to 1963 has been almost 750 million pounds, but this makes up less than three percent of the average total production of all red meat in the US. In Table I the average production per year of the different meats is shown by weight and as a percentage of the total red meat production. The cattle industry accounts for more than 50 percent, and the hog industry for well over 40 percent of the red meat produced. The
lamb industry forms only a minor part of the red meat industry, and a large percentage change of output in the lamb industry of, for example, 20 percent would alter red meat production by only 0.59 percent. The very limited effect that normal fluctuations in lamb production have on the whole meat industry is used in Chapter V to justify making assumptions that simplify a statistical model of the lamb industry.

The production pattern of lamb and mutton during the period studied is shown in Figure I. The highest output of 1054 million pounds was achieved in 1945, but during the next six years this declined considerably, so that in 1951 production was only 521 million pounds or half the 1945 level. Production has gradually expanded since then to over 800 million pounds in 1961, but the production levels of the war years have not been repeated. The production of lamb and mutton has been taken as a combined total in the previous discussion, but in the later analyses lamb and mutton production are considered separately.

The most important factor limiting lamb production is now discussed, and this is the size of the lamb crop. The number of stock ewes over one year old reported for the January 1st inventory is taken as a rough indicator of the potential size of the lamb crop. For the 1945-1963 period a linear regression against time shows a significant decline in the number of stock ewes ($F = 7.2338$, significant at 0.5 percent) of over a quarter of a million head each year, or an average
loss of 1.19 percent per year of the average potential lamb crop. This is three times as great as the decline in sheep and lamb production shown in Table I. However, most of this difference can be explained by an increase of the lambing percentage, which is the number of lambs saved for every hundred stock ewes over one year old. The lambing percentage has risen significantly ($F = 39.9323$, significant at the 0.5 percent level) by an average of 0.60 lambs/100 ewes each year. Although the improvement of the lambing percentage explains much of the difference in the trends between the production of lamb and mutton and the number of stock ewes, the actual production of lamb each year is not exactly proportional to the size of the lamb crop potential for two reasons:

1. The lambing percentage varies from year to year with the different environmental conditions.

2. The proportion of the lamb crop that is slaughtered also varies. (The factors influencing this proportion are discussed more fully in Chapter VI.)

Not all the sheep and lamb consumed in the US are home produced, and in recent years an increasing quantity of lamb and mutton has been imported, predominantly from Australia and New Zealand. This increase resulted partly from a relaxation of trade agreements by these countries with the UK in 1958. Between 1945 and 1958 the meat imported each year accounted for less than one percent of the total quantity of lamb and mutton available in the US except for one
year, 1951; and in this year production in the US was unusually low (Figure I). After 1958, the proportion of imported lamb and mutton has risen to make up nearly 20 percent of the US commercial production, and this is shown in Figure II.

A recent U. S. D. A. publication by G. R. Rockwell (33, p. 28) shows that the majority of this imported meat is mutton and not lamb. The quantities of lamb and of mutton imported are shown in Table II, and the proportions of lamb and of mutton are also given as percentages of the combined total imported. Except for 1958, mutton has made up over 85 percent of the imported lamb and mutton. In Chapter V an estimate of the mutton produced in the US is made, and this indicates that in some of the years since 1958 imported mutton has made up over one third of the total quantity of mutton available in the US. The impact of imported lamb and mutton on the farm price of lambs in the US is discussed in Chapter V.

2. 3 Regional Distribution of Stock Ewes In The US

Although the number of stock ewes has declined in the US since 1945, there has been no marked change in the regional distribution of the stock ewes found in the broad geographical zones considered in Figure III. This histogram shows the percentages of the total ewe flock found in five regions of the US averaged over five year periods. The importance of the Western States for the potential lamb crops is
Figure II. - Imports of Lamb and Mutton into the U.S.
Source (33) Table H

Table II. Proportions of Lamb and Mutton Imported into U.S.

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity of lamb imported</th>
<th>Quantity of mutton imported</th>
<th>Total import of lamb and mutton</th>
<th>% of imports from lamb</th>
<th>% of imports from mutton</th>
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<tr>
<td>1958</td>
<td>6.8</td>
<td>34.3</td>
<td>41.1</td>
<td>16.55</td>
<td>83.45</td>
</tr>
<tr>
<td>1959</td>
<td>9.5</td>
<td>94.7</td>
<td>104.2</td>
<td>9.12</td>
<td>90.88</td>
</tr>
<tr>
<td>1960</td>
<td>12.4</td>
<td>74.6</td>
<td>87.0</td>
<td>14.25</td>
<td>85.75</td>
</tr>
<tr>
<td>1961</td>
<td>10.9</td>
<td>89.8</td>
<td>100.7</td>
<td>10.82</td>
<td>89.18</td>
</tr>
<tr>
<td>1962</td>
<td>13.2</td>
<td>130.0</td>
<td>143.2</td>
<td>9.22</td>
<td>90.78</td>
</tr>
<tr>
<td>1963</td>
<td>18.9</td>
<td>125.7</td>
<td>144.6</td>
<td>13.07</td>
<td>86.93</td>
</tr>
</tbody>
</table>

Source (33) Table H
Figure III. Distribution of U.S. Stock Ewes

Source (39)
clear from Figure III as almost half of the average 20 million stock ewes in the US are found in the 11 Western States—Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Washington, Oregon, and California. The South-Central region has over 20 percent of the stock ewes and most of these are found in Texas. The next most important region is the West North-Central which has expanded slightly in relative importance since 1945 to account for 20 percent of the ewe flock. In contrast the East North-Central region has less than ten percent, and the Atlantic Seaboard less than three percent of the total ewe flock.

Although no major change in the regional pattern of the ewe flock is apparent, certain minor alterations have occurred. In a report by the McKinsey Company, Inc. (27) a decline in the importance of the Texas ewe flock between 1945 and 1950 is attributed to the movement of flocks off the ranges. Other authors have also implied a decline in the large range flocks, which, according to H. B. Pingrey (30, p. 19), accounted for over half the US lamb production in 1955. In the same paper Pingrey noted in particular a considerable fall in the number of sheep found on the eastern plains of Montana and also on south eastern sagebrush area of Oregon. One of the reasons given for this was the change from sheep production to cattle production in these areas. In another paper J. E. Miller and J. H. Winn (28, p. 5) noted a considerable decline in the average size of the Texas ewe
This implied movement of sheep off the ranges may be expected to increase competition for the sheep industry, as with the smaller farm flocks there are probably more alternative enterprises that can be used to replace sheep production. This trend would be expected to change the price elasticity of supply for sheep and lamb as producers would tend to respond to a cut in the price of lamb with a greater reduction of output of lamb if a larger number of substitute commodities could be produced. A further analysis of the movements of sheep off the ranges is not made in this study, but the possible consequences are discussed in the concluding chapter.

2.4 Regional Distribution of The Lamb Industry in The US

The pattern of production of sheep and lamb in the US is very similar to the distribution of stock ewes shown in Figure III. However, the pattern of slaughter and consumption differ considerably from the production pattern, and this is illustrated clearly in Figure IV. In all regions except the West North-Central the percentage slaughter forms a transition between production and consumption, and in this area the high slaughter percentage is probably explained by the shipping of sheep and lambs live from Texas and the Western States.

Available data on consumption is very limited and the percentages
Figure IV - Regional Distribution of Lamb Industry
used in Figure IV are based on a U. S. D. A. survey in 1954 reported on by H. O. Doty, Jr. (11, p. 4). This survey indicated that over half the total consumption of lamb and mutton in the US occurs in the Atlantic Seaboard region and most of this in the north-eastern section (Figure V column 3). The Western States also have a high consumption of over 25 percent of the total and consumption in the East North-Central region accounts for almost 15 percent of the total. However, the South Central and the West North-Central regions, although together producing over 40 percent of the lamb and mutton, consumed less than a sixth of this quantity.

This pattern of consumption cannot be explained entirely by the population distribution at the time of the survey. If the consumption per capita was the same in all regions of the US, the consumption pattern would be identical to the population pattern, and this is shown for the survey year in Figure IV, column 4. The West and the Atlantic Seaboard both have a higher consumption than would be expected on this population basis, and the other three regions all have a lower consumption level.

In a more recent qualitative survey of lamb consumption made for the American Sheep Producers Council, Inc. (3, Appendix Table 1) the proportion of families using lamb is recorded for different regions in the US. The percentage of "non-users" of lamb is much higher in the central regions of the US than it is in the North Eastern States or
in the Western States. The results of this survey show that the two high consumption regions shown in Figure IV were both found to have a higher proportion of families that use lamb.

In another survey for the U. S. D. A. on the availability of lamb in the US, H. O. Doty, Jr. recorded the proportion of stores that sold meat that also carried lamb (12, p. 7). Only one-third of the stores that sold meat in the North-Central region handled lamb, and in the South less than one-fifth. This contrasted with both the Western States and also the North Eastern States where over half and nearly three-quarters respectively of the stores that handled meat also handled lamb.

Neither of the latter two studies indicate that any extensive changes have occurred in the consumption pattern for lamb since the U. S. D. A. consumption survey in 1954. It might be expected that the large increase in the population of the West Coast might have enlarged the proportion of lamb consumed in the Western States. However, part of this population increase probably resulted from the migration to the West Coast of people from central regions of the US. If these individuals were non-users of lamb, and probably a high proportion were, the quantity of lamb consumed would not be greatly effected by them. This infers that the increase of population in the west may not have resulted in a proportional increase in lamb consumption, and this may also apply to the north east region of the US. The available
data are not sufficient to make an accurate estimation of the actual number of lamb consumers in the US. This led to considerable difficulties in arriving at suitable values for the per capita consumption of lamb, and this problem is discussed more fully in Chapter IV.

2. 5 Trends in Farm Prices for Red Meat in The US 1945-1963

During the 19 year period studied, the average price received by farmers for lamb was $19.96/cwt. This price is almost identical to the average farm price for beef cattle ($19.45/cwt) for the same period, and very similar to the average price for calves ($21.69/cwt) and for hogs ($17.87/cwt). However, the average farm price of sheep was little over one-third of the lamb price ($7.60/cwt). This suggests that mutton is an inferior product to the other red meats, although part of the difference may be accounted for by a lower dressing percentage for sheep.

Figure V shows the farm prices of four types of red meat animals. (The price of calves, although slightly higher, has an almost identical pattern to the price of beef cattle and so is omitted.) The price of each meat rose considerably from 1945, and, except for hogs, continued to do so until 1951. The year-to-year prices fluctuated considerably, and for the 1945 to 1963 period only the price of hogs and sheep declined significantly with time ($F = 4.17$ and $53.80$ respectively, significant at the 0.5 percent level). However, even though the
Figure V. U.S. Farm Prices for Meat Animals ($/100 lbs.)
Source (37) Table 180/4
farm prices of lambs and beef cattle have not changed significantly, there has been an improvement of the beef cattle price relative to the lamb price. From 1945 to 1957 the lamb price was consistently greater than the beef cattle price; however, after 1957 the beef cattle price has been considerably higher. The biggest difference since 1957 between the two prices was in 1960 when the beef cattle price was $2.50/cwt higher (Figure V). This alteration in the price relationship between lamb and beef cattle is probably the main reason for the change from sheep production to beef production noted in Section 2.3.

The actual pattern of price movements for lamb, illustrated in Figure V, shows that the prices increased rapidly up to 1951, and in this year farmers received the highest price for lamb during the 19 years studied of $31.00/cwt. In 1951 the farm price of beef cattle was also very high, and this would be expected to inflate the price of lamb, assuming that lamb is a close substitute for beef. This unusually high price was followed by a general decline in the price of lamb, and this may be partly an adjustment to the normal price level of beef rather than a decline in the demand for lamb. This problem forms an important part of the analysis in Chapter V.
CHAPTER III

THE LAMB INDUSTRY IN OREGON 1945-1963

3.1 Production of Red Meat in Oregon

Production of beef cattle and calves makes up 78.25 percent of the average red meat output in Oregon over the period 1945-1963, and has also accounted for most of the increase of red meat production in the State (Table III). This is a similar pattern to the trends in red meat production found in the US (Section 2.1). In Oregon the output from the hog industry accounts for only 11.77 percent of red meat production. This results in a greater importance of sheep and lamb production in Oregon, relative to the US, and this accounted for the remaining 9.98 percent of the output of red meat. These results are summarized in Table III.

Table III. Production of Red Meat in Oregon

<table>
<thead>
<tr>
<th>Type of Meat</th>
<th>Av. change per year of production million lbs</th>
<th>Calculated value of F statistic</th>
<th>Av. production per year million lbs</th>
<th>Av. production per year as % of total production</th>
<th>Av. change per year as % of Av. production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef and Cattle</td>
<td>+10.25</td>
<td>75.02**</td>
<td>361.73</td>
<td>78.25</td>
<td>+2.83</td>
</tr>
<tr>
<td>Hogs</td>
<td>- 0.47</td>
<td>2.49**</td>
<td>54.39</td>
<td>11.77</td>
<td>-0.86</td>
</tr>
<tr>
<td>Sheep and Lamb</td>
<td>+1.98</td>
<td>9.13**</td>
<td>46.16</td>
<td>9.98</td>
<td>+4.29</td>
</tr>
<tr>
<td>All Red Meat</td>
<td>+10.43</td>
<td>78.13**</td>
<td>462.23</td>
<td>100.00</td>
<td>+2.26</td>
</tr>
</tbody>
</table>

**Significant at 0.5% level
*Not significant
Although the average increase in the output of beef and calves is 10.25 thousand pounds each year, compared with 1.98 thousand pounds from the lamb industry (both significant at the 0.5 percent level), this increase is relatively larger in the lamb industry. The cattle industry has increased by 2.83 percent per year, but the lamb industry has increased by 4.29 percent per year. This is in complete contrast to the results found for the whole US (Section 2.1). The production of hogs has not changed significantly in Oregon, and so has not exhibited the expansion found in the US.

The number of stock ewes reported for the January 1st inventory was used again as an indicator of the size of the potential lamb crop in Oregon. A linear regression with time indicated that the number of stock ewes had not altered significantly between 1945 and 1963, even though the output of sheep and lambs had increased. Again this is probably explained mainly by the improvement of the lambing percentage in Oregon.

In 1963 Oregon was the twelfth largest producer of sheep and lamb of any state accounting for three percent of the total US production (37, p. 46). This was almost one-third of the quantity produced by the largest producer state, Texas, which in 1963 made up 10.08 percent of the total US output.

The importance of the Western States for the production of sheep and lamb was emphasized in Section 2.3. Oregon has been
shown to make up an important part of this production. In fact, the sheep industry in Oregon has shown a considerable expansionary trend, and since 1959 the annual production of lamb and mutton has been larger than the production of pork. This situation contrasts with the declining importance of the sheep industry in the US (Section 2.1).

Two possible reasons for this are:

1. The production in Oregon has increased with the population expansion on the West Coast.
2. Oregon has special advantages in lamb production that enables favorable competition to take place with other states.

3.2 Farm Price of Lamb in Oregon 1945-1963

The farm price for all the red meats in Oregon follow very closely the pattern of prices for the US. The price of beef in Oregon, except for 1945, was lower than the price for lamb until 1958 and from 1958 to 1963 beef prices have been consistently higher. This is identical to the situation found in the US (Section 2.5). The improvement in the price of beef relative to lamb is probably an important reason for the beef industry having a larger expansion than the sheep industry, as cattle and sheep enterprises compete with each other for much of the pastureland in Oregon (Section 2.3).

The farm price of lamb in Oregon is very highly correlated to the US price ($r^2 = 0.97$), but since 1945 has been consistently lower than the US price (Figure VI). In contrast the farm price in California
Figure VI. Farm Price of Lamb. Source (38)
has generally been higher than the US price and as a result considera-
bly higher than the Oregon price. This can be explained after con-
sidering the results of the U. S. D. A. consumption survey for 1954
(Section 2.4). In 1954 Oregon produced 45,476 thousand pounds live
weight of sheep and lambs (equivalent to approximately 22,000 thou-
sand pounds dressed weight or three percent of the total US produc-
tion). However, consumption accounted for only 5,740 thousand
pounds dressed weight (0.8 percent of the total US consumption) (11,
p. 10 Table I), and this indicates that Oregon is a surplus producer
of lamb, as in 1954 approximately 75 percent of the production was
consumed out of the State. In contrast, California produced 115,940
thousand pounds live weight (equivalent to approximately 57,000 thou-
sand pounds dressed weight or 7.6 percent of the total US production),
and consumed 154,438 thousand pounds dressed weight (20.9 percent
of the total US consumption). This means that nearly 65 percent of
the lamb consumed in California is brought in from out of state, and
being a deficit producer, the farm price for lamb would be expected to
be larger than the average US price. Figure VI shows that after 1948
the Californian price is consistently higher than the US price, and
this provides the incentive to bring lamb into California from other
states, and also covers the extra costs of transportation. The oppo-
site is true for Oregon, and so the price of lamb tends to be below the
US average. It would be expected that much of the surplus production
of sheep and lamb from Oregon is marketed in California. The importance of influences from the conditions in the California lamb market on the farm price of lamb in Oregon is discussed more fully in Chapter V.
CHAPTER IV

THE MARKET DEMAND SCHEDULE

4.1 The Demand Curve For An Individual Consumer

This study does not contain an extensive coverage of the basic economic theory connected with consumer demand, but a simple explanation of the terms used in the subsequent analysis is made in this section. These definitions are given for an individual consumer in order to be consistent with classical micro theory.

In the classical theory of a market economy, each individual consumer is considered to have a utility function that relates the total purchase of goods and services by this individual to the level of satisfaction that results from these purchases. The size of income limits each consumer to a certain quantity of money that can be spent. This concept of the individual's utility function, limited by size of income, is used to place restrictions on the demand schedule of the consumer for a particular commodity. These restrictions, derived from the utility function, are described in detail by P. A. Samuelson (34, p. 90). The quantity, $X_i$, of a good purchased by an individual can be written as a function of the individual's income, $I$, and the prices, $P_i$, of all available products, $i$, ($i = 1, 2, \ldots, n$) so that the demand function of the individual for a given time period is:
\[ X_i = F(P_1, P_2, P_3, \ldots, P_i, \ldots, P_n, I) \]

The quantity purchased of each product is related not only to the price of the product itself, but also to the prices of the other products. A straightforward definition of the demand schedule of an individual for a single commodity is given by H. M. Riley (32, p. 9) as "a schedule of the quantities of a commodity that an individual is willing to buy at all possible prices (of that commodity), other things (in the demand function) remaining the same." The restrictions from the utility concept infer that a larger quantity of the commodity is purchased at a lower price if all the other factors are constant, or that the demand schedule slopes down to the right, as the price is traditionally measured on the vertical axis.

Two different concepts may be isolated that can account for a change in the quantity of a commodity purchased:

1. The price of the commodity changes when all the other influencing factors are constant. (This is usually termed the "ceteris paribus" assumption.) The alteration of the quantity purchased that occurs is due to a movement along the demand schedule itself.

2. The price of the commodity is fixed but one or more of the other influencing factors changes. This results in a movement of the whole demand schedule, and this effect only is termed a "shift in demand".

Both of these effects can occur simultaneously, and E. J. Working considered that an important part of demand analysis is to separate these two types of behavior (44, p. 17).
The concept of price elasticity of demand is used to relate a change in \( X_i \), the quantity of the commodity purchased, to the corresponding change in \( P_i \), the price of the commodity. (Ceteris paribus is assumed.) The definition is given mathematically by R. G. D. Allen (1, p. 255):

\[
\text{Price elasticity of demand for commodity } i = - \frac{\% \text{ change in } X_i}{\% \text{ change in } P_i} = - \frac{dX_i}{dP_i} \cdot \frac{P_i}{X_i} = - \frac{d(\log X_i)}{d(\log P_i)}
\]

There are two important aspects of this definition that should be emphasized. These are:

1. The changes of price and quantity are given as percentages and not as absolute changes.

2. Price elasticity is defined for a single point on the demand schedule only.

The concept of price elasticity of demand can be used to determine how a change in price will affect the total expenditure of a consumer for a commodity. The different possibilities may be illustrated by considering the consequences of an increase in the price of a commodity, ceteris paribus assumed, if the price elasticity of demand of the consumer is:

1. Price elastic \( (E > 1) \). Total expenditure is lower.

2. Unit price elasticity \( (E = 1) \). Total expenditure is the same.

3. Price inelastic \( (E < 1) \). Total expenditure is higher.
In the statistical models used in the subsequent analysis, the price elasticity of demand is not estimated directly. However, in the single equation models, the inverse of price elasticity or the price flexibility is measured.

\[
\text{Price flexibility of demand for commodity } i = \frac{\% \text{ change in } P_i}{\% \text{ change in } X_i} = \frac{1}{\text{Price elasticity of demand}}
\]

Three other fundamental definitions are given that are closely connected with the behavior of the individual consumer and in the last case with that of a single producer.

1. **Income elasticity of demand** for commodity \( i \) can be defined as:
\[
\text{Income elasticity of demand for commodity } i = \frac{\% \text{ change in } X_i}{\% \text{ change in } I} = \frac{dX_i}{dI} \cdot \frac{I}{X_i}
\]

2. **Cross elasticity of demand** for commodities \( i \) and \( j \) is given by:
\[
\text{Cross elasticity of demand for commodities } i \text{ and } j = \frac{\% \text{ change in } X_i}{\% \text{ change in } P_j} = \frac{dX_i}{dP_j} \cdot \frac{P_j}{X_i}
\]

3. **Price elasticity of supply** for commodity \( i \) is defined as:
\[
\text{Price elasticity of supply for commodity } i = \frac{\% \text{ change in } Q_i}{\% \text{ change in } P_i} = \frac{dQ_i}{dP_i} \cdot \frac{P_i}{Q_i}
\]

At this stage only the demand curve of a single consumer has been considered, but it should be noted that these definitions can also be applied to a market consisting of a large number of consumers and producers. The problems associated with the aggregation of the individual demand schedules to form a market demand curve are discussed briefly in the next section.
4.2 The Aggregation of Data

In nearly all quantitative analysis connected with demand schedules some form of aggregated market data is used. K. A. Fox (20, p. 58) pointed out that a certain degree of aggregation is inevitable, when the prohibitive cost of collecting current data for each component of the aggregate was considered. However, the use of this type of data results in a considerable simplification of the economic forces that influence the demand schedule of a commodity. In fact considerable doubt has been cast by research workers on the validity of some of the estimates based on aggregated market data. In particular, H. F. Breimyer (5, p. 682) outlined a number of weaknesses in this type of analysis. Perhaps the most important criticism was that the results obtained tended to be too far removed from the actual problems facing the individual producer or consumer to be of much value to them. As the following analysis is based on annual market data for the US, the remainder of this section is devoted to justifying the use of aggregated data.

K. A. Fox (20, p. 58) has distinguished between five different types of aggregation that are involved when using annual market data. The implications of each class of aggregation on the statistical models developed later in this chapter are discussed below under headings similar to those used by Fox.
A marketing area may be defined briefly as a region in which each homogenous product is offered for sale at a single price for any time period. This implies that all consumers in this region pay the same price for an identical product at any one time. The aggregation of these marketing areas is discussed in a subsequent paragraph, and the present discussion is directed to the aggregation of consumers for the entire US.

The market demand schedule for the US is formed from the sum of all the quantities of a commodity purchased in a given time period by every individual consumer in the US at different price levels. The total number of consumers of a product may affect the total quantity of that product purchased, and over time an increasing population would be expected to shift the demand curve to the right. In many demand analyses, in order to compensate for the trends resulting from a changing population, the total quantity purchased is given on a per capita basis. This assumes that the number of consumers is directly proportional to the size of the population. For most of the basic food-stuffs this is a realistic assumption as these products are used in nearly every household, and the distribution pattern of consumption of each is fairly even throughout the US. However, the situation for lamb consumption in the US does not comply with these two necessary
conditions. In the consumer survey made for the American Sheep Producers Council, Inc. (3, Appendix A, Table 1), over 60 percent of the total respondents were non-users of lamb, which indicates that only a minority of the households in the US use lamb. Also the consumption of lamb is heavily concentrated in two regions of the US and so is not evenly dispersed throughout the entire market region (Section 2.4). As a result, the total US population is not considered to be a reliable indicator of the number of lamb consumers, and quantity data is not given on a per capita basis. Even though the number of lamb consumers may not alter proportionally with the population, it is probable that the number has increased since 1945 as the US population has increased by over one-third since 1945. The possibility that this demand shift is attributed to another variable is discussed in the next section.

Three different approaches to considering the coefficients, calculated from market series data, as valid estimates of the real coefficients for an individual's demand curve are outlined by R. J. Foote (17, p. 84). One of these, the consistency approach, is discussed by R. G. D. Allen (2, p. 695) and this may be summarized as the use of aggregated variables that are consistent with the micro-relations from economic theory, and also with certain properties from macro theory. This is similar to the approach used by L. R. Klein who concluded that time series analysis is suited to the measurement of price elasticities,
but that income effects tend to be obscured by other highly correlated factors (24, p. 64).

Aggregation of Commodities

In most previous studies of the demand for lamb, the production and consumption of lamb has been combined with mutton, as the majority of the U.S.D.A. data is presented in this combined form. For the coefficients estimated from this pooled data to be applicable to lamb only, one of two assumptions should be valid:

1. That lamb and mutton are complete substitutes for each other.

2. That the total quantity of lamb and mutton is always made up from a constant ratio of the two meats.

The considerable difference between the price of lamb and the price of mutton noted in Section 2.5 indicates that mutton is an inferior product to lamb and so not a good substitute. Also it is shown in the next chapter that the correlation between lamb and mutton production is low \( r^2 = 0.56 \), so that the proportion of lamb or mutton in the total production is not constant. (Only proportional changes are mentioned, as in the analysis logarithmic values of the variables are used). To avoid some of the biases that might result from using the combination of lamb and mutton production, estimates of the number of lambs slaughtered and the number of sheep slaughtered are introduced separately into the analysis.
As slaughter numbers are used rather than the actual production weight of meat, biases could occur from the different slaughter weights of the animals. Over the period studied the average dressed carcass weight of sheep and lambs has increased by approximately two percent, but as this is only a small change no allowance is made for it. A more serious bias may result from the difference between the slaughter weight of a spring lamb and a lamb from a feed lot. If the proportion of feed lot lambs in the total number of lambs slaughtered increased, the actual production of lamb would be expected to be higher than the quantity suggested by the slaughter data. Since 1945 the percentage of the January 1st inventory of sheep and lambs that are on feed has been remarkably constant making up an average of 13.5 percent of the total inventory. The remainder of the inventory is made up of stock sheep, which determine the potential size of the following lamb crop. Thus, the correlation between the lamb crop and the number of lambs on feed is high ($r^2 = 0.91$). This indicates that lamb slaughter data do not include any serious biases that could influence the slope of the estimated demand schedule.

In this analysis no index is made of the different cuts of lamb available to the consumer. This assumes that the carcass composition for both sheep and lamb has remained constant over time. This does not seem an unreasonable assumption as there are no reports of any extensive changes in the composition of carcasses between
1945 and 1963. This might be an important factor if for example an entirely new breed of sheep was introduced on a large scale.

**Aggregation of Firms at The Different Marketing Levels.**

Not all the produce sold at the farm level is passed on immediately to the consumer, but the proportion that is processed or stored is very small compared with the total production. Foreign trade can alter the domestic supply of a product, and this has been an important factor with the supply of mutton for the last five years (Section 2.2). Even so the consumption of lamb and mutton by civilians in the US is still highly correlated to production during the period studied ($r^2 = 0.75$). This, however, is considerably less significant than the value given by K. A. Fox for the period 1922 to 1941 (20, p. 83). The increased variation between consumption and production is explained partly by the large exports and high military consumption in 1945 and the following three years and partly by the large increase in the quantity of mutton imported during the last five years. Fox considered that a correlation coefficient of more than 0.90 was required before consumption could be considered to be determined by production (17, p. 21). During the time period covered in this analysis, consumption varied too much from production to reach this conclusion.

Another important factor when considering the different levels of marketing is the steady divergence of the retail price of lamb from
the farm price of lamb. This is demonstrated by the significant decline \( F_{1,17} = 9.12 \) of the percentage of the retail price of lamb that is passed on to the producer. For the first few years after 1945 about 70 percent of the retail price went to the producer, but this proportion decreased so that for the last two years producers have received only 50 percent of the retail price. This suggests an increasing importance to the consumer of packaging, grading, and other service factors, although H. F. Breimyer considered that rising costs accounted for a major part of the increased marketing proportion (7, p. 15). A market demand schedule based on the retail price level will include the demand for market services as well as the demand for lamb itself. With this trend of the retail price away from the farm price, it is possible that an increase in the retail price may not reflect a similar increase in the farm price, but only an increase in the cost of market services. The prices used throughout this study are the prices received by producers, and do not include any bias from changes in the demand for marketing services. The farm prices also have considerable relevance to the producers, especially when estimating the producer supply curve for lamb.

Aggregation of Transactions From Different Time Periods

In most time series analyses based on market data, the prices used are the weighted annual prices. The slaughter of lamb is not
evenly distributed throughout the year but tends to be greater during the late summer and early fall. This large slaughter is accompanied by a corresponding low price. By weighting the prices by the quantity of lamb sold at each price, a more realistic average price is estimated.

The use of annual prices instead of prices averaged over a shorter time period results in a considerable simplification of the economic forces that influence prices. In fact much of the criticism, especially from producers, aimed at this type of analysis is that the results are difficult to apply to every day situations. This argument is justified but it does not mean the demand analyses based on annual data have no value. A brief discussion of the implications of using this data follows.

To a producer the actual price received for each transaction is most important, but this price is determined by a number of different influencing factors. These are:

1. The prevailing market price.
2. The seasonal fluctuation.
3. The cyclical fluctuation.
4. The long run trend.

Factors 2 and 3 have perhaps the greatest influence on the prevailing market price, 1, but this need not be the price received by the producer as often lots are sold individually so that price can vary
with every transaction. By using annual data all of the first three factors are averaged out and only the long run trend is considered. Although this long run trend has little influence on determining the price of each transaction, it has considerable application for forecasting future price trends. W. R. Maki states that only by eliminating the variation in price caused by cyclical and seasonal fluctuations can these long run influences be isolated (26, p. 612). Annual data are the best for this purpose as a year covers the length of one production cycle.

Included in most of the studies on demand schedules is a discussion of whether coefficients are estimators of the "long run" effects or the "short run" effects. E. J. Working (44, p. 52) recognized that coefficients estimated from data aggregated over different time periods may not be identical. In a study on the demand for meat, Working even averaged data over ten year periods to estimate long run effects. However, more recent studies have indicated that annual data may give reliable estimates of long run coefficients. H. F. Breimyer (7, p. 60) considered that annual data gave long run estimates if the effect of cyclical fluctuations was not dominant. There appears to be no regular cyclical pattern of lamb production as there is with beef and hog production (40, p. 7), so the coefficients calculated from the annual data are taken to be long run estimates. This assumption is in agreement with the conclusions drawn from a study
by W. G. Tomek and W. W. Cochrane (36, p. 717). These authors distinguished between "tastes", which affect the level of demand, and "habits", which affect the rate of adjustment to a change in tastes. As consumers make a large number of separate purchases of meat during a year, complete adjustment of tastes can be expected to occur over this time, so that long run or completely adjusted coefficients can be calculated from annual data.

Aggregation of The Different Marketing Areas

The annual weighted prices of lamb are not identical for each marketing area in the US for any one year. This reflects the differences in the transport costs required to move lamb from the production areas to the consumption areas. An example of this type of price difference is discussed in Section 3.2 when comparing the farm price for lamb in California to the price in Oregon. There is no conclusive evidence that any extensive changes have occurred in either the production pattern or the consumption pattern of mutton and lamb (Section 2.4). This suggests that the proportion of the lamb price that covers transport costs in each area would be consistent throughout the time period studied.

There is another influencing factor mentioned by K. A. Fox (20, p. 64), and this is the difference in the seasonal marketing patterns of lamb from the different producing areas. An example of two
contrasting seasonal patterns is given by the marketing of fat lambs from Oregon and from Montana. In a study by H. Ramsbacher (31, p. 14) almost 90 percent of the fat lambs from Oregon were estimated as being marketed between March and September, and a large proportion of these early in this period. In Montana, however, only 40 percent of the fat lambs were marketed during the same time period, and all these sales occurred during the last half of the period. This reflects the milder winter in Oregon that enables producers to prepare lambs for slaughter earlier in the season than in the mountain states. There were no indications in other studies of the sheep industry that any change has occurred in the seasonal marketing pattern for lamb.

It is assumed in this study that the pattern has been consistent.

It is now possible to summarize the most important implications of using aggregated data into two divisions:

1. Due to the heterogeneity of the components of the aggregation, the coefficients for the whole market are not the same as those for a component. This is especially important when considering the individual consumers, and the general conclusion was that coefficients from time series analyses for price elasticities are more valid than the coefficients for income elasticities.

2. Biases in the aggregate data may result from changes in the structure of the components of the aggregate, and this topic is developed further in the next section.
4.3 Changes In The Structure Of The Demand Schedule

Structural changes that may result in shifts of the demand schedule for a commodity have been divided into two main categories by K. A. Fox (19, p. 413). The first includes the changes in the demographic factors and the second changes in the economic factors. H. F. Breimyer points out that it is extremely difficult to obtain suitable quantitative relationships that can be used to estimate the impact of demographic factors on demand as the data available are inadequate (7, p. 24). However, R. Stone (34) has combined market series data with cross sectional data and introduced variables into the demand function to account for some demographic factors. Breimyer attributes the increase in the demand for beef relative to pork and other red meats to changes in the demographic factors (7, p. 26). In this present study no account of the demographic changes is included in the analysis and the implications that result from this omission are discussed below.

Shifts in the demand schedule caused by demographic changes may be attributed to other variables, but generally structural changes develop consistently over time and do not fluctuate from year to year as some other variables. Between 1945 and 1963 the income per capita increased steadily with no prolonged recessions except for the first three years immediately following 1945, but these years are not
included in the analysis. This suggests that many of the demographic influences may be attributed to the income variable, and this explains more fully the conclusion reached in the previous section that market series analysis does not give an accurate estimate of the true coefficient for the income effect. Breimyer summarizes this view in the following statement (6, p. 190). "Trends in the national income as a measure of demand represent not 'pure' demand but many factors, both economic and institutional, that affect and determine demand." The conclusion from this argument is that much of the influence from changes in demographic factors, including the possible increase in the number of consumers, is attributed to the income variable.

The economic factors are perhaps more independent in their action on the demand schedule than the demographic factors. Fox lists four major economic forces that may influence the structure of the demand schedule (19, p. 418). These are:

1. The general price level.
2. Income level and distribution.
3. Level and distribution of consumer assets.
4. Marketing technology.

There has been a considerable inflationary trend in the general level of retail prices since the war, so that the purchasing power of the dollar has fallen during this period. To allow for this trend most demand analyses are based on a constant value dollar or the deflated
dollar. This is obtained by dividing the current price by an index of retail prices, and in this study the index used was the consumer price index given in the Economic Report of the President (42, p. 261) using 1957-59 average = $1.00. Breimyer, however, considered that the price index should be included as a separate variable as farm products appear to be extremely sensitive to changes in current prices (7, p. 17). This tends to increase the difficulty of interpreting the estimated coefficients as the price index is very closely correlated with other variables, and this aggravates the problem of multicollinearity, which is discussed in the next chapter. Throughout the statistical analysis in the following chapters prices are corrected for the price level and are termed "deflated".

Changes in the distribution of income among the population are shown by L. R. Klein (24, p. 24) to be most important when estimating income coefficients for an individual consumer. However, in this study only the effect of income on the market price of lamb is considered.

The level of consumer assets was considered by Fox to be of importance only immediately after the lifting of rationing in 1945 (20, p. 142), and these first three years are eliminated from the statistical models so that the level of assets is assumed not to influence the demand in the analysis.

Changes in market technology may be partly responsible for the
increase in the demand for beef relative to the other red meats, and this possibility is discussed by Breimyer (7, p. 27). However, this trend would be very similar in type to the trends caused by changes in the demographic factors and any shift in the demand curve would be mainly attributed to the income effect.

The conclusion reached in this discussion is that if no variable is included in the analysis to account directly for structural changes, the time span covered by the analysis should be chosen so that irregular structural changes are avoided. For this reason the war years are usually excluded from the analysis period as rationing was introduced in these years, and this would be expected to alter both the structure and the pattern of demand.
CHAPTER V

THE DEMAND FOR LAMB IN THE US

5.1 The Gross Income Of The Sheep Industry

In Chapter II it was shown that neither the production of lamb and mutton or the farm price of lamb had changed significantly with time from 1945 to 1963. However, D. F. Fienup demonstrated that in three different years since 1945, when the production of lamb and mutton was at the same level of 758 million pounds, the price received by the producers had fallen over time. For this one level of production the farm price in 1947 was $21.90/cwt., in 1955 it fell to $18.40/cwt., and in 1959 the price was down to $18.00/cwt. (13, p. 55). Not only was the farm price successively lower in these three years, but the value of the dollar had also declined (Section 4.3). The gross value of production would also be expected to decrease as the quantity is the same and the price lower. (The total quantity includes some mutton production, so that the gross value is not simply the product of price and quantity.) However, the U. S. D. A. makes an estimate of the annual value of sheep and lamb production (37, p. 34), and this deflated value has decreased significantly over time ($F_{1, 17} = 52.47$) by an average of almost a million dollars each year. As the average value of production from 1945 to 1963 was about 300 million dollars,
the decline represents a 0.30 percent drop per year. This value does not include an estimated value for home consumption, so the decline in the value of production also represents a decline in the gross income received by producers from sales of lamb.

The decreasing revenue from the sales of lamb could be explained by either of two concepts mentioned in Section 4.1, and these are:

1. The market demand curve has shifted to the left, so that consumers pay a lower price for the same quantity supplied. The results from the analysis by Fienup suggest that some movement of the demand curve has occurred.

2. Although there has been no significant change in the annual production, variations in the quantity of lamb and mutton supplied could account for some of the changes of the gross income.

Both of these two factors have influenced the demand situation for lamb and mutton, and this is illustrated by referring to Figure VII. Each year is assumed to represent an equilibrium position between the demand curve and the supply curve for lamb and mutton, and this position is plotted on the graph. The general path of the equilibrium is traced out by the line joining each successive year. This figure indicates that there has been a considerable shift to the left of the demand curve between the first four years of the period and the most recent years. One of the objectives of this analysis is to introduce suitable variables into a statistical model to account for these shifts as well as to assess the effect of movements along the
Figure VII. Annual Equilibrium Positions for the Demand and Supply of Lamb.
demand curve itself.

It must be remembered that the years included in the analysis should cover a period of fairly constant structural development unless specific variables are introduced to account for structural changes (Section 4.3). For this reason the first three years, 1945, 1946, and 1947 are not included in the model. During these years exports of lamb and mutton were higher than at any other time since 1945, and this would be expected to increase the price of lamb. Also the period came immediately after the end of food rationing, and with the generally high level of assets that consumers had accumulated during the war (Section 4.3), the level of demand would tend to be unusually high during this period. Although there have been considerable structural changes between 1948 and 1963, this has been a period of fairly consistent economic expansion, and it is assumed that structural changes have developed steadily.

5.2 The Formation of a Statistical Model

The statistical model usually employed in market demand analysis represents a considerable simplification of the economic relationships that determine the equilibrium position of the demand and supply curves. K. A. Fox has distinguished three stages in the formation of a model for the demand schedule of a commodity (20, p. 24). These divisions are used to introduce a discussion of a model of the
schedule for lamb in the US.

**Specifying Which Economic Relationships to Include in the Model**

The quantity of a commodity purchased by a consumer can be written as an explicit function of the prices of all available products, and the income of the individual (Section 4.1). To a single consumer the prices may be considered as fixed or predetermined at any one time, as an individual's purchases are usually too small to influence the prices. For many agricultural products, because of the length of the production period, the quantity available in the market is determined more by the size of the harvest than by the current prices. As a result, the demand function of a commodity for an entire market is usually written with price as the explicit variable.

Although theoretically the price of all other commodities influence the price of lamb, it will be assumed that only the closest substitutes, which for lamb are taken to be the other meats, are important. In this study the production of beef, pork, and veal are pooled together to form a single variable to represent the substitute products, and this variable is termed the quantity of "other red meat". The quantity of the substitutes is used rather than an index of the prices as this may be considered as a predetermined factor. The price of substitutes is probably influenced by the current price of lamb and is not predetermined. Using the pooled output means that the calculated
coefficient for this variable may not be the same as the actual coefficient for each individual meat unless each meat has identical properties of substitution for lamb. This problem is similar to the one outlined in Section 4.2, which involved aggregating the demand of individual consumers to form a market demand schedule.

The other important economic relationship that is included in the model is the consumer income factor. The other factors that may be attributed to the income effect were discussed in Section 4.3. This means that the income factor and the quantity of other red meat are the only two relationships used in the model to account for shifts in the demand curve. If the model enables suitable coefficients to be estimated, then these simplifications are justified.

Forming a Suitable Mathematical System

In this study the variables for each year are considered to represent a separate equilibrium position between the demand and supply curves for lamb. This is a static model, and each year is assumed to be independent of all the other years. Another approach is to consider year to year changes of the variables and so form a dynamic model. R. J. Foote (17, p. 29) considered that the static approach is more suited to obtaining long run coefficients, and as the purpose of this study is to estimate long run trends in the sheep industry, the static method is employed.
To make computations easier, the demand schedule is usually considered to be a linear function of the variables. L. R. Klein points out that there is no "a priori" economic reasoning that determines this linearity, and that the assumption of linearity is only a convenience (24, p. 22). The validity of the assumption may be investigated using graphic analysis developed by L. H. Bean (4).

Variables may be expressed either in absolute terms or as logarithms and in the latter case the changes in the variables represent proportional differences. K. A. Fox (20, p. 69) considered that the logarithmic form was the best suited for demand functions, and logarithmic variables probably give a better comparison between changes in the quantity of lamb and in the quantity of other red meat because of the large difference in absolute size between them (Section 2.2). The demand function for lamb in any one year can now be written in the logarithmic form as:

\[ \log P_L = \log A_0 + A_1 \cdot \log Q_L + A_2 \cdot \log Q_{RM} + A_3 \cdot \log Y + \log U. \]

- \( P_L \) = Price of lamb.
- \( Q_L \) = Quantity of lamb.
- \( Q_{RM} \) = Quantity of other red meat.
- \( Y \) = Disposable income per capita.
- \( U \) = Unexplained residual.
- \( A_i \) = Constant.
The unexplained residual is the difference between the estimated value of $P_L$ and the actual value. R. J. Foote lists three types of error that may result in this discrepancy between the real and the estimated values (17, p. 172).

1. Measurement error in the collection of the data used to represent the variables.

2. Omission of certain influential economic relationships from the function.

3. Making incorrect simplifications in developing the statistical model.

The properties of these residual terms have important implications when using the estimates of the coefficients to determine confidence limits for the actual coefficients, and this is discussed in a subsequent paragraph.

To solve this system as a single equation, it is necessary for all the variables except price to be predetermined, or, in other words, to be determined outside the system (exogenous). The price variable is considered to be dependent on the other variables in the system and so is endogenous. The sheep industry is small enough, relative to the size of the meat industry and the whole economy, that it may be assumed that variations of the lamb price do not cause significant changes in the production of other meats or the real value of the consumer disposable income, and so these two variables are taken to be predetermined. However the quantity of lamb supplied
may be influenced by the current price of lamb and may be another endogenous variable. At this stage in the analysis, the production of lamb and mutton is taken to be predetermined, and further discussion of whether this assumption is justified is left until the next chapter.

Obtaining Estimates of the Statistical Coefficients

The normal method of solving a single equation model is to use the least squares technique. By this method the sum of the squared unexplained residuals is minimized, and this results in the highest linear correlation between the estimated values and the real values of the endogenous variable. However, Klein emphasizes that it is not as important to obtain a high correlation as it is to obtain the best estimates of the coefficients for the variables (24, p. 30). The actual computational technique is described in detail by J. Friedman (21, p. 2-15) and is a modification of the Doolittle method.

If the calculated coefficients are to be used for estimating confidence limits for the real coefficients, the model must possess certain other properties, and these are outlined by Klein (24, p. 30).

1. There must be no error in the collection of data for the predetermined variables. This type of error is more important with single observations than with aggregated data, and is ignored in this study.

2. The unexplained residuals must be independent of each other. The Durbin-Watson test is used to test if there is any significant serial correlation between the residuals. If this test is negative, the residuals are assumed to be independent.
3. The distribution of the true unexplained residuals should be known, but as only a sample is used in the model, the measured residuals tend to follow the normal distribution (central limit theorem). It is assumed that the real residuals also follow the normal distribution, and this distribution is used as the basis for the estimation of the confidence limits for the coefficients.

There is another problem that occurs when there is a high degree of correlation between the predetermined variables, and this is termed multicollinearity. Klein (24, p. 64) points out that if two of the predetermined variables are highly correlated together then there is a certain degree of indeterminacy over the true value of the coefficients for these variables. R. J. Foote shows how multicollinearity also increases the difficulty of obtaining the least squares estimates from a graphical analysis (14). In this model of the demand schedule for lamb, the income variable is highly correlated to the production of other red meats ($r^2 = 0.98$), and this has two implications that may affect the analysis.

1. The confidence intervals for the coefficients of these two variables will tend to be larger than might be expected.

2. Certain structural changes that were formally attributed solely to the income variable may be partly explained by the quantity of red meat variable.

5.3 A Single Equation Model of the Demand Schedule for Lamb

In this section the first of three different single equation demand functions, A, B and C, is given. All three of these functions
are of the same basic form as the model developed in Section 5.2. As the estimate used for the quantity of lamb in Equation A is similar to the equivalent variables used in other studies, the coefficients determined in Equation A are compared with those found in other demand functions for lamb. The variables are entered into the demand function as logarithms, so the coefficients of the predetermined variables represent the percentage change in price that is associated with a one percent change of the variable. In the case of the quantity of lamb produced, the coefficient is a direct estimate of the price flexibility. Although in the economic definition the price flexibility is the inverse of the price elasticity, this is not true statistically as the sum of the squared residuals is minimized with respect to price and not quantity. If quantity is considered as the dependent variable, then the price elasticity can be estimated directly, but this is inconsistent with the theory developed in the previous section as price was shown to be the dependent variable. However, it is not necessarily a handicap to be unable to estimate the price elasticity as it is more important in this type of study to assess what changes in price are associated with changes in the size of the predetermined variables. Also it is still possible to relate changes in the quantity of lamb supplied to the price of lamb and assess changes in the gross revenue from lamb production.

In Equation A the variable for the quantity of lamb is given by
the combined production of lamb and mutton, and so is restricted to
the assumptions given in Section 4.2. The observations used for this
and all subsequent equations are listed in the Appendix.

Equation A:

\[ P_L^* = 7.48 - 0.83 \cdot Q_{LA}^* - 1.44 \cdot Q_{RM}^* + 0.78 \cdot Y^* \]

\( (R^2 = 0.96) \quad (0.17) \quad (0.52) \quad (0.79) \)

(Durbin-Watson test for serial correlation negative)

\( P_L \) = deflated farm price of lamb (dollars/cwt).

\( Q_{LA} \) = production of lamb and mutton (million pounds).

\( Q_{RM} \) = production of other red meat (million pounds).

\( Y \) = deflated disposable income per capita (dollars).

* indicates that the variable is used as a logarithm.

A variable in a linear equation carries no weight if the coefficient is
zero (24, p. 47). To test the hypothesis that the confidence interval
of a coefficient includes zero, the coefficient is divided by the corre-
sponding standard error (given in parentheses) to give a "t" value.
If the value is greater absolutely than the limits given in the "t"
tables, the coefficient is significantly different from zero.

1. The coefficient for \( Q_{LA} \) is - 1.44 (significant at
one percent), and as this is an estimate of
the price flexibility, in Equation A the price of lamb is inflexible (equivalent to being price elastic). The coefficients determined by Breimyer (-0.26) and by Fienup (-0.56) also show that the price of lamb is inflexible, but these estimates indicate a considerably higher degree of inflexibility than is shown in Equation A. This, however, would be expected as the price at retail is normally more elastic and hence inflexible than at the farm level. Also it is probable that prices are more inflexible in a dynamic model than in a static model as consumer expectations may partly offset the effect of year to year changes in the quantity produced. As the price of lamb is inflexible, a certain percentage decline in lamb production would be associated with a smaller percentage increase in the price (assuming ceteris paribus), and hence the gross income received by producers from lamb production would decrease.

2. The coefficient for $Q_{RM}$ is -1.44 (significant at one percent), and the negative sign indicates that the other red meats are substitutes for lamb. A one percent increase in the production of other red meats is associated with a much larger decrease in the price of lamb than is associated with a one percent increase in the production of lamb. This suggests that an increase in the production of other red meats could easily offset an expected rise in the price of lamb following a cut back of lamb production. The models developed by Breimyer and Fienup support this conclusion as in both models the estimated coefficient for the production of substitute meats is larger absolutely than the corresponding coefficient for the production of lamb and mutton.

3. The coefficient for $Y$ is +0.78 (not significantly different from zero) and the sign being positive indicates that an increase in the income per capita is associated with a shift to the right of the demand schedule for lamb. In both the model developed by Breimyer and by Fienup the estimated coefficient for the income variable is positive. This suggests that although lamb makes up only a small part of the total meat production, it is not an inferior meat. It must be remembered that in this study the positive coefficient may reflect changes in other factors such as an increase in the number of consumers (Section 4.3).
Although Equation A produces coefficients that are consistent with the coefficients estimated in other studies, it was concluded in Section 4.2 that mutton is an inferior product to lamb, so that using the combined production may result in the estimates being biased. In the following section a model is developed that includes a variable for lamb production only.

5.4 Estimation of the Total Number of Lambs Slaughtered Each Year

The commercial slaughter data prepared by the U.S.D.A. reports only the combined total of the number of sheep and lambs slaughtered each year (37). It is possible from other U.S.D.A. data to obtain three estimates of the number of lambs slaughtered commercially and the formation of each estimate is considered in turn.

1. The sheep and lambs that are killed in federally inspected slaughter houses are divided into two classes (37). The first class includes lambs and yearlings and the second sheep. This classification covers nearly 90 percent of the entire commercial slaughter of sheep and lambs. If the federally inspected data are taken as a sample of the total slaughter, it is possible to estimate the total number of lambs and yearlings slaughtered each year.

2. Each year the number of lambs in the lamb crop is reported and the lambs that survive may be considered to have four possible fates (as exports of lamb are very small, foreign trade is excluded as a possibility): a) kept for stock; b) kept on feed; c) slaughtered commercially; d) slaughtered on farms. The number of lambs not slaughtered as "spring" lambs (less than one year old) are reported in the January 1st inventory (39) as either being on feed or being kept for stock, and these numbers are subtracted from the lamb crop. The estimate of the number of lambs slaughtered on
on farms is also subtracted to give the number of spring lambs slaughtered commercially. It is assumed that all the animals reported on feed on January 1st are slaughtered that year, and so are added to the number of spring lambs slaughtered to give the total commercial slaughter. It must also be assumed that all the animals on feed are lambs, but even if sheep are included, the quality of the meat is probably considerably better than from animals taken directly from a breeding flock. The total number of lambs slaughtered commercially may now be written as an identity:

$$ (L'_{Kt} + L'_{Ft}) = L'_{Ct} - (L'_{F(t+1)} + L'_{S(t+1)}) - L'_{Ht}. $$

$L'_{K}$ = number of spring lambs slaughtered commercially.
$L'_{F}$ = number of lambs on feed (January 1st).
$L'_{C}$ = size of the lamb crop (lamb deaths excluded).
$L'_{S}$ = number of lambs kept for stock (January 1st).
$L'_{H}$ = number of lambs slaughtered on farms.

("t" refers to year t)

A similar estimate can be obtained for the number of sheep slaughtered by considering the change in the inventory of stock sheep each year and adding to it the number of new stock lambs present at the beginning of each year.

$$ S'_{Kt} = (S'_{S(t+1)} - S'_{St}) + L'_{St} - S'_{Ht}. $$

$S'_{K}$ = number of sheep slaughtered commercially.
$S'_{S}$ = number of stock sheep (January 1st, sheep deaths excluded).
$L'_{S}$ = number of lambs kept for stock.
$S'_{H}$ = number of sheep slaughtered on farms.

Some of the quantities used in these two identities are U.S. D.A. estimates and are not based on complete records.
However, it is possible to compare the sum of the combined estimates for sheep and lambs with the total commercial slaughter data given by the U. S. D. A. For the years 1945 to 1963 there is a high degree of correlation between the two quantities ($r^2 = 0.97$), and this suggests that the estimates give acceptable slaughter data.

3. Estimates of the total number of lambs sold in each state are also given by the U. S. D. A. (38), but these values include animals that are sold out of the state as well as all the animals sold in state. However, an estimate of the number of lambs that are shipped into each state is also made, and by subtracting this quantity for the whole US from the total marketings, an estimate of the commercial slaughter is obtained.

\[
\text{Commercial marketings} = \text{Total marketings} - \text{Total inshipments}
\]

The number slaughtered of both lambs and sheep obtained from this estimation method are almost perfectly correlated to the values obtained from the two identity equations, and for this reason only one of the last two techniques is used as the two estimates are for most practical purposes identical.

The variable for the quantity of lamb used in Equation A can now be replaced by the estimated number of lambs slaughtered determined either from the federally inspected data or from the identity equation. The demand function obtained using the federally inspected slaughter does not give satisfactory coefficients and no further analysis is made using this data. However, the demand function estimated using the identity data does produce results that are consistent with Equation A, and so this analysis is developed.

By omitting any variable for the number of sheep slaughtered from the demand function, it must be assumed that mutton production
has no influence on the price of lamb. However, it is possible to relax this assumption and enter a variable for mutton production into the equation. This variable should take into account the imports of mutton as well as the domestic slaughter of sheep, as both are expected to influence the price of lamb. As imports into the US have been predominantly of mutton (Section 2.2) and exports have been almost negligible since 1948, it is assumed that all foreign trade is with mutton only. The estimated net import of mutton is now determined by subtracting the quantity of meat exported from the quantity of meat imported (37). As the net import is recorded as the total dressed carcass weight, a transformation is made to the equivalent number of sheep carcasses by dividing this weight by the average dressed carcass weight for sheep (assumed in this study to be 100 pounds). The transformed net imports are added to the number of sheep slaughtered, and the demand equation is now written as:

Equation B:

\[
PL^* = 9.27 - 0.88(K + F)^* - 0.03(S + 1)^* - 1.11 Q_{RM}^* + 0.20 Y^*
\]

\[
R^2 = 0.97 \quad (0.19) \quad (0.04) \quad (0.56) \quad (0.84)
\]

(Durbin-Watson test for serial correlation inconclusive)

\[P_L, Q_{RM}, Y\] and \[Y\] are identical to the variables used in Equation A.

\[L_K\] = number of spring lambs slaughtered (thousand head).

\[L_F\] = number of lambs on feed on January 1st (thousand head).
\( S_K \) = number of sheep slaughtered (thousand head).

\( I \) = net imports of mutton as a carcass equivalent (thousand head).

* indicates that the variable is used as a logarithm.

The coefficients for the predetermined variables have the same signs and also are not significantly different from the corresponding coefficients in Equation A. This suggests that although the slaughter data are based partly on estimates, Equation B does give a reliable model of the demand schedule for lamb. The prices predicted from Equation B are plotted with the actual prices for lamb in Figure VIII, and this shows that the predicted values follow the true values fairly consistently throughout the period.

The conclusions outlined in the previous section for Equation A are in agreement with the conclusions that can be made from Equation B. The price of lamb is shown to be inflexible with the number of lambs slaughtered. Also a one percent increase in the production of other red meat is associated with a larger proportional decrease in the price of lamb than is associated with a similar one percent increase in the number of lambs slaughtered. The income variable has a positive coefficient that is not significantly different from zero; however, this variable is included in the equation for the same reasons that were given for Equation A. The coefficient for the number of sheep available for consumption has a small negative coefficient, and
Figure VIII. Lamb Prices Predicted from Equation B.
this indicates that mutton is a poor substitute for lamb and that increases in the production of mutton are associated with small decreases in the price of lamb. Although the coefficient is not significantly different from zero, it is still possible to make an estimate of the effect of imports of mutton on the price of lamb.

Using Equation B, a possible causal explanation can be given for the fluctuations in the farm price of lamb by considering the corresponding fluctuations of the predetermined variables. The decline in price between 1958 and 1959 is given as an example, for in this period mutton imports increased considerably and also the prices predicted from Equation B are close to the true values for these years. Between 1958 and 1959 the predicted price fell by $2.76/cwt from $22.30/cwt to $18.59/cwt and the true price fell by $2.43/cwt. As the variables used in Equation B are logarithms the price changes associated with the changes in the predetermined variables are given as percentages. However, the dollar value of the price decline is predicted as $2.76/cwt, so that the percentages can be converted into the corresponding dollar value by calculating the proportion of the total decline that can be attributed to each variable.

1. A 6.71 percent increase in the number of lambs slaughtered \((L_K + L_F)\) resulted in a 5.90 percent decline in price.

2. A 39.30 percent increase in the number of sheep slaughtered \((S_K + I)\) resulted in a 1.00 percent decline in price.
3. A 6.71 percent increase in the quantity of other red meat produced ($Q_{RM}$) resulted in a 7.45 percent decline in price.

4. A 3.50 percent increase in the disposable income per capita ($Y$) resulted in a 0.70 percent increase in the price.

Both the production of lamb and the production of other red meat increased by 6.71 percent and accounted for 41 percent and 52 percent respectively of the predicted decline in price. In contrast the production of sheep increased proportionally by almost six times as much but only accounted for seven percent of the price decline.

By combining the sheep slaughter ($S_K$) with the net imports of mutton ($I$) in one variable, an assumption is made that imported mutton is a perfect substitute for domestically produced mutton. There appears to be no evidence that refutes this assumption, so an estimate can be made of what the price of lamb would have been if no mutton had been imported into the US and hence provide an indication of the decline in price due to importing mutton. As Equation B is computed with the variables as logarithms it is probably best to compute the estimated price directly using the coefficients from Equation B. Instead of considering the quantity of mutton as the sum of the domestic slaughter and the net imports, only the number of sheep slaughtered in the US is entered into the variable. The estimated price can now be converted from logarithms to the dollar value and then compared with the price predicted from Equation B. Imports of mutton were extremely small before 1958 and only the prices for the last six years
are calculated.

Table IV. Effect of Mutton Imports on the Price of Lamb in the US.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total slaughter (SK+1)</th>
<th>Domestic slaughter SK</th>
<th>I as a % of (SK+1)</th>
<th>$P_L$ (Using (SK+1)) $/cwt</th>
<th>$P_L$ (Using SK) $/cwt</th>
<th>Difference in $P_L$ $/cwt</th>
</tr>
</thead>
<tbody>
<tr>
<td>58</td>
<td>2,090</td>
<td>1,701</td>
<td>18.61</td>
<td>22.30</td>
<td>22.44</td>
<td>-0.14</td>
</tr>
<tr>
<td>59</td>
<td>2,911</td>
<td>1,891</td>
<td>35.04</td>
<td>19.54</td>
<td>19.79</td>
<td>-0.25</td>
</tr>
<tr>
<td>60</td>
<td>3,542</td>
<td>2,692</td>
<td>24.00</td>
<td>18.58</td>
<td>18.58</td>
<td>-0.15</td>
</tr>
<tr>
<td>61</td>
<td>4,315</td>
<td>3,325</td>
<td>22.94</td>
<td>17.30</td>
<td>17.44</td>
<td>-0.14</td>
</tr>
<tr>
<td>62</td>
<td>4,291</td>
<td>2,891</td>
<td>32.63</td>
<td>17.71</td>
<td>17.93</td>
<td>-0.22</td>
</tr>
<tr>
<td>63</td>
<td>4,090</td>
<td>2,650</td>
<td>35.21</td>
<td>17.14</td>
<td>17.36</td>
<td>-0.22</td>
</tr>
</tbody>
</table>

Between 1958 and 1963 the estimated quantity of mutton imported has made up a considerable proportion of the total quantity of mutton available in the US, and, in fact, in 1959 and 1963 over one-third of the mutton available was imported. However, as the coefficient of the variable for sheep production is small (-0.03), the price of lamb estimated as though no mutton had been imported is only slightly lower than the price predicted when imports are included. The largest estimated reduction in the price of lamb of $0.25/cwt is shown in Table IV to have occurred in 1959, and for the other five years the estimated reduction was between $0.14 and $0.22/cwt. It should be emphasized that the estimated decline in the price of lamb provides only a rough indication of the real decline in price. It has been assumed that the other variables and the coefficients in Equation B
would be identical even if no mutton imports had entered the US. However, if producers reduced the number of sheep slaughtered as imports of mutton increased, the estimated decline in the price of lamb would actually be smaller than the values shown in Table IV. An even smaller reduction in price would result if the number of lambs slaughtered decreased with increasing mutton imports, as the coefficient for lamb production is larger absolutely than the coefficient for sheep production.

5.5 Demand for Lamb in Oregon

Although the farm price for lamb is closely related to the US price ($r^2 = 0.97$), the demand schedule for Oregon lamb is not necessarily identical to the schedule for the entire US, and, in fact, economic theory suggests that the demand in Oregon should be more price elastic or price inflexible. The explanation for this may be illustrated by considering a year when Oregon lamb production is lower than the average level. If the coefficient of flexibility was the same in Oregon as for the US, the farm price of lamb in Oregon would be expected to be considerably higher than normal assuming ceteris paribus. However, as lamb can be transported relatively cheaply, any increase in the Oregon price that is sufficient to cover transport costs provides an incentive for producers outside Oregon to ship lamb into the Oregon market. This increased quantity tends to reduce the
price of lamb in Oregon below the price that would be reached if no lamb was shipped into the State. A similar sequence of events occurs if the production of lamb in Oregon is higher than normal. The price of lamb tends not to decline as much if markets are available outside Oregon that offer prices high enough to provide an incentive for producers to ship to these markets. This latter situation is similar to the one that exists in Oregon with the California markets providing the price incentive (Section 3.2). The result is that regional prices for lamb are highly interrelated throughout the US, and, also, that prices for lamb in each State tend to be more inflexible to the changes in lamb production than for the US.

The results of the lamb survey in 1954, reported by H. O. Doty, Jr. (11, p. 4), show that of all the Western States, only California is not a surplus producer of lamb, and, in fact, after California, Illinois is the nearest deficit producer to Oregon. This suggests that California provides an important market for Oregon lamb, and the price of lamb in California may be expected to have considerable influence on the Oregon price.

To develop a single equation demand function for Oregon lamb, the farm price of lamb in Oregon is taken as the dependent variable. The remaining variables should be predetermined so production quantities are used instead of prices. The movement of lambs between states creates difficulties in estimating the production quantity
for Oregon from an inventory identity similar to the one outlined in Section 5.4, so the number of lambs slaughtered is determined by subtracting inshipments of lamb from the total marketings. The production of lamb in Oregon and in California, together with the production of other red meat in Oregon, are used as separate predetermined variables. These variables are entered into the function as logarithms and so the coefficients obtained represent price flexibilities.

Equation C:

\[
P_{LO}^* = 7.53 - 0.54 Q_{LO}^* - 0.95 Q_{LC}^* - 0.75 Q_{RMO}^*.
\]

\(R^2 = 0.90\) \((0.26)\) \((0.27)\) \((0.24)\)

(Durbin-Watson test for serial correlation inconclusive)

\(P_{LO}\) = deflated farm price of lamb in Oregon (dollars/cwt).

\(Q_{LO}\) = number of lambs produced in Oregon (thousand head).

\(Q_{LC}\) = number of lambs produced in California (thousand head).

\(Q_{RMO}\) = production of other red meats in Oregon (million pounds).

* indicates that the variable is used as a logarithm.

The coefficient for the production of lamb in Oregon indicates that the farm price for lamb in Oregon is more inflexible to production than the equivalent coefficient for the US in Equation B. However, the Oregon price is far less inflexible to the production of lamb in
California, and this indicates the strong influence of the Californian market on the Oregon price. Although California is the only deficit producer of lamb in the Western States, Oregon producers still market lamb in other states as lamb can be ready for slaughter earlier than in the mountain states. H. B. Pingrey illustrates this point (30, p. 50) and also shows that Oregon producers can get a considerable price advantage by selling early.
CHAPTER VI

THE STRUCTURE OF THE SHEEP INDUSTRY

6.1 Identification

The single equation models of the demand schedule for lamb developed in Chapter V are all based on the assumption that the quantity of lamb and mutton available each year is determined independently from the current price of lamb. When the quantity supplied is taken as predetermined, the supply curve may be considered as being vertical or completely inelastic. As a result all movements of the equilibrium positions from the estimated demand curve are attributed to independent variables in the demand function. If, however, the supply curve is not vertical, the movements of the equilibrium positions may be explained by independent variables in either the demand function or the supply function. So when the quantity supplied is partially dependent on the current price, the problem of the identification of the true demand curve and the true supply curve is introduced.

A number of authors have discussed identification, but most of them refer back to the classic account given in 1927 by E. J. Working (44). In this article Working shows that even if the equilibrium positions of price and quantity trace out a negatively sloped "demand" curve, as for example given in Figure VI, the least squares estimate
of the slope of this curve may differ considerably from the slope of the true demand curve. The reason for this may be demonstrated graphically and Figure IX shows two diagrams that illustrate this point.

![Diagram A](Image)

**Diagram A**

Price

D1

D2

D3

D4

D'

S1

S2

S3

S4

Quantity

**Diagram B**

Price

D1

D2

D3

D4

D'

S1

S2

S3

S4

Quantity

**Figure IX. Identification of a Demand Curve.**

In Diagram A four equilibrium positions are given by the intersection of the true demand curves Di (i = 1, 2, 3, 4) with the true supply curves Si (i = 1, 2, 3, 4). In this example both the demand and the supply are dependent on the current price; however, a single equation least squares estimate of the demand schedule would give an apparent demand curve D'D'. The flexibility coefficient of the estimated curve D'D' would be considerably larger than the true value. In Diagram B, however, the quantity supplied is determined independently of the current price, and the shifts in the true demand curve D'D' to Di (i = 1, 2, 3, 4) may be attributed to other predetermined variables. The
calculated value of the flexibility coefficient obtained by single equa-
tion least squares analysis is an estimate of the true value in Diagram
B if the demand shifts are accurately explained by the other exogenous
variables.

L. R. Klein (24, p. 10-13) gives an algebraic account of the
problem of identification and shows that in an unidentified equation
such as D'D' in Diagram A the estimated coefficient can be deter-
mined as a linear combination of the demand curves and the supply
curves. If an equation in a system of equations is identified, it is
not possible to obtain a linear combination of the other equations in
the system that contains identical variables to the equation in ques-
tion. However, Working has indicated (44, p. 2) that if the shifts of
the demand curve are consistently correlated to the shifts of the sup-
ply curve, a single equation estimate of the demand curve, such as
D'D' in Diagram A, could be used to estimate price from the quantity.
In this present study, however, an accurate estimate of the flexibility
coefficients for lamb are required, and the possibility that the quan-
tity of lamb supplied is not predetermined is investigated further in
the next section.

It is possible to obtain valid estimates of the flexibility coeffi-
cients for a demand function even if the quantity supplied is dependent
on the current price. The method is based on forming a fully identi-
fied system of equations that includes both the demand and the supply
function and a comparison of the single equation technique and the simultaneous approach is given by R. J. Foote (16). The conclusion reached by Foote is that the use of simultaneous equations can be justified by theoretical considerations.

6. 2 The Supply of Lamb in the US

The number of lambs born each year is dependent on two main factors: 1) the number of stock ewes; 2) the environment. As neither of these factors are influenced by the current price of lamb, the lamb crop can be taken as predetermined. The number of animals on feed at the beginning of each year is also determined independently of the current price, but the number of lambs that are slaughtered during the year may not depend entirely on the size of the lamb crop and the number of lambs on feed. If the proportion of lambs that are kept for stock or put on feed varies with the current price of lamb, the number of lambs slaughtered will also be influenced by the price.

In a study of the beef and hog industries, W. R. Maki suggests that with a rise in price animals are withheld from slaughter in order to increase the number of animals for stock and on feed (26, p. 619). Using the inventory estimate of the number of lambs slaughtered outlined in Section 5. 4, it is found that the slaughter of lambs (excluding the animals on feed at the beginning of the year) has a relatively low correlation to the size of the lamb crop \( r^2 = 0.74 \). This suggests
that although the number of spring lambs slaughtered is partially dependent on the size of the lamb crop, it is considerably influenced by other factors. In fact, for the years 1945 to 1963 the percentage of the lamb crop slaughtered each year is highly negatively correlated to the annual price of lamb \( r^2 = 0.79 \). This result shows that the proportion of the lamb crop slaughtered is smaller when the price of lamb is high and also suggests that the number of lambs slaughtered each year is influenced by the current price.

H. F. Breimyer states in a discussion of a single equation demand function for lamb and mutton, "there is more interrelationship, in a dynamic sense, between demand and supply than is usually assumed" (7, p. 81). However, even if this interrelationship between demand and supply is present, K. A. Fox concludes that for many agricultural products the structural coefficients obtained from a system of equations are very similar to the coefficients obtained from a single equation (20, p. 73). In the next section the coefficients estimated from the structural equations are compared with the corresponding coefficients in Equation B (Section 5.3).

6.3 The Structural Model of the Lamb Industry

The system of equations now developed contains five endogenous variables and ten predetermined variables, and the basic structure is to have a different equation for each of the endogenous variables. The
The form chosen for the system is:

1. A demand function for lamb.
2. A demand function for mutton.
3. A supply function for stock lambs.
4. A supply function for lambs on feed.
5. A supply function for sheep slaughter.

The total number of sheep and lambs slaughtered are estimated from two identity expressions. Due to the large number of calculations required to solve this system, it is preferable to use a computer, and the analysis technique is:

1. Each endogenous variable is run by least squares regression against all of the predetermined variables.
2. From each regression a set of predicted endogenous variables is calculated.
3. Each predicted endogenous variable is run by least squares against the corresponding predicted endogenous variables and predetermined variables given in each equation of the system. The coefficients obtained from these regressions give the structural coefficients of the system. As identities are used in the system, the variables are entered as absolutes and not as logarithms so the coefficients do not give a direct estimate of the flexibilities. It is possible to calculate flexibility coefficients using the average values of variables in the expressions given in Section 4.1, and this method is described by F. V. Waugh (43, p. 56).

The first system developed included the quantity of mutton imported as one of the predetermined variables. The demand function for lamb was identical in form to Equation B, but the estimated coefficient for the quantity of mutton was consistently positive. A graphic
analysis following the technique described by L. H. Bean (4) was used to determine the relationship of the production of mutton with the price of lamb. During the years when imports have been high, the quantity of mutton is positively correlated to the price, and this suggests that imports are not predetermined but are partially dependent on the price of lamb. To introduce the imports of mutton into the system as an endogenous variable would involve having an equation that included world prices. As the UK imports a far larger quantity of lamb and mutton than any other country, prices in the UK could be used as an indicator of the world situation. However, for the years 1948 to 1963 no consistent data are available for the UK that refer to the price of one grade of imported mutton. The domestic price of mutton in the UK is also unsuitable for this analysis as it varies considerably from the price of imported mutton due to subsidy payments. As a result, a simplified system of equations is developed that does not include a variable for imported mutton, and the demand function for mutton is reduced to a linear relationship between the price of mutton and the price of lamb.

System A.

1) \[ P_L = 65.1679 - 2.0290(L_K + L_F) - 1.0965Q_{RM} \]

\[ (R^2 = 0.97) \quad (0.3142) \quad (0.4973) \]

+ 5.2558 Y.

\[(9.7751)\]
2) \( P_S = -6.6608 + 0.6776 P_L \).
\[ R^2 = 0.97 \quad (0.0292) \]

3a) \( L_{S(t+1)} = -7.4176 + 0.1315 P_L - 0.2659 S_K + 0.3974 L_C \).
\[ R^2 = 0.92 \quad (0.0207) \quad (0.0670) \quad (0.0794) \]
\[ - 0.0042 P_{L(t-1)} + 3.8421 R. \]
\[ (0.0166) \quad (1.1740) \]

b) \( L_{S(t+1)} = -7.4176 + 0.1273 (P_L + 0.0330 (P_L - P_L(t-1))) \).
\[ - 0.2659 S_K + 0.3974 L_C + 3.8421 R. \]

4a) \( L_{F(t+1)} = -3.6329 - 0.0032 P_L + 0.4005 L_C + 0.0424 P_L(t-1) \).
\[ R^2 = 0.91 \quad (0.0127) \quad (0.0496) \quad (0.0105) \]
\[ - 0.0838 Q_{CS}. \]
\[ (0.0631) \]

b) \( L_{S(t+1)} = -3.6329 + 0.0392 (P_L - 1.0816 (P_L - P_L(t-1))) \).
\[ + 0.4005 L_C - 0.0838 Q_{CS}. \]

5) \( S_K = -6.0217 + 0.3611 P_S - 1.2237 L_S(t+1) \).
\[ R^2 = 0.95 \quad (0.0456) \quad (0.1315) \]
\[ + 0.6872 S_S - 0.0536 P_{L(t-1)} - 0.0200 P_W. \]
\[ (0.0638) \quad (0.0152) \quad (0.0066) \]

6) \( L_K = L_C - (L_{S(t+1)} + L_{F(t+1)}). \)
Endogenous variables

\[ P_L = \text{deflated farm price for lamb (dollars/cwt.)} \]
\[ P_S = \text{deflated farm price for sheep (dollars/cwt.)} \]
\[ L_S = \text{number of lambs kept for stock (million head)} \]
\[ L_F = \text{number of lambs kept on feed (million head)} \]
\[ S_K = \text{number of sheep slaughtered (million head)} \]
\[ L_K = \text{number of spring lambs slaughtered (million head)} \]
\[ L_C = \text{lamb crop excluding deaths (million head)} \]
\[ S_S = \text{number of stock sheep excluding deaths (million head)} \]
\[ Q_{RM} = \text{production of other red meat (billion pounds)} \]
\[ L_F = \text{number of lambs on feed (million head)} \]
\[ P_L = \text{deflated farm price for lamb (dollars/cwt.)} \]
\[ Y = \text{deflated disposable income per capita (thousand dollars)} \]
\[ R = \text{U. S. D. A. index of range conditions for September (100 percent = 1.00)} \]
\[ P_W = \text{deflated farm price for wool (dollars/cwt.)} \]
\[ Q_{CS} = \text{production of feed corn and sorghum (billion bushels)} \]

"t" refers to year t.

The actual observations used for the computations are given in the appendix together with the source of the data. Two of the variables appear both as endogenous and predetermined variables, but this is because there is a difference in the time element.

The first equation is of essentially the same form as the
demand equations developed in Chapter V, but as imports are excluded from the system, no variable for mutton production is present. The signs of the coefficients are the same as those of the equivalent coefficients in the single equation model. The flexibility coefficients estimated using the average value of the variables are:

1. -1.2166 for the slaughter of lamb \((L_K + L_F)\).

2. -1.1776 for the production of other red meat \(Q_{RM}\).

3. +0.4230 for the disposable income \((Y)\).

The first two coefficients are both larger absolutely than the corresponding coefficient in Equation B, and both coefficients are price flexible (equivalent to price inelastic). Also a one percent change in lamb slaughter influences the price more than an equivalent change in the production of substitute meats. The structural coefficients show that the demand curve developed using the single equation technique tends to underestimate the influence that changes in lamb slaughter have on the price. With a flexible price an increase in the production of lamb would result in a decrease of the gross income of producers. K. A. Fox found that for the years 1922 to 1941 the farm price of lamb was flexible to changes in the production of lamb and mutton (20, p. 78). The income coefficient is positive and does not refute any of the conclusions reached in Chapter V.

To use a system of equations to predict values for one of the endogenous variables, it is necessary to solve the whole system.
This can be done by eliminating all the endogenous variables except the one to be predicted with the use of simple algebraic manipulation. In this way the endogenous variable is written as a function of all the predetermined variables, and the demand equation for lamb becomes:

Equation D

\[
P_L = 52.3436 - 0.0263L_C - 0.6812S - 1.3592Q_{RM} - 2.5153L_F + 0.1441P_{L(t-1)} + 6.5153Y + 14.3249R + 0.0198P_W - 0.2108Q_{CS}.
\]

\(R^2 = 0.93\)

The variables used in Equation D are identical to those described in System A and are not listed again. Due to the large number of variables in this equation, it is probably more convenient to use Equation B (Section 5.3) when considering the explanation of year to year changes of the price of lamb.

The second equation in System A shows that there is a very high correlation between the price of lamb and the price of mutton. This suggests that although the price of mutton is considerably lower than the lamb price, mutton is a substitute for lamb, and this is in agreement with the conclusions reached in Chapter V.

The supply function for stock lambs is rewritten in Equation 3b with the two lamb prices combined to form a single price variable, the expected price of lamb. This variable has the positive coefficient
of a supply function and includes a dynamic element in the form of the price change from one year to the next. The reason for using the expected price is to provide a more realistic variable than using only the current price. The coefficient is negative for sheep slaughter, which indicates that if producers wish to increase the number of stock ewes, more lambs are kept for stock and also less stock ewes are slaughtered. The positive coefficients for the size of the lamb crop and for range conditions indicate that more lambs are kept for stock with a large lamb crop and also if the conditions of the ranges are good.

The supply function for lambs on feed is also rewritten with an expected price variable which has the positive coefficient of a supply curve. The number of lambs on feed is positively related to the size of the lamb crop. The coefficient for the production of feed corn and sorghum has a negative sign, which is not consistent with economic theory. If the production of feed grain increases, the price would be expected to fall and provide an incentive to keep more lambs on feed. This sign probably relates to the improvement of the price of beef relative to lamb (Section 2.4), and Equation 4 gives a too simplified account of the economic relationships involved. To obtain an entirely satisfactory supply equation for the lambs kept for feed, it probably would be necessary to use a model of the whole meat industry similar to the one developed by C. Hildreth and F. G. Jarrett (23),
and such a model is outside the scope of this study.

The supply function for sheep slaughter shows the expected positive supply relationship with the price of sheep. The negative coefficient for stock lambs indicates a similar relationship to the one described for the supply function of stock lambs. The number of sheep slaughtered is as would be expected positively related to the number of stock sheep. In order to make the equation identified, no variable for the price of lamb is included, but as most ewes are slaughtered early in the year, the previous years lamb price is probably a more realistic variable than one that includes the current price of lamb. The negative sign of this variable indicates that if the price of lamb is high, less sheep are slaughtered, and so the size of the breeding flock is increased. Also fewer sheep are slaughtered if the price of wool is high. The variable for the price of wool is taken as predetermined, as it is governed predominately by the world market, and also may be influenced by the federal incentive payments. The negative coefficients for both the price of lamb and wool are consistent with economic theory, as producers would be expected to slaughter more sheep if the prospects for the industry are poor.
CHAPTER VII

CONCLUSION

Flexibility coefficients for the farm price of lamb have been estimated using both a single equation demand function and a system of simultaneous equations. The flexibility coefficient for the number of lambs slaughtered was estimated in the single equation (Equation 8, Section 5.3) to be -0.88, and this contrasts with the estimated structural flexibility coefficient of -1.22 (Section 6.3). The reason for this difference is probably that the single equation is biased due to the number of lambs slaughtered being partly dependent on the current price of lamb, and as a result, the slope of the demand curve is underestimated. The structural coefficient probably is a better estimate of the true coefficient, even though it refers only to a single point on the demand schedule, as there has been no significant trend over time of either the price or the production of lamb (Chapter II).

The general conclusion is that the price of lamb is slightly price flexible (price inelastic) to the number of lambs slaughtered, and a cut in production would be expected to increase the price proportionally more with other factors constant, and so increase the gross revenue of producers.

The coefficient for the production of substitute red meats was estimated as -1.11 in the single equation, and the structural
flexibility coefficient was -1.18. These two coefficients are very similar, and both indicate that the price of lamb is considerably influenced by the level of production of other red meats. Since 1945 the production of meat has expanded steadily, and most of the increase can be attributed to beef production (Section 2.1). This has resulted in a considerable decline in the price of lamb. In spite of this production expansion, the price of beef cattle has improved relative to lamb prices (Section 2.5). This improvement in the relative position of beef has been attributed partly to structural changes within the meat industry (Section 4.3). These structural changes, if attributed to the variable for other red meat, may account for the high flexibility coefficient for the years 1948 to 1963. In fact, this coefficient would be expected to become more inflexible with time unless structural changes continue to improve the position of beef relative to lamb. For the period 1922 to 1951 K. A. Fox (20, p. 50) estimated the coefficient of the production of substitute meats to be inflexible to the farm price of lamb, and the current coefficient may be expected to move towards the prewar level.

The coefficient for the disposable income per capita was estimated in the single equation to be +0.20, and the structural flexibility coefficient was +0.42. As neither of these coefficients are significantly different from zero, due probably to the high degree of multicollinearity with the variable for other red meat, the conclusions that
can be reached from these coefficients are limited. Also certain structural changes, such as the increase in the number of lamb consumers, may be attributed to the income variable. However, as both the coefficients are positive, the indication is that lamb prices do increase as income increases, and even though the consumption of lamb is low, lamb is not an inferior meat.

It was established in Chapter IV that mutton was an inferior meat to lamb, and so a change in the production of mutton would not be expected to influence the lamb price as much as an equivalent change in the production of lamb. As mutton imports into the US have become increasingly important, a variable for the total quantity of mutton available was included in Equation B. This variable contained a factor for the number of mutton carcasses imported, and so enabled an estimate to be made of the decline in price due to importing mutton. Although there has been a large increase in the quantity of mutton imported since 1958, the coefficient for sheep slaughter is very close to zero, and the maximum decline in lamb price was found to be $0.25/cwt. The estimated price differences are subject to certain restrictions that are discussed in Section 5.3, but the conclusion reached is that even if the importation of mutton was prevented, the price of lamb would not increase by a large amount. In fact, most of the decline in the price of lamb in recent years was shown to be attributable to increases in the slaughter of lambs and the production
of other red meat rather than the increase of mutton imports. There were indications discussed in Section 6.3 that the quantity of mutton imported was partly dependent on the current price of lamb. However, the data available were insufficient to develop a satisfactory function with the quantity of mutton imported as a dependent variable, and no other estimation of the impact of imported mutton on the price of lamb was made.

Although the relative importance of lamb production in the meat industry has declined between 1945 and 1963 in the US, in Oregon the production of lamb and mutton has increased proportionally more than any of the other red meat industries. The demand situation for lamb in Oregon is illustrated by Equation C (Section 5.4), and the coefficient for the lamb slaughter is considerably more inflexible to the price of lamb than was found for the US. However, the coefficient for the production of lamb in California shows a high degree of flexibility, and this indicates the important influence that the Californian market has on the lamb price in Oregon, as California provides an outlet for much of the surplus lamb produced in Oregon. There are indications in other studies that Oregon may have a considerable seasonable advantage in lamb production over other western states, as lambs can be slaughtered early in the year. One of the limitations of using annual prices in the analysis is that seasonal patterns cannot be isolated, and seasonal factors may be very important in estimating the market
It is difficult to evaluate the future trend in the price of lamb as there has been no significant change in the quantity of lamb and mutton produced between 1945 and 1963 on which to base a projection (Section 2.1). However, two important variables, the production of other red meat and the disposable income per capita, have followed a consistent expansionary trend. The analyses in Chapters V and VI include the years 1948 to 1963 and during this period the correlation coefficients against time are \( r = 0.96 \) and \( r = 0.98 \) respectively for the production of other red meat and the income variable. As both variables are predetermined in the structural model of the sheep industry, it is possible to determine the effect of these variables on the price of lamb.

For the period 1948 to 1963 linear regressions against time show that the production of other red meat has increased by 637 million pounds each year (equivalent to 2.70 percent of the average production), and the deflated disposable income has increased by 30 dollars each year (equivalent to 1.69 percent of the average income). The effect of these increases on the price of lamb can be estimated directly for the whole system using the coefficients in the single equation demand function (Equation D, Section 6.3). The coefficient for the production of other red meat is \(-1.3592\), and the increase in production is estimated to cause an annual decrease in the price of lamb.
of $0.87/cwt (production is measured in billion pounds in the model). The coefficient for the income variable is +6.5153 and the increase in income is estimated to result in an annual increase in the price of lamb of $0.20/cwt (income is measured in thousand dollars in the model). If both variables continue to expand by the same quantities, the net affect is estimated to cause a decline in the price of lamb of $0.67/cwt each year (equivalent to 3.05 percent of the average price). However, the structural model indicates that producers respond to a decrease in the price of lamb by reducing the size of the breeding flock and the number of lambs kept on feed. The breeding flock is made smaller by keeping fewer lambs for stock (Equation 3) and also by slaughtering a larger number of stock sheep (Equation 5). This would be expected to reduce the size of the following lamb crop and hence decrease the number of lambs slaughtered. The result would be to partially offset the decline in the price of lamb. The conclusion reached is that the price of lamb can only be maintained at the present level if the size of the breeding flock decreases each year.


3. American Sheep Producers Council, Inc. Lamb and the consumer. A research project in cooperation with the US Department of Agriculture. 1964. 22 numb. leaves.


29. Miller, J. E. Major economic factors affecting returns for lamb feeding in Texas. College Station, 1960. 6 p. (Texas. Agricultural Experiment Station. MP-435)


46. ________ How much progress has been made in the study of the demand for farm products? Journal of Farm Economics 37:968-974. 1955.
APPENDIX
Appendix Table 1.

<table>
<thead>
<tr>
<th>Year</th>
<th>$P_L^o$ $/cwt</th>
<th>$P_S^o$ $/cwt</th>
<th>L_S(t + 1) million head</th>
<th>L_F(t + 1) million head</th>
<th>S_K million head</th>
<th>L_C million head</th>
<th>S_S million head</th>
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<tbody>
<tr>
<td>1948</td>
<td>27.21</td>
<td>11.56</td>
<td>4.801</td>
<td>4.003</td>
<td>4.218</td>
<td>17.658</td>
<td>21.368</td>
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<td>1950</td>
<td>29.95</td>
<td>13.84</td>
<td>5.667</td>
<td>3.382</td>
<td>1.863</td>
<td>16.188</td>
<td>18.607</td>
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<tr>
<td>1951</td>
<td>34.25</td>
<td>17.68</td>
<td>5.876</td>
<td>4.038</td>
<td>2.542</td>
<td>16.253</td>
<td>19.089</td>
</tr>
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<td>1956</td>
<td>19.54</td>
<td>5.91</td>
<td>4.343</td>
<td>4.306</td>
<td>2.289</td>
<td>18.486</td>
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<td>1957</td>
<td>20.31</td>
<td>6.17</td>
<td>4.914</td>
<td>4.050</td>
<td>1.481</td>
<td>17.950</td>
<td>19.512</td>
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<td>5.005</td>
<td>4.411</td>
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<td>1962</td>
<td>16.89</td>
<td>5.38</td>
<td>4.157</td>
<td>4.062</td>
<td>2.891</td>
<td>18.251</td>
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<td>1963</td>
<td>16.96</td>
<td>5.40</td>
<td>3.952</td>
<td>3.618</td>
<td>2.650</td>
<td>17.354</td>
<td>19.188</td>
</tr>
</tbody>
</table>

Source: (37, p. 263) (37, p. 263) (37, p. 4) (37, p. 4) Identity Section 5.3 (37, p. 34) (37, p. 4)

Single Equation: A, B, D  B  D  D
Equation of System: A 1, 2, 3, 4  2, 5  3, 6  4, 6  3, 5  3, 4, 6  5

*Exclude deaths (37, p. 34)

^0Dollar value deflated by the Consumer Price Index (42, p. 261)
### Appendix Table 1 (Continued).

<table>
<thead>
<tr>
<th>Year</th>
<th>( Q_{R,M} ) billion pounds</th>
<th>( L_L ) million head</th>
<th>( P_{L(t-1)} ) $/cwt</th>
<th>( Y^o ) thousand $</th>
<th>( R ) 100% = 1.00</th>
<th>( P_{OC}^D ) $/cwt</th>
<th>( Q_{CS} ) billion pounds</th>
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<td>1948</td>
<td>18.575</td>
<td>4.851</td>
<td>26.35</td>
<td>1.541</td>
<td>0.81</td>
<td>58.71</td>
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<td>19.257</td>
<td>4.003</td>
<td>27.21</td>
<td>1.533</td>
<td>0.81</td>
<td>59.52</td>
<td>3.0947</td>
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<td>1950</td>
<td>19.782</td>
<td>3.644</td>
<td>26.99</td>
<td>1.634</td>
<td>0.84</td>
<td>74.11</td>
<td>2.9976</td>
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<td>19.711</td>
<td>3.382</td>
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<td>1.630</td>
<td>0.78</td>
<td>107.29</td>
<td>3.0918</td>
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<td>34.25</td>
<td>1.644</td>
<td>0.75</td>
<td>58.49</td>
<td>3.0715</td>
</tr>
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**Source**
- (37, p. 148)
- (37, p. 4)
- (37, p. 263)
- (42, p. 227)
- (37, p. 117)
- (37, p. 264)
- (41, p. 9)

**Single Equation**
- A, B, D
- B, D
- D
- A, B, D
- D
- D
- D

**Equation of System A**
- 1
- 1
- 3, 4, 5
- 1
- 3
- 5
- 4

*\( ^o \)Dollar value deflated by the Consumer Price Index (42, p. 261)
### Appendix Table 1 (Continued).

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<th>Year</th>
<th>L&lt;sub&gt;K&lt;/sub&gt; million head</th>
<th>Q&lt;sub&gt;L&lt;/sub&gt; million pounds</th>
<th>I million head</th>
<th>P&lt;sub&gt;LO&lt;/sub&gt;$/cwt</th>
<th>Q&lt;sub&gt;LO&lt;/sub&gt; thousand head</th>
<th>Q&lt;sub&gt;LC&lt;/sub&gt; thousand head</th>
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*Identity*<sup>3</sup>  
Source: Section 5.3  

Equation of System A: 1

*Dollar value deflated by the Consumer Price Index (42, p. 261)*