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An economic analysis of the tallow market

Robert Dean Remmele

Iowa State University

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An economic analysis of the tallow market

by

Robert Dean Remmele

A Thesis Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
MASTER OF SCIENCE

Department: Economics
Major: Agricultural Economics

Iowa State University
Ames, Iowa

1977
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<th>Description</th>
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<td>94a</td>
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</table>
CHAPTER I. INTRODUCTION

Fluctuations in the prices of by-products of primary agricultural commodities are caused by (1) changes or shifts in supply and demand schedules and (2) changes in quantities supplied and demanded. The extent of the price changes depends upon the price elasticities\(^1\) of supply and demand as well as upon the extent of the shifts in the supply and demand schedules. This study analyzes the supply and demand for one agricultural by-product, tallow, and determines how changes in supply and demand affect the price of tallow.

The tallow sector has been characterized by continued growth and by a transformation of the markets for tallow. The growth of the tallow sector was caused by the expansion of the livestock sector of the United States. Because tallow and beef are produced jointly, the expansion of beef production also increased the production of tallow.

The quantity of tallow produced is almost completely determined by the quantity of beef produced. Changes in the price of tallow have little effect upon the quantity of tallow produced. According to U.S. Department of Agriculture estimates [26, p. 278], tallow accounted for less than four

\(^1\)Price elasticities indicate the percent that quantity demanded or supplied changes as price changes one percent. The price elasticity of demand is defined as the ratio of the percent change in quantity to the percent change in price. The price elasticity of supply is defined similarly. If the elasticity, when defined as a positive number, is less than unity, so that a percentage change in price results in a smaller percentage change in consumption, we say that demand is inelastic. For such commodities, as supply increases the total value tends to decrease. If the elasticity is larger than unity, we say that demand is elastic. For such commodities, as supply increases the total value tends to increase. If the elasticity equals unity, then the total value remains unchanged regardless of the quantity.
percent of the carcass value of cattle. Thus, a ten percent increase in the price of tallow, with the price of other beef products constant, would increase the value of the beef carcass by only 0.004 percent. Reutlinger [16, p. 918] estimated the price elasticity of beef supply to be 0.162. Thus a full one percent increase in the value of the beef carcass would cause the quantity of beef supplied in future periods to increase by only 0.162 percent. A 10 percent increase in the price of tallow would increase the value of the beef carcass by 0.004 percent and the quantity of beef supplied would increase by approximately 0.0007 percent. If tallow production is a constant proportion of beef production, the 10 percent increase would cause the quantity of tallow supplied to increase by 0.0007 percent. Thus, the supply of tallow would be extremely price inelastic. Shifts in the supply schedule rather than movements along the supply schedule would be the major determinants of the quantity of tallow supplied.

Until 1950, the utilization of tallow was dominated by the soap industry. At that time, the soap market accounted for 70 percent of the U.S. tallow consumption. This market declined in importance since 1950 and now accounts for only 20 percent of the domestic consumption of tallow. Not only has the share of the domestic disappearance accounted for by the soap industry fallen, but the quantity of tallow consumed has also fallen from the 1950 levels. The soap industry consumed a record 1,363 million pounds of tallow in 1953, but only 662 million pounds of tallow were consumed by the soap industry in 1975.

The decline of the soap market as an outlet for tallow was caused by the replacement of tallow-based soaps by synthetic detergents. Synthetic
detergents replaced tallow-based soaps because the synthetic detergents were superior cleaning agents. Synthetic detergents performed much better than tallow-based soaps in "hard" water and also functioned in acidic solutions, a property that is important for several industrial cleaning purposes.

Fortunately, new markets for tallow were found. The major new market was the animal feed market; tallow is used in feeds as a concentrated source of energy. The first year that tallow utilization in feeds was reported by the U.S.D.A. was 1953. At that time, only 111 million pounds of tallow were consumed in animal feeds. Since then, the animal feeds market has become the largest domestic market for tallow. In 1975, 1,282 million pounds of tallow were consumed in animal feeds. This accounted for 47 percent of domestic utilization of tallow.

The other domestic growth market for tallow was the fatty acid market. A record of 889 million pounds of tallow were used by this market in 1973. Utilization of tallow by this sector fell in 1974 and 1975 because of the recession; however, this market still accounted for 25 percent of the domestic disappearance of tallow in 1975.

Approximately 570 million pounds of tallow were consumed annually in food products. Edible tallow was utilized as a shortening and a margarine ingredient.

Perhaps the most important development in marketing tallow was the growth of foreign demand for tallow. Exports expanded from 536 million pounds in 1950 to a high of 2,624 million pounds in 1974. Thus, the foreign markets played a major role in reducing the quantity of tallow in the United States.
Objectives of This Study

When studying agricultural prices, we need to measure how much the supply or demand changes and how much the price changes in response. The price change depends upon the price elasticities of supply and demand. The purpose of this study; therefore, is (1) to estimate the price elasticities of tallow supply and demand and (2) to identify and empirically evaluate the influence of outside forces upon the demand and supply curves of tallow.

These objectives are accomplished by specifying and statistically estimating supply and demand equations for the tallow sector. From the estimated equations, estimates of the price elasticities and measurements of the change in supply and demand resulting from changes in the values of the exogenous forces are derived.
CHAPTER II. WORLD MARKETS FOR FATS AND OILS

Since 1961, production and trade of fats and oils has expanded to meet rising demand stimulated by population and income growth around the globe. Production of all fats and oils has increased by 42 percent and exports have increased by 65 percent.

Because it is possible to substitute one fat or oil for another, the world's production and consumption of fats and oils will have an impact upon the tallow price and the quantity of tallow consumed. Therefore, the position of tallow in the fats and oils complex must be examined. The following sections present historical trends concerning the production, consumption, trade, and price of the major fats and oils. The role of tallow in the fats and oils complex is emphasized.

Production of Fats and Oils

The growth in production of fats and oils can only partially be attributed to the industry responding to increased demands caused by income and population growth. Other factors which caused the quantity of fats and oils produced to increase are (1) advances in soybean oil processing, (2) expansion of palm oil plantations, and (3) the growth of the livestock and poultry sectors of the world.

Improvements in the soybean oil extraction process increased the amount of soybean oil that could be obtained from a bushel of soybeans. Prior to 1947, about 70 percent of the soybean oil was obtained by mechanical processes. In this case, the crude oil is removed from cracked and flaked soybeans by mechanical pressure and heat. The other 30 percent
was processed by the chemical solvent method. In this process, dehulled, cracked, and flaked soybeans are introduced into a volatile fat solvent. The oil dissolves into the solvent and drains away from the flakes. Crude soybean oil is then recovered by vaporization of the solvent. The solvent method is more efficient in oil recovery and lower in per unit costs for larger mill sizes [5, p. 45].

Since 1947, most of the industry has converted to the solvent extraction process. As the industry converted to the solvent process, the average oil obtained from a bushel of processed beans increased from 9.7 pounds per bushel in 1947 to 10.6 pounds per bushel in 1967. Most of this increase was due to more efficient chemical extraction methods and to the higher average oil content of the beans [5, p. 45]. These factors increased the quantity of soybean oil supplied.

Expansion of plantations which produce palm oil has been another factor leading to increased production of fats and oils. Led by Malaysia and Indonesia, the world's production of palm oil has doubled since 1969. Currently palm oil accounts for 6 percent of all fats and oils produced, but palm oil production is expected to expand further and may double again by 1980 [2, p. 11].

The growth of the livestock and poultry sector indirectly caused the production of fats and oils to increase in three ways. First, the increased production of livestock directly led to increased production of tallow, especially in the United States. Second, oilseed production was expanded to satisfy protein requirements of the livestock industry. Oilseeds were produced primarily for their protein meal but oil was produced
jointly with the meal.\textsuperscript{1} Thus the volume of oils produced from oilseeds increased with the increased production of oilseeds. Third, the expanded livestock production was accompanied by the adoption of protein-intensive feeding practices. These feeding practices further stimulated the production of oilseeds for their protein content. The result was an increase in the production of oils.

\textbf{Production of vegetable oils}

Production of vegetable oils has grown faster than the production of animal fats. The faster rate of growth caused the share of the oils and fats production accounted for by vegetable oils to increase from 61.5 percent in 1961 to 68.4 percent in 1975. The growth of the vegetable oil sector was led by increased production of soybean oil. World production of soybean oil increased from 3,870 metric tons in 1961 to 10,195 metric tons in 1975 (see Table 1); this was primarily the result of increased production of soybeans for their meal content.

\textbf{Production of animal fats}

Even though the share of the fats and oils market that is accounted for by animal fats fell, the production of animal fats increased from 1961 to 1975. In 1961, there were 12,710 metric tons of butter, lard, and tallow produced; this volume increased to 14,860 metric tons in 1975 (see Table 1).

\textsuperscript{1}Each bushel of soybeans yields approximately 10 pounds of oil and 48 pounds of protein meal.
Tallow production grew from 3,695 metric tons in 1961 to 5,470 metric tons in 1975 (see Table 1). The rate of growth of tallow production has been almost the same as the rate of growth of the total fats and oils economy. Thus, the share of the fats and oils production accounted for by tallow has remained relatively constant at approximately 11 percent.

Table 1. World production of selected fats and oils, 1961-1975a

<table>
<thead>
<tr>
<th>Year</th>
<th>Soybean</th>
<th>Coconut</th>
<th>Palm</th>
<th>Butter</th>
<th>Lard</th>
<th>Tallow</th>
<th>Other</th>
<th>Total</th>
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<tbody>
<tr>
<td>1961</td>
<td>3870</td>
<td>2130</td>
<td>1085</td>
<td>4625</td>
<td>4390</td>
<td>3695</td>
<td>13250</td>
<td>33045</td>
</tr>
<tr>
<td>1962</td>
<td>4250</td>
<td>2115</td>
<td>1050</td>
<td>4700</td>
<td>4465</td>
<td>3790</td>
<td>14005</td>
<td>34375</td>
</tr>
<tr>
<td>1963</td>
<td>4395</td>
<td>2180</td>
<td>1100</td>
<td>4650</td>
<td>4240</td>
<td>4105</td>
<td>13910</td>
<td>34580</td>
</tr>
<tr>
<td>1964</td>
<td>4540</td>
<td>2230</td>
<td>1125</td>
<td>4750</td>
<td>4095</td>
<td>4345</td>
<td>15210</td>
<td>36295</td>
</tr>
<tr>
<td>1965</td>
<td>4840</td>
<td>2220</td>
<td>1120</td>
<td>5040</td>
<td>4150</td>
<td>4200</td>
<td>15630</td>
<td>37200</td>
</tr>
<tr>
<td>1966</td>
<td>5305</td>
<td>2335</td>
<td>1140</td>
<td>5060</td>
<td>4150</td>
<td>4365</td>
<td>15500</td>
<td>37855</td>
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<td>1967</td>
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<td>2220</td>
<td>1305</td>
<td>5195</td>
<td>3995</td>
<td>4950</td>
<td>16785</td>
<td>40095</td>
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<tr>
<td>1969</td>
<td>6090</td>
<td>2065</td>
<td>1390</td>
<td>5065</td>
<td>3910</td>
<td>5055</td>
<td>16360</td>
<td>39935</td>
</tr>
<tr>
<td>1970</td>
<td>7700</td>
<td>2375</td>
<td>1745</td>
<td>4950</td>
<td>4365</td>
<td>5270</td>
<td>15085</td>
<td>41490</td>
</tr>
<tr>
<td>1971</td>
<td>7500</td>
<td>2565</td>
<td>1905</td>
<td>5205</td>
<td>4265</td>
<td>5235</td>
<td>15685</td>
<td>42360</td>
</tr>
<tr>
<td>1972</td>
<td>8035</td>
<td>2445</td>
<td>2010</td>
<td>5305</td>
<td>4075</td>
<td>5070</td>
<td>14965</td>
<td>41905</td>
</tr>
<tr>
<td>1973</td>
<td>9535</td>
<td>2050</td>
<td>2265</td>
<td>5265</td>
<td>4215</td>
<td>5600</td>
<td>16325</td>
<td>45255</td>
</tr>
<tr>
<td>1974</td>
<td>8620</td>
<td>2490</td>
<td>2655</td>
<td>5295</td>
<td>4275</td>
<td>5335</td>
<td>16096</td>
<td>44766</td>
</tr>
<tr>
<td>1975</td>
<td>10195</td>
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<td>2930</td>
<td>5315</td>
<td>4075</td>
<td>5470</td>
<td>16215</td>
<td>46970</td>
</tr>
</tbody>
</table>

Source: [36].

World Trade of Fats and Oils

World trade of fats and oils has also expanded; in fact, the rate of increase in world trade has been faster than the rate of increase in world production of fats and oils. From 1961 to 1975, trade of fats and oils expanded by 65.7 percent.
The proportions of production of individual oils that are exported tend to vary greatly. For the palm type oils, palm and coconut, the percentage of production which was exported was greater than 50 percent; but for butter, for example, the proportion of production which was exported was only 12.6 percent. Thus, increased production of the palm type oils will have a greater impact upon the world's fats and oils market than would an equivalent increase in the production of butter.

Tallow was the only major animal fat of which a substantial percentage of production was exported. In 1975, over 26 percent of the tallow production was exported. Only 9.6 percent of the lard production was exported.

Table 2. Exports of fats and oils as a percentage of production

<table>
<thead>
<tr>
<th>Fat or oil</th>
<th>Production (metric tons)</th>
<th>Exports</th>
<th>Percent of production exported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palm</td>
<td>2930</td>
<td>1808</td>
<td>61.7</td>
</tr>
<tr>
<td>Coconut</td>
<td>2770</td>
<td>1517</td>
<td>54.4</td>
</tr>
<tr>
<td>Peanut</td>
<td>3440</td>
<td>1517</td>
<td>44.1</td>
</tr>
<tr>
<td>Soybean</td>
<td>10195</td>
<td>3604</td>
<td>35.4</td>
</tr>
<tr>
<td>Tallow</td>
<td>5470</td>
<td>1454</td>
<td>26.6</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>2610</td>
<td>604</td>
<td>23.1</td>
</tr>
<tr>
<td>Sunflower</td>
<td>3425</td>
<td>659</td>
<td>19.2</td>
</tr>
<tr>
<td>Cottonseed</td>
<td>2520</td>
<td>386</td>
<td>15.3</td>
</tr>
<tr>
<td>Butter</td>
<td>5315</td>
<td>671</td>
<td>12.6</td>
</tr>
<tr>
<td>Lard</td>
<td>4075</td>
<td>391</td>
<td>9.6</td>
</tr>
</tbody>
</table>

Sources: [36].

World trade of fats and oils was dominated by soybean oil. Soybean oil accounted for 26 percent of the fats and oils exported in 1975. Ranked second and third were palm oil and coconut oil, respectively. Palm
and coconut oil were elevated to these positions in 1975 because of the large increase in production of these oils since 1969. Prior to 1975, the quantity of tallow exported was second to soybean oil; tallow was in fourth place in 1975 in terms of quantity exported.

Table 3. World exports of selected fats and oils, 1961-1975

<table>
<thead>
<tr>
<th>Year</th>
<th>Soybean</th>
<th>Coconut</th>
<th>Palm</th>
<th>Butter</th>
<th>Peanut</th>
<th>Tallow</th>
<th>Other</th>
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<td>(metric tons)</td>
<td></td>
<td></td>
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<tr>
<td>1961</td>
<td>1029</td>
<td>1266</td>
<td>568</td>
<td>477</td>
<td>857</td>
<td>1051</td>
<td>3078</td>
<td>8326</td>
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<td>1962</td>
<td>1426</td>
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<td>984</td>
<td>1013</td>
<td>3215</td>
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<td>3338</td>
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<tr>
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<td>631</td>
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<td>1968</td>
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<td>641</td>
<td>817</td>
<td>1517</td>
<td>4208</td>
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<td>1971</td>
<td>3006</td>
<td>1291</td>
<td>971</td>
<td>571</td>
<td>700</td>
<td>1620</td>
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<td>12610</td>
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<td>1524</td>
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<td>527</td>
<td>881</td>
<td>1589</td>
<td>4710</td>
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<td>1973</td>
<td>3360</td>
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<td>827</td>
<td>1488</td>
<td>4594</td>
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<td>1974</td>
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<td>933</td>
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<td>671</td>
<td>718</td>
<td>1454</td>
<td>4028</td>
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</tbody>
</table>

*Source: [36].

World Consumption of Fats and Oils

Consumption of fats and oils can be separated into three distinct categories: industrial oils, visible food oils, and invisible food oils. Fats and oils are used by industry as raw materials for the manufacture of soap, as energy sources in animal feeds, and as raw materials for the production of fatty acids, lubricants, and other minor products. The visible food oil category is composed of shortening products, margarine,
salad oils, butter, and other similar uses. Fats which are consumed through meats, milk, cheese, and eggs compose the invisible food oil category. This latter category will not be considered further in this study.

The U.S. visible food oil sector is approximately twice as large as the industrial oil sector. The average annual consumption of food oils from 1966 to 1975 was 10,683 million pounds per year; the industrial consumption of oils averaged 5,325 million pounds per year. Table 4 lists the annual domestic consumption of food and industrial oils for the years 1966 to 1975.

Table 4. Domestic disappearance of food and nonfood fats and oils

<table>
<thead>
<tr>
<th>Year</th>
<th>Disappearance in foods</th>
<th>Disappearance in nonfoods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966</td>
<td>9721</td>
<td>5432</td>
</tr>
<tr>
<td>1967</td>
<td>9805</td>
<td>5327</td>
</tr>
<tr>
<td>1968</td>
<td>10249</td>
<td>5359</td>
</tr>
<tr>
<td>1969</td>
<td>10466</td>
<td>5492</td>
</tr>
<tr>
<td>1970</td>
<td>10862</td>
<td>5337</td>
</tr>
<tr>
<td>1971</td>
<td>10761</td>
<td>5293</td>
</tr>
<tr>
<td>1972</td>
<td>11071</td>
<td>5392</td>
</tr>
<tr>
<td>1973</td>
<td>11338</td>
<td>5157</td>
</tr>
<tr>
<td>1974</td>
<td>11241</td>
<td>5452</td>
</tr>
<tr>
<td>1975</td>
<td>11321</td>
<td>5014</td>
</tr>
</tbody>
</table>

*aSource: [29].

The industrial oils sector

The fats and oils that are consumed in industrial uses are usually the inedible fats and oils. Edible oils are generally more expensive than inedible oils, thereby prohibiting their use for industrial purposes.
However, foots\textsuperscript{1} of the edible oils are produced in large quantities and are priced competitively with the inedible fats and oils. Foots have, therefore, become an important raw material for industrial users of inedible oils.

Tallow has dominated the industrial fats and oils market. Since 1965, tallow accounted for 48 percent of the total U.S. nonfood uses of fats and oils [29]. Other industrial type oils are linseed oil, tung oil, castor oil, and tall oil.

Worldwide, the largest industrial use of tallow was the production of soap. Although synthetic detergents captured a major portion of the detergent markets of the industrialized countries, the less developed countries are expanding their consumption of tallow-based soaps.

\textbf{The visible food oils sector}

Soybean oil has been the leading vegetable oil in the visible food fat economy of the United States. In 1960, soybean oil accounted for 36 percent of domestic food fat consumption, but by 1973 it accounted for 57 percent of a 35 percent larger market [29]. Butter, lard, and cottonseed oil are the other major food fats in the domestic market. Other oils that are consumed domestically as margarine and cooking oils are palm oil, coconut oil, corn oil, and edible grades of tallow.

For the period from 1973 to 1975, per capita consumption of visible fats and oils in the United States was approximately 53 pounds annually. The largest use of food fats was for shortenings; the per capita

\textsuperscript{1}Foots are the semisolid residue which settles to the bottom of the tank or car in which crude oils are stored or shipped.
consumption of shortenings was 16.6 pounds per year. Margarine was the second largest consumption category with a per capita consumption of 11.3 pounds yearly [29].

There has been a definite shift from the consumption of edible animal fats--butter, lard, and edible tallow--to the consumption of edible vegetable oils. This resulted from increased consumer acceptance of vegetable oil substitutes for butter and lard and the trend away from saturated animal fats for health reasons. Consumption of the edible animal fats fell from 42 percent of the food fats in 1960 to 19 percent in 1975. This trend is projected to continue as greater quantities of vegetable oils become available [29].

Table 5. Domestic consumption of food fats and oils

<table>
<thead>
<tr>
<th>Fat or oil consumed</th>
<th>1960</th>
<th>1965</th>
<th>1970</th>
<th>1975</th>
<th>1985(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(millions of pounds)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean oil</td>
<td>2989</td>
<td>4218</td>
<td>5780</td>
<td>6696</td>
<td>7905</td>
</tr>
<tr>
<td>Other vegetable oils</td>
<td>1856</td>
<td>2447</td>
<td>2083</td>
<td>2244</td>
<td>3409</td>
</tr>
<tr>
<td>Animal fats</td>
<td>3458</td>
<td>3146</td>
<td>2984</td>
<td>2130</td>
<td>2357</td>
</tr>
<tr>
<td>Total</td>
<td>8303</td>
<td>9811</td>
<td>10847</td>
<td>11070</td>
<td>13671</td>
</tr>
</tbody>
</table>

|                     | (percent) |        |        |        |             |
| Soybean oil         | 36.0      | 43.0   | 53.3   | 60.5   | 57.8        |
| Other vegetable oils| 22.4      | 24.9   | 19.2   | 20.3   | 24.9        |
| Animal fats         | 41.6      | 32.1   | 27.5   | 19.2   | 17.3        |

\(^a\)Source: [29].

\(^b\)Projected.
Factors which influence the consumption of fats and oils

Income  In the developed countries, the per capita consumption of fats and oils has nearly reached the saturation level. It is unlikely that further increases in income will induce substantial increases in the consumption of fats and oils. This hypothesis is supported by estimated income elasticities of demand for fats and oils. The income elasticity of demand is the relative responsiveness of quantity demanded to changes in income. In other words, it is the proportional change in the quantity demanded divided by the proportional change in nominal income. The Food and Agriculture Organization [23] estimated that the income elasticity of demand for fats and oils in the United States was 0.04; the estimated elasticity for Canada was 0.01. This indicates that consumption of fats and oils in the United States would increase by 0.4 percent if income were to increase by 10 percent. The expected change in the quantity of fats and oils demanded would be even less in Canada. The estimated income elasticities were higher in the European Economic Community (EEC) countries; the average estimated income elasticity of demand for the EEC countries was 0.22. Southern Europe and Japan had income elasticities which were considerably higher than those of the other developed countries; the estimated elasticities were 0.30 and 0.52 for Southern Europe and Japan, respectively.

1 Three types of demand functions were used by the Food and Agriculture Organization to derive the income elasticities: logarithmic, semi-logarithmic, and log-inverse. The logarithmic and semi-log functions were used to estimate the income elasticities in the developing countries where the consumption is far below the saturation level. The log-inverse function was used to estimate the elasticities in the developed countries. The elasticities derived by this function tend to zero when income tends toward infinity.
### Table 6. Income elasticities of demand for fats and oils

<table>
<thead>
<tr>
<th>Countries and Regions</th>
<th>Elasticity</th>
<th>Countries and Regions</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td></td>
<td>Japan</td>
<td>0.52</td>
</tr>
<tr>
<td>United States</td>
<td>0.04</td>
<td>Australia</td>
<td>0.02</td>
</tr>
<tr>
<td>Canada</td>
<td>0.01</td>
<td>New Zealand</td>
<td>0.01</td>
</tr>
<tr>
<td>Western Europe</td>
<td>0.23</td>
<td>Latin America</td>
<td>0.40</td>
</tr>
<tr>
<td>Bel-Lux.</td>
<td>0.13</td>
<td>Cuba</td>
<td>0.42</td>
</tr>
<tr>
<td>Germany</td>
<td>0.18</td>
<td>Mexico</td>
<td>0.35</td>
</tr>
<tr>
<td>France</td>
<td>0.22</td>
<td>Venezuela</td>
<td>0.47</td>
</tr>
<tr>
<td>Italy</td>
<td>0.42</td>
<td>Argentina</td>
<td>0.16</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.15</td>
<td>Brazil</td>
<td>0.43</td>
</tr>
<tr>
<td>Northern Europe</td>
<td>0.14</td>
<td>Paraguay</td>
<td>0.49</td>
</tr>
<tr>
<td>Austria</td>
<td>0.26</td>
<td>Uruguay</td>
<td>0.11</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.08</td>
<td>Africa</td>
<td>0.80</td>
</tr>
<tr>
<td>Finland</td>
<td>0.12</td>
<td>Ethiopia</td>
<td>0.59</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.17</td>
<td>Kenya</td>
<td>0.60</td>
</tr>
<tr>
<td>Norway</td>
<td>0.14</td>
<td>Madagascar</td>
<td>0.79</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.10</td>
<td>Malawi</td>
<td>0.68</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.12</td>
<td>Mozambique</td>
<td>0.57</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0.14</td>
<td>Uganda</td>
<td>0.62</td>
</tr>
<tr>
<td>Near East</td>
<td>0.60</td>
<td>Far East</td>
<td>0.90</td>
</tr>
<tr>
<td>Iran</td>
<td>0.72</td>
<td>Burma</td>
<td>0.75</td>
</tr>
<tr>
<td>Iraq</td>
<td>0.71</td>
<td>Ceylon</td>
<td>0.62</td>
</tr>
<tr>
<td>Jordan</td>
<td>0.48</td>
<td>India</td>
<td>1.03</td>
</tr>
<tr>
<td>Lebanon</td>
<td>0.43</td>
<td>Indonesia</td>
<td>0.81</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>0.74</td>
<td>Malaysia</td>
<td>0.67</td>
</tr>
<tr>
<td>Sudan</td>
<td>0.55</td>
<td>Korea</td>
<td>0.90</td>
</tr>
<tr>
<td>Syria</td>
<td>0.61</td>
<td>Thailand</td>
<td>0.67</td>
</tr>
<tr>
<td>U.A.R.</td>
<td>0.62</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Source: [23].

In the less developed countries (LDC), the per capita consumption of fats and oils is much lower than the per capita consumption in the developed countries. Fats and oils are often scarce so that they may be considered a luxury item in the LDC. As per capita incomes in these countries rises, it is expected that consumption of fats and oils would increase considerably. The estimated income elasticities of demand in the LDC were generally much higher than those of the developed countries; the
estimated elasticities varied from a low of 0.60 to a high of 1.03 (see Table 6).

**Population**  Consumption of fats and oils tends to increase proportionately with increases in the population.

**Regional consumption patterns**  Consumption patterns for fats and oils tend to follow geographic production patterns. Areas which are large producers of animal fats tend to be large consumers of these fats. Likewise, areas which produce palm-type oils consume large quantities of these oils.

The consumption of locally produced oils may take place even though less expensive oils are available. For example, palm oil and coconut oil have been used extensively in Asian countries for manufacturing soaps even though less expensive industrial type oils were available on the world markets. The consumption of more expensive locally produced oils occurs because (1) local oils often receive economic protection through import tariffs on foreign oils, (2) transportation facilities do not always exist which are needed to bring imported oils to interior markets, and (3) consumers will often buy local oils out of habit rather than purchase less expensive foreign oils.

**Technology**  From a technical point of view, most fats and oils are interchangeable since the various characteristics of the oils can be altered by processing. The ability to deodorize, harden, bleach, and preserve fats and oils has enabled individual oils to enter new markets, thereby increasing competition among the oils. For example, the hardening of soybean oil enabled this oil to be used in margarine and compete with
butter. These technological advances have made it possible to use a wider variety of fats and oils for the final product.

Because technology has made substitution possible, the relative prices of fats and oils will often determine how much of a certain fat or oil will be used in a final product. For some products, any increase in the price of one oil will eliminate the oil from being used. For products which use a combination of several fats and oils, such as margarine or shortening, an increase in the price of one fat or oil relative to the price of the others may only change the mix of fats and oils. In this case, the more expensive oil may continue to be used, but in a smaller proportion. Other products may not react to changes in the relative prices of fats and oils. In order to produce a product of "superior" quality, a firm may continue to use a more expensive oil rather than substitute a less expensive oil which might alter the characteristics of the final good.

Price Trends of Fats and Oils

Prices of fats and oils tend to move together because of the ability of consumers to substitute less expensive fats and oils for more expensive ones. Consumers of oil are likely to substitute less expensive oils whenever the price of an individual oil rises relative to the price of others. The increased demand for the substitute oils will then raise the price of the substitute oils so that the relative price differences are decreased.

During the period of 1950 to 1971, prices of fats and oils were relatively stable. Part of this stability can be attributed to government
programs which affected the price of soybeans. Two programs that directly affected the price of soybeans are (1) the price-support system for soybeans at the farm level and (2) exports of soybean oil under P.L. 480.

The price-support system established a national floor price for soybeans. Farmers could sell their beans on the market or place them in storage as collateral for a government loan at the support rate. If market prices moved high, farmers usually sold their stored soybeans on the open market and paid off the loan at the support rate plus interest. If market prices were near or below the loan rate, farmers retained the loan cash and consigned the beans to the government in full payment of the loan. The Commodity Credit Corporation (CCC), the government agency which handled the price support system, acquired stocks of soybeans in years when the market prices and support prices were close together. In other years, the CCC would sell its holding of soybeans when market prices moved above support rates by a specified amount. Over the years, the support rate generally had been lower than the open market price for soybeans. Thus, the support rate did not have a major impact on the price of soybeans.

Government programs have also indirectly influenced the price of soybeans. Price-support and acreage restrictions for other commodities which compete with soybeans for available cropland had an indirect effect on the supply of soybeans and hence, the price of soybeans was also influenced.

These actions tended to stabilize the price of soybeans and hence the price of soybean oil. Because soybean oil has dominated both domestic consumption and world trade of fats and oils, these programs tended to stabilize the prices of other fats and oils also.
In 1973 and 1974, prices for fats and oils reached record highs in the United States due to a combination of factors: crop failures in several Asian countries made the importation of U.S. food grains a necessity; the devaluation of the dollar made U.S. grains more attractive to foreign purchasers; the U.S. crops in these years did not reach the expected production levels; large purchases of grain by the Russians reduced stocks of grain in the United States. The combination of these factors caused the price of domestic soybeans and other grains to increase. As the price of soybeans rose, so did the price of soybean oil. The price of other fats and oils soon followed the soybean oil price increase.

In 1974, the price of tallow reached a high of 20.7 cents per pound of tallow. This was more than double the average price of tallow for the years 1950-1972. Over the period from 1950-1972, the price of tallow had varied between 4 and 8 cents per pound. Since 1974, the price of tallow has again fallen. The price of tallow has remained near 15 cents per pound since 1974.

The price of tallow has been much lower than the price of the major edible fats and oils. The tallow price has been approximately 60 percent of the price of soybean oil for the period from 1950 to 1975. This percentage has varied, though, from a low of 35 percent to a high of 87 percent of the soybean oil price.

The long term price movements of soybean oil, lard, tallow, coconut oil, and palm oil are graphed in Figures 1 and 2. It can be seen that the price of tallow was consistently lower than the price of other oils. Palm and coconut oil were the most expensive of the major oils.
These figures show that the fluctuations in the price of fats and oils were much smaller over the period that government stabilization programs were in effect. Prior to 1955, the prices of fats and oils often changed by 100 percent from year to year. Changes of this magnitude also occurred after 1972. From 1972 to 1974, prices of fats and oils nearly tripled. However, over the stabilization period, price fluctuations were generally less than 33 percent from year to year.
Figure 1. Prices of soybean oil, lard, and tallow, 1930-1975

Soybean oil \( Z \)

Lard \( Y \)

Tallow \( X \)
Figure 2. Prices of palm oil, coconut oil, and tallow, 1930-1975

Palm oil  \( Z \)
Coconut oil  \( Y \)
Tallow  \( \bar{X} \)
CHAPTER III. THE SUPPLY AND DEMAND OF TALLOW

The objectives of this chapter are (1) to identify and evaluate the forces that shift the tallow supply and demand schedules and (2) to determine what impact price changes have upon the quantity of tallow supplied and demanded. These objectives are accomplished by using ordinary least squares regression techniques to estimate supply and demand equations.

The Data and Variables

This study uses secondary data obtained from government publications for the analysis. The data are calendar quarter figures for the ten year period from the first quarter of 1966 through the fourth quarter of 1975. Much of the quarterly data was obtained by averaging or summing monthly data. Monthly production and consumption variables were summed to obtain quarterly data; for example, the production of tallow in the first quarter of each year was obtained by summing the reported production of January, February, and March. Quarterly prices were obtained by averaging the prices of the three months of each quarter.

The number of fed cattle marketings was not reported by the U.S. Department of Agriculture prior to 1973. Data for fed cattle marketings (FCM) from 1966 to 1973 were obtained following the method used by Kamal-Abdou [7, p. 74]. Fed cattle marketings from 39 states were estimated through the following equation:

\[ FCM = 245.44 + 1.0006 \times FCM_{23} \]

where FCM 23 is the reported number of fed cattle marketings from 23
states. Thus, the FCM series consists of constructed data for the time period 1966 to 1972 and U.S.D.A. reported figures for 1973 to 1975.

A second variable, nonfed steers and heifer marketings (NFSH) was also derived. Subtracting FCM from TCCS (total commercial cattle slaughter) gives the total number of nonfed cattle marketings, TNFCM; TNFCM = TCCS - FCM. TNFCM consists of nonfed steers and heifers, cows, bulls and stags, and calves. By subtracting the reported slaughter of cows, bulls and stags, and calves from the total nonfed cattle marketings we get the number of nonfed steers and heifers; NFSH = TNFCM - COWS - BULLS - CALVES.

A final variable which was constructed was the quantity of feed consumed by broilers, BRF. The procedure to construct this variable is discussed in Appendix A.

Table 7. Endogenous variables

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Unit of measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export</td>
<td>Mil. lb.</td>
<td>Exports of inedible tallow and grease</td>
</tr>
<tr>
<td>Fatty acids</td>
<td>Mil. lb.</td>
<td>Consumption of tallow in fatty acids</td>
</tr>
<tr>
<td>Feed</td>
<td>Mil. lb.</td>
<td>Consumption of tallow in animal feeds</td>
</tr>
<tr>
<td>Food</td>
<td>Mil. lb.</td>
<td>Consumption of tallow in foods</td>
</tr>
<tr>
<td>Soap</td>
<td>Mil. lb.</td>
<td>Consumption of tallow in soap manufacture</td>
</tr>
<tr>
<td>TTQ</td>
<td>Mil. lb.</td>
<td>Production of tallow</td>
</tr>
<tr>
<td>Variable name</td>
<td>Unit of measure</td>
<td>Description</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>BIMP</td>
<td>Mil. lb.</td>
<td>Imports of beef</td>
</tr>
<tr>
<td>BRF</td>
<td>Mil. lb.</td>
<td>Feed consumed by broilers</td>
</tr>
<tr>
<td>CADW</td>
<td>Lb.</td>
<td>Average dressed weight of cows</td>
</tr>
<tr>
<td>COWS</td>
<td>1000 head</td>
<td>Commercial cow slaughter</td>
</tr>
<tr>
<td>CP</td>
<td>$</td>
<td>Price per bushel of corn</td>
</tr>
<tr>
<td>D2</td>
<td>--</td>
<td>One in second quarter, zero otherwise</td>
</tr>
<tr>
<td>D3</td>
<td>--</td>
<td>One in third quarter, zero otherwise</td>
</tr>
<tr>
<td>D4</td>
<td>--</td>
<td>One in fourth quarter, zero otherwise</td>
</tr>
<tr>
<td>DDYN</td>
<td>$</td>
<td>Deflated disposable income per capita</td>
</tr>
<tr>
<td>FABRIC</td>
<td>Mil. linear yards</td>
<td>Production of woven fabrics</td>
</tr>
<tr>
<td>FBQ</td>
<td>Mil. lb.</td>
<td>Fed beef production</td>
</tr>
<tr>
<td>FCADW</td>
<td>Lb.</td>
<td>Average dressed weight of fed cattle</td>
</tr>
<tr>
<td>FCM</td>
<td>1000 head</td>
<td>Fed cattle marketings</td>
</tr>
<tr>
<td>HAW</td>
<td>Lb.</td>
<td>Average liveweight of hogs</td>
</tr>
<tr>
<td>HQ</td>
<td>1000 head</td>
<td>Commercial hog slaughter</td>
</tr>
<tr>
<td>JIIP</td>
<td>--</td>
<td>Index of Japanese industrial production, 1963=100</td>
</tr>
<tr>
<td>NFADW</td>
<td>Lb.</td>
<td>Average dressed weight of nonfed cattle</td>
</tr>
<tr>
<td>NFBQ</td>
<td>Mil. lb.</td>
<td>Nonfed beef production</td>
</tr>
<tr>
<td>NFBQ*</td>
<td>Mil. lb.</td>
<td>Nonfed beef production minus veal production</td>
</tr>
<tr>
<td>NFCM</td>
<td>1000 head</td>
<td>Nonfed cattle marketings; COWS+NFSH +CALVES+BULLS+STAGS</td>
</tr>
<tr>
<td>NFSH</td>
<td>1000 head</td>
<td>Nonfed steer and heifer marketings</td>
</tr>
<tr>
<td>Variable name</td>
<td>Unit of measure</td>
<td>Description</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>PLA80</td>
<td>Mil. lb.</td>
<td>Shipments of tallow and grease under P.L. 480</td>
</tr>
<tr>
<td>POP</td>
<td>c</td>
<td>Cents per pound for palm oil, tank cars, New York</td>
</tr>
<tr>
<td>PQ</td>
<td>Mil. lb.</td>
<td>Commercial production of pork</td>
</tr>
<tr>
<td>SBMP/CP</td>
<td>--</td>
<td>Ratio of cents per pound of soybean meal to cents per pound of corn</td>
</tr>
<tr>
<td>SBOP</td>
<td>c</td>
<td>Cents per pound for soybean oil, crude, tank cars, Decatur</td>
</tr>
<tr>
<td>SHADW</td>
<td>Lb.</td>
<td>Average dressed weight of steers and heifers</td>
</tr>
<tr>
<td>T</td>
<td>--</td>
<td>Linear trend, 1=first quarter 1966, 2=second quarter 1966,..., 40=fourth quarter 1975</td>
</tr>
<tr>
<td>T1</td>
<td>--</td>
<td>Trend, 1=first quarter of 1966, 2=second quarter of 1966,..., 25=fourth quarter of 1971, 25 thereafter</td>
</tr>
<tr>
<td>T2</td>
<td>--</td>
<td>Trend, 1=first quarter of 1972, 2=second quarter of 1972,..., 16=fourth quarter of 1975; 0 otherwise</td>
</tr>
<tr>
<td>TP</td>
<td>c</td>
<td>Price per pound of tallow, bleachable, fancy, Chicago</td>
</tr>
<tr>
<td>UNEMP</td>
<td>%</td>
<td>Rate of civilian unemployment</td>
</tr>
</tbody>
</table>
The Supply of Tallow

Production of tallow

Tallow is produced by a process called rendering. This process converts animal raw materials into tallow and other by-products. In most cases, the fatty tissues are cooked, and the fat is released by temperature and cell rupture. In other processes, the temperature is kept low, and the fat is released primarily through physical rupture of the cells.

There are two differences between rendering edible and inedible material. First, the composition and freshness of the materials determines whether or not the material can be rendered as edible. Only those fats from certain carcass locations of sound, healthy animals may be rendered as edible. Offal and fat from esthetically nonappealing parts of the carcass are separated and rendered as inedible. Most animals delivered dead or diseased to the packing plant must be rendered as inedible. Second, the process used to render edible materials differs from the process used to render inedible materials. Edible rendering is usually conducted by a wet or low temperature process. This process usually produces a product which is low in free fatty acids, has little color, and has a mild flavor. Almost all inedible tallows are produced by dry rendering where the material is cooked with no addition of water.

1"Tallow" as used in this study is synonymous with "tallow and grease." Most tallow is rendered from beef fat. Cattle slaughter probably provides over three-fourths of the tallow production. Grease is obtained mainly from pork fat and depends largely on hog slaughter. Census reports on production, use and stocks did not show separate statistics for tallow and grease until 1976.
When sufficient moisture has been cooked out and the fat released from the tissue, the mixture is dumped into strainers where the cracklings (the residue left after the fat has been separated from the tissue) are removed.

There are two principal producers of tallow: independent renderers and captive renderers. Independent renderers reprocess discarded animal materials such as fats, bones, hides, feathers, blood, offal, and dead stock into saleable by-products, almost all of which are inedible for human consumption. Captive rendering operations are usually part of a meat packing or poultry processing operation and are housed in a separate building on the same premises. Captive renderers produce almost all of the edible tallow in addition to producing inedible by-products.

While the captive renderers obtain most of their raw animal material from the packing plant, independent renderers must send out trucks daily to collect discarded fat and bone trimmings, meat scraps, blood, feathers, and entire animal carcasses from butcher shops, supermarkets, restaurants, poultry processors, slaughterhouses, farmers, and ranches.

As of 1968, there were 770 firms operating 850 facilities engaged in the rendering of inedible animal matter. Independent renderers operated 460 facilities and 330 were controlled by the meat packing and poultry industries. It is estimated that 275 of the plants controlled by the meat industry are involved in edible rendering [36, p. 11].
Factors influencing the quantity of tallow supplied

Beef and tallow are joint products; that is, they are "commodities which have a common origin and are produced simultaneously with the processing of the original commodity" [5, p. 11]. The slaughter of cattle, therefore, yields meat, tallow, and other by-products.

Beef production increased in the past 25 years in response to consumer demands for more meat; hence, the production of tallow also increased. The increase of tallow production was not a response to consumer demand for more tallow, but was a by-product of the increased production of beef.

Tallow production increased by approximately the same percentage as beef production and cattle slaughter in the last 25 years. From 1950 to 1975, tallow production increased by 126 percent; beef production increased by 132 percent; and cattle slaughter increased by 128 percent.

Table 9. U.S. tallow production, beef production, and cattle slaughter

<table>
<thead>
<tr>
<th>Year</th>
<th>Commercial beef production (mil. lbs.)</th>
<th>Commercial cattle slaughter (1000 head)</th>
<th>Tallow production (mil. lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>9248</td>
<td>17901</td>
<td>2351</td>
</tr>
<tr>
<td>1955</td>
<td>13213</td>
<td>25722</td>
<td>3151</td>
</tr>
<tr>
<td>1960</td>
<td>14374</td>
<td>25224</td>
<td>3859</td>
</tr>
<tr>
<td>1965</td>
<td>18325</td>
<td>32347</td>
<td>4913</td>
</tr>
<tr>
<td>1966</td>
<td>19493</td>
<td>33727</td>
<td>5074</td>
</tr>
<tr>
<td>1967</td>
<td>19996</td>
<td>33896</td>
<td>5331</td>
</tr>
<tr>
<td>1968</td>
<td>20683</td>
<td>35026</td>
<td>5282</td>
</tr>
<tr>
<td>1969</td>
<td>20953</td>
<td>35237</td>
<td>5188</td>
</tr>
<tr>
<td>1970</td>
<td>21485</td>
<td>35025</td>
<td>5466</td>
</tr>
<tr>
<td>1971</td>
<td>21690</td>
<td>35585</td>
<td>5753</td>
</tr>
<tr>
<td>1972</td>
<td>22210</td>
<td>35779</td>
<td>5626</td>
</tr>
<tr>
<td>1973</td>
<td>21063</td>
<td>33687</td>
<td>5321</td>
</tr>
<tr>
<td>1974</td>
<td>22838</td>
<td>36812</td>
<td>6241</td>
</tr>
<tr>
<td>1975</td>
<td>23644</td>
<td>40911</td>
<td>5313</td>
</tr>
</tbody>
</table>

Source: [26, 29, 30].
The similarity of these increases would seem to indicate that either beef production or cattle slaughter would be good indicators of the tallow production. But in the short run, tallow production does not always increase when beef production or cattle slaughter increases. From 1966 to 1975, beef production increased in every year except 1973; the number of cattle slaughtered increased in all years except 1970 and 1973. However, the production of tallow declined in 1968, 1969, 1972, 1973, and 1975.

Regression analysis further emphasized that changes in the production of tallow do not always coincide with changes in beef production or cattle slaughter. Ordinary least squares regression techniques were used to regress annual tallow production upon beef production and upon cattle slaughter. The estimated equations are:

\[
TTQ = 1972.2 + 0.1627 \, BQ
\]
\[
(2.814)
\]
\[
R^2 = 0.468 \quad F = 7.92 \quad S.E. = 277.9
\]

and

\[
TTQ = 3155.7 + 0.0639 \, CQ
\]
\[
(1.29)
\]
\[
R^2 = 0.156 \quad F = 1.67 \quad S.E. = 350.0
\]

where TTQ is millions of pounds of tallow produced annually, BQ is millions of pounds of beef produced annually, and CQ is thousands of head of cattle slaughtered annually. The t value testing the significance of the regression coefficient is presented in parentheses directly below the estimated coefficient. The coefficient of multiple correlation $R^2$, F test statistics, and the standard error of the estimate S.E. are presented below the regression equations.
In equation 1, beef production only explained 47 percent of the variation in tallow production. Cattle slaughter explained even less of the variation; only 16 percent of the variation was explained by CQ in equation 2.

An examination of the residuals of the above equations indicated that the estimates of tallow production were poorest in 1974 and 1975. Eliminating these two years from the sample period and estimating the equations again improved the results. The revised equation using beef production as the explanatory variable accounted for 78 percent of the variation in tallow output. The revised equation using cattle slaughter as the explanatory variable accounted for 63 percent of the variation in tallow production. The equations derived using the sample period of 1966-1973 are:

\[ TTQ = 1308.5 + 0.1911 \times BQ \]
\[ (5.00) \]
\[ R^2 = 0.781 \quad F = 24.9 \quad S.E. = 130.8 \]  

and

\[ TTQ = -1032.5 + 0.1845 \times CQ \]
\[ (3.49) \]
\[ R^2 = 0.634 \quad F = 12.2 \quad S.E. = 169.0 \]

The above equations indicate that tallow production is positively correlated with beef production and cattle slaughter; however, neither beef production nor cattle slaughter gives enough information to accurately estimate tallow production. In order to improve the ability to predict the quantity of tallow supplied, other factors that influence the quantity of tallow supplied were used in a supply equation. The factors that were hypothesized to affect the quantity of tallow supplied
can be classified into the following groups: the price of tallow, the
type of livestock slaughtered, the average weight of the livestock, and
imports of beef. The estimated supply equation and a discussion of the
factors that influence the quantity of tallow supplied follows.

The estimated supply equation

The quantity of tallow supplied is considered to be dependent upon
the price of tallow (TP), fed cattle marketings (FCM), nonfed steer and
heifer marketings (NFSH), cow marketings (COWS), average dressed weight
of cows (CADW), average dressed weight for steers and heifers (SHADW),
hog marketings (HQ), average live weight of hogs (HAW), and beef imports
(BIMP). The equation is:

\[
TTQ = -1892.4 + 6.494 \text{ TP} + 0.1622 \text{ FCM} + 0.2944 \text{ NFSH} \\
- 0.0635 \text{ COWS} + 1.866 \text{ CADW} + 2.891 \text{ SHADW} + 0.0144 \text{ HQ} \\
- 3.843 \text{ HAW} - 0.2604 \text{ BIMP}.
\]

\[
(1.97) \quad (4.80) \quad (6.98) \quad (2.28) \quad (1.63) \quad (2.91) \quad (2.76) \quad (2.70) \quad (1.63)
\]

\[
D.W. = 2.24 \quad R^2 = .865 \quad F = 21.44 \quad S.E. = 43.2
\]

The t values used to test the significance of the regression coeffi-
cients are presented in parentheses below the estimated coefficients.
Below the estimated equation are presented the Durbin-Watson D.W. statis-
tic, the coefficient of multiple correlation \(R^2\), the F value of the
estimated equation, and the standard error, S.E., of the estimates.

The coefficient of tallow price indicates that the quantity of tallow
supplied increased by 6.5 million pounds for every one cent per pound
increase in the price of tallow. The mean price elasticity\(^1\) of the tallow supply was estimated to be 0.045. That is, a one percent increase in the price of tallow caused the quantity of tallow supplied to increase by only 0.045 percent. This indicates that the supply of tallow was indeed very price inelastic. The quantity of tallow supplied was determined by the quantity and type of livestock slaughtered rather than by changes in the price of tallow.

Fed cattle marketings (FCM) had a powerful effect upon the quantity of tallow supplied. Every additional 1,000 head of FCM increased the quantity of tallow by 162,000 pounds or by 162 pounds per head. Nonfed steer and heifer marketings (NFSH) caused the quantity of tallow supplied to increase by 294,000 pounds for every additional 1,000 head of NFSH. This is equivalent to 294 pounds of tallow being produced for every additional head of NFSH. Compared with reported yields of tallow per head of cattle, the estimated yields are too high; one industry source [14b, p. 168] states that the average yield per 1,000 pound steer is 65 pounds of rendered tallow. However, since the tallow produced by independent renderers is not included in the industry figure, the per head yield would be slightly higher than the reported 65 pounds. Even so, it is not likely that the per head yield of tallow would approach 162 pounds.

---

\(^1\)The mean elasticity is defined to be: 
\[ E(y, x_i) = \frac{\partial y}{\partial x_i} \ast \frac{x_i}{y}, \]
where \(x_i\) is the independent variable influencing the dependent variable \(y\). It is estimated as:
\[ \hat{E}(y, x) = \hat{B} \ast \frac{x_i}{y}. \]
The coefficients of FCM and NFSH have the right sign and are statistically significant, but it is not logical that the coefficient of NFSH should be greater than the coefficient of FCM. Logically, more tallow should be obtained per head of corn-fed cattle than per head of grass-fed cattle. Thus, the coefficient of FCM should be greater than the coefficient of NFSH, but it is not.

The quantity of tallow supplied decreased by 64,000 pounds for every additional 1,000 cows marketed. Slaughter of cows will increase the quantity of tallow which can be rendered by captive renderers; however, cow marketings will decrease the quantity of tallow available for rendering by independent renderers. Retail meat outlets may add additional animal fats to the ground beef which comes from slaughtered cows. This will reduce the quantity of tallow that could be rendered by independent renderers. Thus, the net effect of large numbers of cow marketings was a reduction in the total quantity of tallow.

The quantity of tallow supplied was positively related to the average dressed weight of cows and steers and heifers. A one pound increase in CADW resulted in an additional 1.86 million pounds of tallow being supplied. This is logical because heavier cows yield more tallow at the packing plant. Also, it is possible that meat produced from heavier cows does not require as much fat to be combined with it. This allows more fat to be rendered by the independent renderers. The quantity of tallow increased by 2.891 million pounds as SHADW increased by one pound.

The number of hogs slaughtered increased the grease component of tallow. For every increase of 1,000 hogs slaughtered, there was an additional 14,000 pounds of grease rendered. The average liveweight of
hogs was 240 pounds; thus, the 14 pounds of grease per hog represents 6 percent of the live hog that was rendered as grease.

The quantity of tallow and grease supplied should have increased as the average live weight of hogs increased. However, the estimated coefficient for HAW is negative which indicates that the quantity decreased as HAW increased. This variable could have been eliminated from the equation because the coefficient has the wrong sign, but when the coefficient is significantly different from zero statistically and has the wrong sign, the variable should be retained in the equation. This is done so that other researchers may be able to explain the apparent inconsistency. The variable was therefore retained.

Beef imports decreased the quantity of tallow supplied by 260,000 pounds for every million pounds of beef imported. This is another case where animal fats may be mixed with lean imported meat at the retail level. This reduces the quantity of tallow which would be rendered by the independent renderers.

**Alternative specifications**

Several alternative forms of the supply equation were tested before the final equation was decided upon. The first alternative specification took into account the fact that beef from corn-fed cattle would be fatter than beef from grass-fed cattle. Thus, two exogenous variables included in the equation were fed beef production (FBQ) and nonfed beef production (NFBQ). Other variables included were the price of tallow (TP), production of pork (PQ), a time trend (T), and seasonal dummy variables (D2, D3, D4). The estimated equation is:
TTQ = -779.7 + 14.65 TP + 0.271 FBQ + 0.234 NFBQ + 0.244 PQ
(4.00) (3.79) (4.29) (5.49)
- 7.31 T - 35.58 D2 - 61.05 D3 - 128.9 D4.
(3.10) (1.41) (2.19) (4.49) (6)
D.W. = 1.34  R² = .769  F = 12.9  S.E. = 55.6

This specification gave very realistic coefficients for the variables. The quantity of tallow supplied was positively related to the price of tallow. This indicates that renderers exerted a greater effort to recover and produce tallow as the price of tallow rose. The quantity of tallow supplied historically has been approximately 25 percent of the quantity of beef; therefore, the size of the coefficients for FBQ and NFBQ are acceptable. It is also encouraging to note that the coefficient associated with FBQ is greater than the coefficient of NFBQ. This result supports the hypothesis that fed beef yield more tallow than nonfed beef.

In an attempt to improve the R² of this equation, the production of veal was subtracted from nonfed beef production. This was done because calves slaughtered for veal production do not have much fat on them. The estimated equation with the adjusted nonfed beef production variable (NFBQ*) is:

TTQ = -761.4 + 14.17 TP + 0.276 FBQ + 0.257 NFBQ* + 0.239 PQ
(4.06) (4.00) (4.54) (5.46)
- 7.854 T - 36.20 D2 - 63.27 D3 - 130.3 D4.
(3.36) (1.46) (2.31) (4.64) (7)
D.W. = 1.38  R² = .779  F = 13.68  S.E. = 54.5

The coefficient for NFBQ* is 0.257. In the former specification, the coefficient of NFBQ is 0.234. The increase in the size of the coefficient shows that a higher yield of tallow was obtained from cows, bulls and stags, and nonfed steers and heifers than from calves.
Although this equation shows that veal production did not have much of an impact upon the quantity of tallow supplied, this equation did not improve the $R^2$ of the supply equation very much. Other specifications of the tallow supply equation were then tested which used livestock slaughter variables instead of meat production variables as exogenous variables.

The following specification of the tallow supply equation included the price of tallow (TP), the number of fed cattle marketings (FCM), the number of nonfed cattle marketings excluding calves (NFCM), the fed cattle average dressing weight (FCADW), the nonfed cattle average dressing weight (NFADW), hog slaughter numbers (HQ), a time trend (T), and seasonal dummy variables (D2, D3, D4). The resulting equation is:

\[
TTQ = -4339.3 + 5.757 TP + 0.0788 FCM + 0.109 NFCM + 2.556 FCADW + 6.302 NFADW + 0.022 HQ - 2.994 HAW - 3.482 T + 44.46 D2 + 50.89 D3 + 1.61 D4.
\]

\[
(1.14) \quad (1.84) \quad (4.24) \quad (1.65) \quad (3.63) \quad (3.98) \quad (1.75) \quad (1.71) \quad (1.48) \quad (1.44) \quad (0.03)
\]

\[D.W. = 1.919 \quad R^2 = .867 \quad F = 16.58 \quad S.E. = 44.52\]

This equation, like equations 6 and 7, included several dummy variables as exogenous variables. While dummy variables can account for much of the variation in the quantity of tallow supplied, they are not as informative as other variables would be. For example, the above equation estimates that the second quarter tallow quantity will be 45 million pounds greater than the first quarter tallow quantity, but it gives no indication as to what causes this increase. Equation 5 was therefore chosen as the best specification, because the equation explained
approximately the same amount of the variation in the quantity of tallow
supplied without the use of dummy variables.

The Demand for Tallow

Since the supply of tallow can be regarded as predetermined, the role
of the tallow price is to adjust the quantity of tallow demanded so that
the quantity of tallow demanded equals the predetermined quantity sup-
plied. The price of tallow must rise or fall until the total use rises
or falls enough to match the quantity of tallow available.

Tallow is generally used as a factor of production of some final
consumer good. The quantity of tallow demanded, therefore, is related to
the volume of final products sold. The variation in the volume of prod-
ucts sold that use tallow as an input also caused the demand for tallow
to vary. Some of the industries that use tallow are the soap industry,
the animal feed industry, the fatty acid industry, and the food industry.

Table 10. Disappearance of tallow

<table>
<thead>
<tr>
<th>Year</th>
<th>Soap</th>
<th>Animal feeds (millions of pounds)</th>
<th>Fatty acids</th>
<th>Food</th>
<th>Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>1363</td>
<td>--</td>
<td>229</td>
<td>145</td>
<td>536</td>
</tr>
<tr>
<td>1955</td>
<td>864</td>
<td>181</td>
<td>278</td>
<td>270</td>
<td>1296</td>
</tr>
<tr>
<td>1960</td>
<td>746</td>
<td>449</td>
<td>386</td>
<td>402</td>
<td>1696</td>
</tr>
<tr>
<td>1965</td>
<td>651</td>
<td>717</td>
<td>540</td>
<td>519</td>
<td>2119</td>
</tr>
<tr>
<td>1966</td>
<td>667</td>
<td>893</td>
<td>583</td>
<td>505</td>
<td>1974</td>
</tr>
<tr>
<td>1967</td>
<td>643</td>
<td>972</td>
<td>545</td>
<td>518</td>
<td>2224</td>
</tr>
<tr>
<td>1968</td>
<td>639</td>
<td>1011</td>
<td>573</td>
<td>509</td>
<td>2240</td>
</tr>
<tr>
<td>1969</td>
<td>635</td>
<td>1078</td>
<td>608</td>
<td>498</td>
<td>1896</td>
</tr>
<tr>
<td>1970</td>
<td>602</td>
<td>1098</td>
<td>585</td>
<td>557</td>
<td>2242</td>
</tr>
<tr>
<td>1971</td>
<td>588</td>
<td>1143</td>
<td>585</td>
<td>588</td>
<td>2607</td>
</tr>
<tr>
<td>1972</td>
<td>640</td>
<td>1111</td>
<td>731</td>
<td>623</td>
<td>2357</td>
</tr>
<tr>
<td>1973</td>
<td>676</td>
<td>1122</td>
<td>899</td>
<td>617</td>
<td>2299</td>
</tr>
<tr>
<td>1974</td>
<td>633</td>
<td>1149</td>
<td>893</td>
<td>651</td>
<td>2624</td>
</tr>
<tr>
<td>1975</td>
<td>662</td>
<td>1282</td>
<td>698</td>
<td>623</td>
<td>1979</td>
</tr>
</tbody>
</table>

Source: [29, 32].
Demand for tallow by the soap industry

Traditionally, the soap manufacturing industry was the largest market for tallow. However, with the advent of synthetic detergents, the use of tallow-based soaps fell drastically; consequently, consumption of tallow by the soap industry also fell. Table 11 shows the decline of soap consumption as synthetic detergents captured a larger share of the detergent market.

Table 11. Soap and synthetic detergent consumption<sup>a,b</sup>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Soap consumption</td>
<td>2.9</td>
<td>1.6</td>
<td>1.2</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Synthetic detergent consumption</td>
<td>1.4</td>
<td>2.8</td>
<td>4.0</td>
<td>4.9</td>
<td>5.6</td>
</tr>
<tr>
<td>Total</td>
<td>4.3</td>
<td>4.4</td>
<td>5.2</td>
<td>6.0</td>
<td>6.7</td>
</tr>
</tbody>
</table>

<sup>a</sup>Source: [29].

<sup>b</sup>Estimates of the Soap and Detergent Association.

Soaps lost their dominant position in the detergent market for several reasons. Soaps lose much of their cleansing power in "hard" water. Hard water contains dissolved salts of calcium and magnesium which react chemically with soap. These mineral salts replace the sodium in the soap molecule. The resulting calcium and magnesium soaps are extremely insoluble in water. Before the original soap can have any
cleansing ability, all the magnesium and calcium must be removed from the water.

The amount of soap that must be used before the soap is able to function as a cleansing agent depends upon the degree of hardness of the water. Hardness in water is expressed in grains per gallon. It has been estimated that one hundred gallons of twenty grain hardness, which is quite common in the United States, will consume three pounds of soap before the soap can even begin to exert any cleansing power. Thus, it is not very economical to use soap in water that is very hard.

Soaps are also at a disadvantage from an industrial standpoint. Industry, particularly the textile industry, often requires soaps to be used in an acid solution. However, soaps react with the acid solution and form precipitates. These precipitates tend to adhere to textile fabrics during processing. This is likely to prevent an even application of the dyes, resulting in light spots on the finished fabrics.

By selecting the proper raw materials, producers of synthetic detergents are able to produce detergents which function properly in both hard water and in acid solution. These raw materials are also available at low cost. Therefore, the substitution of synthetic detergents for soaps is an economic reality.

Further displacement of soaps by synthetic detergents is unlikely in the near future. Synthetic detergents have not been able to penetrate the toilet bar soap sector, which is the last major user of fats and oils in the detergent market. Unless the synthetic detergent industry can develop a facial cleanser which does not irritate the skin, substantial
quantities of fats and oils will continue to be demanded for this specialty product.

The concern about water pollution has been a second factor which has slowed further growth of the synthetic detergent industry. In certain lakes and ponds, algae started reproducing at an unprecedented rate. This was blamed on the extensive use of phosphates in synthetic detergents.

Another factor which may affect the production of synthetic detergents in the future is the energy crisis. Since many of the synthetic detergents are petroleum-based, further petroleum price increases may make it uneconomical to produce synthetic detergents from petroleum.

A recent development in the soap industry may eventually lead to fats and oils recovering their importance in this industry. A new soap, developed by the U.S.D.A.'s Eastern Regional Research Center at Philadelphia, is effective in hard water at both high and low water temperatures. This soap is also biodegradable. If successful, this soap has the potential to recover much of the powdered and liquid detergent markets in the United States, Japan, and Western Europe. Such a soap is of particular importance where the phosphate pollution from synthetic detergents is the greatest. Several Japanese firms have already announced that they would begin commercial production and marketing of these tallow-based detergents [2, p. 12].

The estimated demand equation. Tallow has long been the basic ingredient of soap made in the United States. Tallow soap is firm, has good keeping qualities and is an efficient cleaning material. Inedible tallow is often mixed with coconut oil in soap to improve the solubility
and lathering properties of the product. It is refined and bleached before being charged to the soap kettle. In 1972, tallow accounted for 77 percent of all fats and oils used in soap manufacture and coconut oil accounted for another 22 percent [29].

Since the demand for tallow by the soap industry is derived from the demand for the soap which is produced, economic forces which affect the consumer's demand for soap will also affect the demand for tallow. Therefore, the demand equation includes both the tallow price (TP) and demand shifters. The demand shifters are fabric production (FABRIC), deflated disposable personal income (DDYN), and two dummy variables (T1, T2). The estimated soap demand equation follows.

\[
\text{SOAP} = -45.07 - 0.5566 \text{TP} + 0.02244 \text{FABRIC} + 0.04283 \text{DDYN} \\
\quad - 1.073 T1 + 1.066 T2 \\
\quad (0.719) \quad (2.50) \quad (1.26) \\
\quad (1.46) \quad (1.66) \\
\text{D.W.} = 1.73 \quad R^2 = .349 \quad F = 3.65 \quad \text{S.E.} = 10.3
\]  

The quantity of tallow demanded was negatively related to the price of tallow; however, the estimated coefficient of TP was statistically insignificant. The price elasticity of demand calculated at the means was estimated to be -0.033. This means that every one percent increase in the price of tallow reduced the quantity of tallow demanded by only 0.033 percent. This low elasticity suggests that soap producers did not substitute less expensive oils for tallow when the price of tallow rose; rather, they continued to use tallow in their soaps in order to preserve properties which were promoted in their tallow-based soaps.

The textile industry consumed substantial quantities of soaps; therefore, the productivity of this industry influenced the quantity of tallow
used to produce textile soaps. It was estimated that 224,000 pounds of
tallow were demanded by the soap industry for every million linear yards
of woven fabric produced in the United States.

Per capita income influenced the quantity of personal soaps pur-
chased. The soap industry increased its demand for tallow by 43,000
pounds for every additional dollar of personal income.

The quantity of tallow demanded by the soap industry decreased until
the fourth quarter of 1971. The decrease can be attributed to synthetic
detergents capturing a larger share of the market. Since then, the
quantity demanded by the soap industry increased. This increase can
possibly be attributed to a reduction in the quantity of synthetic deter-
gents produced due to environmental concerns. To test this hypothesis,
two time trends were included in the demand equation. The first trend
(T1) covers the period from the first quarter of 1966 through the fourth
quarter of 1971. The second trend (T2) begins in the first quarter of
1972 and continues through the fourth quarter of 1975. The coefficient
of T1 indicates that the quantity of tallow demanded decreased by 1.07
million pounds per quarter from 1966 to 1971. The quantity of tallow
demanded increased after 1971 by 1.066 million pounds each quarter.

Although this equation has a $R^2$ of only .349, the estimates are
actually quite accurate. One way of looking at the accuracy of the esti-
mated equation is to consider the standard error of the estimate in
relation to the mean of tallow demand. In this equation, the standard
error, as a percentage of the mean, is $10.3/159.6 = 6.45$ percent. Thus
this equation is actually quite accurate. In a market such as this one
where the quantity of tallow demanded is actually quite stable, an equation with a relatively poor \( R^2 \) still estimates the quantity demanded quite accurately.

**Alternative specifications** Other specifications of the demand equation included prices of substitute oils. The prices of coconut oil and palm oils were found to be insignificant; neither of these prices were statistically significant nor did they improve the \( R^2 \) or F of the equation.

**Demand for tallow as a feed ingredient**

Since the introduction of tallow into animal feeds in the early 1950's, there has been a continuous and rapid expansion of the quantity of tallow used in animal feeds. This market has grown to become the largest domestic outlet for tallow; presently, over one billion pounds of tallow are consumed in animal feeds annually.

Tallow and other fats are the most concentrated sources of energy for animal feeds. Since fats will supply 2.25 times as much energy as will an equivalent weight of carbohydrates or proteins, fats are an economical source of energy whenever the price per pound of carbohydrates or proteins approaches 45 percent of the price per pound of tallow.

Besides being a source of calories, there are several nonnutritional reasons to use fats in animal feeds. Fats and oils (1) increase the palatability of feeds, (2) reduce dustiness, (3) reduce wear on handling, mixing and pelleting machinery by acting as a lubricant, (4) aid in homogenizing and stabilizing the mixture of fine particled feed additives, and (5) give the feed a better appearance.
Although there are no published figures on the quantity of fat consumed by the various livestock and poultry sectors, it is safe to assume that the broiler industry is the leading consumer of fats. Modern broiler feeding practices which are energy and protein intensive have brought about the addition of tallow to the broiler ration.

The addition of fats to nutritionally complete diets often produces a slight increase in growth and improves the efficiency of feed utilization. These benefits can only be obtained when the amounts of all other nutrients in the diet are increased in proportion to the increase in the energy level.

When broilers are fed a high energy diet, the total feed consumption tends to be reduced. Therefore, the quantity of high energy feed which is consumed must also contain the necessary protein, minerals, and vitamins. Thus, the high energy feeds are also high in protein, minerals, and vitamins. These feeds produce a pound of broiler with a smaller volume and weight of feed being fed. If the high energy feeds are only a little more expensive than low energy feeds, the result is a lower feed cost per pound of broiler.

Broiler rations often contain up to 6 percent fat. It has been demonstrated that broiler feeds may contain as much as 35-50 percent fat and 45-50 percent protein and still exhibit excellent growth results for the broilers [17, p. 50].

The estimated feed demand equation The equation specified for tallow demand by the animal feed sector contains five independent variables. The first three variables are related to the supply of energy.
Tallow consumption in feeds is hypothesized to depend upon the price of tallow (TP) and the price of corn (CP), which is the most important energy substitute for fat. The third variable is the ratio of the price per pound of soybean meal to the price per pound of corn (SBMP/CP). The fourth variable is the quantity of feed consumed by the broiler industry (BRF). Finally, a time trend (T) is used as a proxy for the adoption of high energy feeding methods over time. The estimation result is:

\[
\text{FEED} = 140.08 - 3.943 \text{TP} + 16.18 \text{CP} - 8.158 \text{SBMP/CP} + 0.01861 \text{BRF} + 1.931 \text{T}.
\]

(\text{3.82}) (\text{2.12}) (\text{2.34}) (\text{3.99}) (\text{5.95})

\[D.W. = 1.61 \quad R^2 = .860 \quad F = 41.76 \quad S.E. = 11.45\]

The quantity of tallow demanded by the feed sector decreased by 3.93 million pounds as TP increased by one cent per pound. The estimated price elasticity of demand was -0.1375. Although this price elasticity was greater than the price elasticity of the soap sector, this market was still price inelastic.

Tallow is a substitute for corn as an energy source. Therefore, the quantity of tallow demanded should rise as corn prices increase. The estimated coefficient of CP is 16.18; the demanded quantity increased by 16.2 million pounds for each dollar increase in the price of corn.

The coefficient of SBMP/CP is -8.158. Both soybean meal and corn are sources of protein for broilers; the protein content of soybean meal is 44 percent and the protein content of corn is 8 percent. If the price of soybean meal increases relative to the price of corn, it would be economical to feed more corn as a source of protein. However, increasing
the quantity of corn in the ration will also increase calories. Thus, the need for tallow as an energy source is reduced.

The quantity of tallow demanded increased by 18 thousand pounds for every additional million pounds of feed consumed by broilers. According to this coefficient, tallow composed approximately two percent of broiler feeds. This percentage is lower than that reported for typical broiler rations, but it is not unrealistic.

The coefficient associated with the linear trend T means that, on the average, an additional 1.93 million pounds of tallow were demanded for animal feed each quarter since 1966.

Alternative specifications tested To test if tallow consumption in animal feeds was influenced by turkey production, a variable which approximates the quantity of feed consumed by turkeys produced in the United States was constructed. The results of this trial were unsuccessful because the turkey feed variable was statistically insignificant. It is possible that the turkey feed variable was not significant in the 1966-1975 period because the practice of feeding fats to turkeys has not been practiced as long as it has with broilers. It is also not apparent that this practice has been adopted by all turkey producing regions.

It was reported by Preston and Willis [12, p. 341] that large quantities of tallow are consumed in feed fed to cattle in the large southwestern United States cattle lots. This practice is used primarily for dust control purposes. A variable which approximated the number of cattle being fed in lots of over 9,000 head was constructed and tested in the equation. The coefficient for this variable was statistically
insignificant and the predictive ability of the equation was not improved by this variable; therefore, this variable was dropped from the demand equation.

Likewise, a variable to examine whether or not the pig crop influenced tallow consumption was tested. Again the results of this test were insignificant, so this variable was not included in the final form of the equation.

Demand for tallow by the fatty acids industry

The growth of the fatty acid industry provided an expanding market for tallow and other fats. The production of fatty acids in the United States expanded from 462 million pounds in 1958 to 809 million pounds in 1971. Accordingly, the quantity of fats consumed as raw materials rose over this period. In fact, the quantity of tallow consumed in the production of fatty acids doubled since 1958.

The major raw materials used in the production of fatty acids are tallow, tall oil,¹ and vegetable oils. Today, tallow and tall oil account for 90 percent of the raw materials used by this industry. Although the vegetable oils are usually too expensive to be used in manufacturing fatty acids, the by-products of refining vegetable oils for food are priced competitively with tallow and other industrial oils. The by-products, called foots, are obtained from refining cottonseed and soybean oils and are an important source of raw materials for the fatty acid industry.

¹Tall oil is a by-product of kraft paper manufacture. It is not a true fat or oil but consists of a natural mixture of 45 percent each of rosin acids and fatty acids and 10 percent unsaponifiable matter.
The soap industry has been increasing its use of fatty acids. While soap can either be made with natural fats or with fatty acids as the raw material, the decision as to which raw material to use in production is essentially an economic one. However, fatty acids do have several advantages over natural fats in the manufacture of soaps. They require no boiling, react with less input of heat to the process, react considerably faster than fats and oils, and yield 4-8 percent more soap than do natural fats [9, p. 2710]. While these advantages are important, the main reason for the use of fatty acids in the manufacture of soap is the superior quality of the final product made with fatty acids. Fatty acids are produced to meet rigid specifications with respect to quality which assures the soapmaker of uniformity in the final product.

The textile industry is one of the largest consumers of chemicals in the United States. A significant portion of the chemicals consumed by the textile industry can be attributed to fatty acid chemicals. The bulk of fatty acids used in textile manufacturing are in the form of soaps.

Fatty acids are also used in the processing of paper, cosmetics, rubber, foods, protective coatings, lubricants, pharmaceuticals, and other miscellaneous uses.

The estimated demand equation The demand relationship for this sector depends upon (1) the price of tallow (TP), (2) the price of competing oils, (3) textile production (FABRIC), (4) unemployment (UNEMP), and (5) the level of consumer income (DDYN). The equation is estimated as:
FATTY ACIDS = -533.8 - 1.259 TP + 1.795 SBOP + 0.0505 FABRIC
(1.08) (3.23) (3.80)
- 4.996 UNEMP + 0.1496 DDYN.
(2.11) (8.53) (11)

D.W. = 1.16  R² = .890  F = 55.2  S.E. = 11.8

A one cent increase in the price of tallow caused the demanded
quantity to be reduced by 1.26 million pounds. The price elasticity of
demand calculated at the means is -0.0708; again, this is a very price
inelastic market.

The soybean oil price is included in this equation to indicate how
changes in the price of soybean oil and the foots derived from soybean
oil influence the quantity of tallow demanded. A time series for the
price of soybean oil foots would have been the best variable, but such a
time series could not be located. It is thought that the price of foots
moves in the same direction as the price of soybean oil. The coefficient
of SBOP indicates that a one cent per pound increase in the price of
soybean oil caused an additional 1.79 million pounds of tallow to be
demanded.

The fabric industry consumes many chemicals which are derived from
fatty acids; thus, the production of fabric will influence the demand for
tallow. For each million linear yards of fabric produced, it was esti-
medated that an additional 59,000 pounds of tallow were used to produce
fatty acids.

Unemployment and disposable income affected consumer expenditures
for final goods. Purchases of final goods, in turn, affected the quantity
of tallow demanded by the fatty acid sector. For every increase of one
percent in the unemployment rate, the quantity demanded was reduced by 4.49 million pounds. An increase of one dollar of DDYN increased the quantity demanded by 149 million pounds per quarter.

**Alternative specifications** Because tall oil is the other major oil used to produce fatty acids, the price of this oil should affect the consumption of tallow in fatty acids. However, substituting the price of tall oil for the price of soybean oil did not improve the explanatory effectiveness of the equation. There are two factors that may have caused this variable to be insignificant. First, the fatty acids derived from tall oil are chemically different from those derived from tallow.¹ Because of the chemical difference, the fatty acids which are produced from tallow may be used in markets which are independent of the markets which use tall oil fatty acids. If this is the case, tallow and tall oil fatty acids would not be competitors, and the price of tall oil would then not be expected to influence the demand for tallow. Second, the only price series available for tall oil was the crude tall oil price. Since the tall oil fatty acids must be separated from the rosin before they can be used, the price of refined tall oil fatty acids may be quite different from the price of crude oil.

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¹The fatty acids derived from tall oil are primarily linoleic, oleic, and linolenic acid. The fatty acids derived from tallow are primarily stearic and palmitic.
Demand for tallow for human consumption products

Approximately 570 million pounds of tallow have been consumed in edible products annually since 1966. More than 90 percent of the edible tallow is utilized as a shortening. Another 2 percent of the edible tallow is used to produce margarine.

As a shortening, tallow is in competition with other edible vegetable oils and lard. The quantity of tallow demanded as a food product is influenced by the relative prices of these oils.

Because of U.S.D.A. standards, only selected portions of fat from the carcass of beef animals can be used for edible purposes. Therefore, in each year there is an upper limit on the quantity of tallow which can be consumed as edible. No matter how profitable it may be to produce edible tallow, it is not possible to process more tallow than is allowed under the federal standards.

There has been an important shift in consumer preferences from the consumption of animal fats to the consumption of vegetable oils. Due largely to the preferences consumers have for unsaturated oils, there has been a shift from saturated animal fats. The market price and consumption patterns of tallow and lard have both been affected by this change in consumer taste.

The estimated demand equation for the food sector

The variables included in the estimated food demand equation are tallow price (TP), soybean oil price (SBOP), deflated disposable income per capita (DDYN), total tallow supply (TTQ), and a time trend (T). The resulting estimate is:
The price of tallow was negatively related to the demand for tallow in food products. As TP increased by one cent per pound, consumer demand fell by 5.18 million pounds. The price elasticity of demand was estimated to be -0.3448. This elasticity is much higher than any of the other elasticities which were estimated. It is possible that the food demand for tallow is more sensitive to price changes than the other sectors because tallow is a final consumer good when used as a shortening. In all of the other cases, tallow was used as an input in a production process.

A one cent per pound increase in the price of soybean oil increased the quantity of tallow demanded for food by 1.91 million pounds.

Income increased the quantity of shortenings purchased by consumers. This is reflected in the positive coefficient linking disposable personal income per capita (DDYN) to FOOD. Domestic food demand for tallow increased by 109,000 pounds for each increase of one dollar in DDYN. Assuming a domestic population of 214 million people, this is equivalent to an additional 0.0005 pounds of tallow being purchased quarterly per person as income per capita increased by one dollar.

A larger quantity of tallow has generally been used in food products when there was a larger quantity of total tallow supplied. Each additional million pounds of tallow supplied resulted in an average of 50,000 more pounds of edible tallow being demanded.
The variable T allows for decreases over time due to changes in consumer preferences. Demand for tallow by this sector decreased by 681,000 pounds each quarter of the sample period.

**Demand for tallow by foreign markets**

The United States is the most important exporter of tallow in the world. Approximately 70 percent of the world exports of tallow since 1970 originated from the United States. Of the U.S. export markets, the largest are the European Economic Community and Japan. These two markets accounted for 36 percent of the total exports of the United States. Other countries which have imported substantial quantities of tallow from the United States are Egypt, India, and the Republic of Korea.

Although recent data on tallow utilization in foreign countries is unavailable, it is thought that the soap industry is still the largest consumer of tallow. The replacement of soaps by synthetic detergents has not occurred as rapidly overseas as it has in the United States.

The use of tallow in animal feeds is expected to grow in the foreign markets. As foreign livestock and poultry producers adopt meat production practices which are being used in the United States, there will be larger quantities of concentrated feeds fed to their animals. As the quantity of concentrates being fed increases, it is likely that more tallow will be utilized in feeds.

The foreign fatty acid industry is expected to utilize greater quantities of tallow in the future. West Germany is a current leader in the production of fatty acids and also exports substantial quantities of these products. Often, the fatty acids which West Germany exports are
used to manufacture soaps. Therefore, these fatty acid exports compete with American tallow for foreign soap markets.

Exports of tallow were promoted by government policy. Under Public Law 480, tallow and other agricultural commodities were exported as part of the United States' assistance program for the less developed countries. For the period from 1966 to 1973, exports of tallow under P.L. 480 averaged 121.1 million pounds per year. This represented about 5.3 percent of the total exports of tallow from the United States. For several years during this period, P.L. 480 shipments accounted for a much greater proportion of the exports; the highest percentage of exports accounted for by the P.L. 480 program occurred in 1969 when 19.98 percent of the exports from the United States were made under this program. Shipments of tallow under this program ceased after the fiscal year 1973.

Although the P.L. 480 program was designed to supplement U.S. exports, there does exist some substitution between P.L. 480 sales and commercial sales. Therefore, one can not make the assumption that exports of U.S. tallow would have been reduced by an equivalent amount if the program had not existed.

The major recipients of government financed assistance exports have been Asian countries. India, Pakistan, the Republic of Korea, and the Republic of China received the largest P.L. 480 shipments. Other countries which have received significant quantities of tallow through the government program are Turkey, Morocco, Egypt, and Ghana.

The estimated export equation Tallow exports are considered to be a function of the price of tallow (TP), the price of palm oil (POP),
Japanese industrial production of the previous quarter (JIIP\textsubscript{t-1}), and the stock of tallow in the United States (STOCK). The export equation is:

\begin{equation}
\text{EXPORT} = -58.45 - 12.50 \text{ TP} + 6.433 \text{ POP} + 1.286 \text{ JIIP}\textsubscript{t-1} + 0.8939 \text{ STOCK}.
\end{equation}

\text{(13)}

D.W. = 2.15 \quad R^2 = 0.583 \quad F = 12.3 \quad S.E. = 57.1

The export market has reacted to price changes of tallow and substitute oils. For every cent increase in the price of one pound of tallow, exports were reduced by 12.5 million pounds. The price elasticity of demand for exports of tallow is estimated to be -0.22; this elasticity is considerably higher than all other elasticities except the elasticity for the food sector. This suggests that the price of tallow has a great influence on the quantity of tallow exported. If the price of tallow were to rise in relation to other oils which were on the world market, the quantity of tallow demanded would be decreased considerably. This is feasible since there are many oils that can act as substitutes in the international market. Price increases for palm oil increased the quantity of tallow exported by 6.43 million pounds for every cent increase in the price of one pound of palm oil.

Tallow is used mainly as an industrial oil; therefore, the industrial productivity of foreign countries influenced tallow exports. An index of Japan's industrial productivity was included to capture this effect. As this index increased by one point, exports of tallow increased by 1.286 million pounds.

Exports of tallow increased as stocks of tallow in the United States increased. This implies that greater efforts were exerted to export
tallow when stocks of tallow were high in order to reduce the quantity of surplus tallow in the United States. Exports increased by 893,000 pounds as stocks of tallow increased by one million pounds.

**Alternative specifications** The export equation was estimated by several different specifications. Soybean oil prices were substituted for the prices of palm oil. This specification was used because of the major role that soybean oil played in the fats and oils market. The estimated equation explained less of the variance in exports ($R^2 = .537$) and the coefficient of the SBOP was not statistically different from zero. The soybean oil price was therefore eliminated in favor of the price of palm oil.

The supply of tallow in Western Europe should have had a negative effect upon imports of tallow from the United States. Because quarterly production of tallow in Western Europe could not be found, quarterly beef production from six Western European countries was used as a proxy for tallow production. This variable did have a negative coefficient associated with it; however, the coefficient was not statistically significant. The variable was therefore eliminated from the equation.

Exports of tallow under P.L. 480 should increase the quantity of tallow exported. A time series of exports under this program was included in the equation, but P.L 480 exports were not found to be significant in determining the quantity of tallow exported. Exports of tallow under this program may substitute for other commercial sales and therefore the total volume of tallow exported would not be increased.
Total demand for tallow

The total demand function for a commodity is obtained by summing the demand functions of each market. Therefore, the total domestic demand function for tallow can be obtained by summing the estimated demand functions. This gives a demand equation which includes all of the variables of the individual sector demand equations. By summing the estimated demand equations of the soap industry, the animal feed sector, the fatty acid industry, and the food market, we obtain the following total demand equation:

\[
\text{Demand} = -740.39 - 10.94 \text{ TP} + 3.707 \text{ SBOP} + 16.18 \text{ CP} \\
- 8.158 \text{ SBMP/CP} + 0.7294 \text{ FABRIC} + 0.01861 \text{ BRF} \\
+ 0.3015 \text{ DDYN} - 4.996 \text{ UNEMP} - 1.073 \text{ T1} + 1.250 \text{ T2} \\
+ 1.250 \text{ T} + 0.05032 \text{ TTQ}. \tag{14}
\]
CHAPTER IV. PRICE DETERMINATION IN THE TALLOW SECTOR

The extent of the tallow price changes depends upon the price elasticities of supply and demand as well as the extent of the shifts in supply and demand. If supply and demand are inelastic, shifts in supply or demand will cause a percentage change in the price of tallow that is greater than the percentage shift in supply or demand. Thus unstable prices are characteristic of markets that have inelastic supply and demand schedules.

In Chapter III, it was found that supply and demand were both price inelastic. This finding must be further clarified. The following sections will discuss (1) the implications of the estimated price elasticities and (2) the influence of exogenous variables upon the supply and demand for tallow. The information concerning the price elasticities and the forces that shift the supply and demand schedules will then be used to evaluate how the price of tallow is determined.

Price Elasticities of Supply and Demand

Price elasticity of supply

The price elasticity of supply must be spoken of with reference to the time period that was investigated. There is no curve which can be regarded as the one-and-only supply curve. Thus, the elasticity of a particular supply curve depends upon how much time is allowed for variations in output due to changes in technology and production costs to take place.
The price elasticity of supply was estimated in this study based on quarterly data. Thus this elasticity must be regarded as a short-term elasticity. Because tallow is a by-product, it was expected that the short-term supply of tallow was price inelastic. In a longer term, however, the supply of tallow could respond more to changes in the price of tallow. If the quantity of tallow produced became excessive and production was expected to be excessive for many years in the future, beef production techniques could be altered so that leaner cattle would be produced. Such a change has already occurred in the hog industry where meat-type hogs have replaced lard-type hogs because of the excessive amount of lard that was being produced. However, such a change is not foreseen for beef cattle in the near future.

The price elasticity of supply, estimated at the means, was 0.0451. This implies that there apparently is some opportunity to increase the yield of tallow from a given beef slaughter volume in response to absolute tallow price increases. Perhaps this is accomplished by extracting slightly greater quantities of tallow from meat and bone meal. More of the tallow can also be collected and rendered by the independent renderers if the price of tallow justifies some additional collection expense. However, these responses will not greatly increase the quantity of tallow supplied. Most of the tallow quantity is predetermined by the quantity of livestock being slaughtered.
Price elasticity of demand

The elasticity of demand also varies according to the time period under consideration. Elasticities based on long-term data are believed to be greater than those based on short-term data. That is, the more time that is given a manufacturer to change his production processes, the more the production processes will be changed.

The demand for tallow depends upon the development of technology to process tallow into soaps, fatty acids, and feeds. Once this technology has been established, tallow will continue to be used in the short run even if the tallow price should temporarily increase. However, in the long run, the technology may not be replaced if it appears that the price of tallow would continue to be higher than the price of substitutes for tallow.

In both the short-term and the long-term, the elasticity of demand is dependent upon the availability of economical substitutes for tallow. The demand for a factor of production such as tallow will be more inelastic when the factor is essential, or nearly essential to the production of some final good; that is, when no good substitutes are available at moderate prices, demand will be inelastic.

The extent to which substitute fats and oils have been used in the tallow markets was checked. It was found that substitute fats and oils were not used extensively by the soap industry, the fatty acid industry, or the animal feed industry. This finding supports the validity of the estimated elasticities for these sectors. The food and export sector used many fats and oils that substitute for tallow. This suggests that
these demands should be more elastic than the demands by the soap, fatty acid, or feed sectors.

Substitutes for tallow in the soap industry In the domestic soap industry, tallow accounted for 78 percent of all fats and oils used in soap manufacturing [29, 32]. Coconut oil accounted for an additional 19 percent of the fats and oils utilized by the soap industry, but coconut oil is generally a complement of tallow rather than a substitute for tallow. (Coconut oil improves the lathering ability of tallow-based soaps.) Thus, over the years 1966 to 1975, there have been no important substitutes for tallow in the soap manufacturing industry. This suggests that the demand for tallow in the soap industry would be price inelastic and supports the validity of the estimated price elasticity of demand by the soap sector.

Substitutes for tallow in the fatty acid industry Tallow had only minor competition from other fats and oils in the fatty acid industry. Tallow accounted for 75 percent of the fats and oils consumed in fatty acid production. Other important sources of raw materials for the fatty acid industry were coconut oil and vegetable oil foots [32, p. 128]. However, the chemical composition of the fatty acids derived from these sources is different from that of the fatty acids derived from tallow. Thus, the fatty acids produced from substitute fats

---

1This percentage was calculated by dividing tallow used in fatty acid manufacturing by the total fats and oils used to produce fatty acids excluding tall oil used in the production of fatty acids. Tall oil was excluded because only crude tall oil used in fatty acid production was reported by Census. The reporting of crude tall oil overstates the amount of tall oil going into fatty acid production as crude tall oil also yields rosin acids and secondary products.
and oils are not good substitutes for the fatty acids produced from tallow. Again, this implies that the demand for tallow by the fatty acid industry is price inelastic and supports the validity of the estimated price elasticity of demand for tallow by the fatty acid industry.

**Substitutes for tallow in the animal feed industry**

It is more difficult to analyze the substitution possibilities of the animal feed sector. The Economic Research Service [32, p. 92] did not report any other fats or oils that substituted for tallow, but that does not mean that there were no other substitutes for tallow in animal feeds. Because tallow is used as an energy source, any ingredient that supplies energy in the ration must be considered a substitute for tallow. Thus corn and soybean meal must be considered substitutes for tallow in this sector. This suggests that the price elasticity of demand by this sector would be greater than the price elasticities of the previous two sectors. The estimated price elasticity concurs with this hypothesis.

**Substitutes for tallow in the food and export sectors**

In the food sector and the export sector, there are many fats and oils that substitute for tallow. Soybean oil, cottonseed oil, and lard dominate the shortening market. Palm oil, soybean oil, and coconut oil have a great impact upon the foreign demand for tallow. Thus, it would be expected that these two markets would be more price elastic than the former market. The estimated elasticities of demand by the food and the export sectors were greater than the previous three domestic markets, as hypothesized.
Table 12. Estimated price elasticities of demand for tallow

<table>
<thead>
<tr>
<th>Sector</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soap</td>
<td>-0.03301</td>
</tr>
<tr>
<td>Feed</td>
<td>-0.1375</td>
</tr>
<tr>
<td>Fatty acids</td>
<td>-0.0708</td>
</tr>
<tr>
<td>Food</td>
<td>-0.3448</td>
</tr>
<tr>
<td>Exports</td>
<td>-0.2111</td>
</tr>
<tr>
<td>Weighted average</td>
<td>-0.1705</td>
</tr>
</tbody>
</table>

Shifts in the Supply and Demand Curves

Changes in the position of the demand and supply curves are caused by changes in the value of the exogenous forces. For instance, changes in the number of fed cattle marketings affect the position of the supply curve. Changes in disposable income, unemployment, and fabric production are some of the variables that affect the position of the demand curve.

The exogenous variables with positive coefficients shift the curves to the right when the value of the exogenous variable increases. The extent of the shift is only partially disclosed by the estimated coefficients of Chapter III. The size of a positive coefficient indicates the number of additional million pounds of tallow supplied or demanded per unit increase in the value of the exogenous variable. For example, 16 million additional pounds of tallow, on the average, were fed for each dollar per bushel increase in the corn price. However, the significance of 16 million more pounds of tallow being fed is obscure unless one knows
that the average amount of tallow fed per quarter in recent years was 296 million pounds. Furthermore, the chance of a one dollar per bushel change in the corn price must be known to evaluate the influence or impact of the exogenous variable, corn price, as a demand shifter. In fact, the corn price has seldom varied from the average corn price by as much as a dollar as indicated by the mean corn price of $1.74 with a standard deviation of $0.75.

The influence of an exogenous variable upon the position of the supply or demand schedules depends upon (1) the responsiveness of supply or demand to changes in the value of the exogenous variables and (2) the variability of the exogenous variable. The responsiveness of demand or supply to changes in the values of exogenous variables is indicated by impact multipliers. The impact multipliers indicate the percentage change in supply or demand that results for a one percent change in the value of an exogenous variable. The variability of an exogenous variable is indicated by the ratio of the standard deviation of the exogenous variable to the mean of the exogenous variable. This ratio expresses the variation in the value of the exogenous variable as a percentage of the mean. Multiplying the impact multiplier by the ratio of the standard deviation to the mean expresses the change in the supply or demand which resulted from variations in the exogenous variable as a percentage.

The influence of the exogenous variable was determined by the following conditions: (1) if the percentage change of the value of the exogenous variable was large and the impact multiplier was also large, demand or supply was greatly influenced by shifts in the value of the
exogenous variable; (2) if the impact multiplier was large but the average percentage change in the value of the exogenous variable was small, i.e., the exogenous variable was relatively stable over the historical period, the influence of the exogenous variable was not as great as in the first condition; (3) if the impact multiplier was small but the percentage change was large, the influence of the exogenous variable upon supply or demand was significant but less than the first case; (4) if both the impact multiplier and the percentage change were small, demand or supply would not have been greatly influenced by the exogenous variable.

The estimated impact multipliers for all of the exogenous variables, the ratios of the standard deviations to the means of the exogenous variables, and the estimated change in supply or demand resulting from changes in the values of the exogenous variables are presented in Tables 13-18.

The influence of exogenous variables upon the tallow supply

The two factors which had the greatest impact upon the supply of tallow were fed cattle marketings (FCM) and nonfed steers and heifers (NFSH). Changes in the number of FCM caused the supply of tallow to change by an average of 7.07 percent over the ten year period. Changes in the number of NFSH caused the supply to change by 10.47 percent. It is interesting to note (see Table 13) that the impact multiplier of FCM is much larger than the impact multiplier of NFSH. This implies that a one percent change in FCM had a much greater effect on the supply of tallow than did a one percent change in NFSH. Thus, NFSH had a greater
impact upon the tallow supply because of the greater variability in NFSH and not because supply is influenced more by a percentage change in NFSH.

A second feature of the tallow supply which should be noted is the impact multiplier of the steer and heifer average dressed weight (SHADW). The impact multiplier of SHADW is 1.3635; this suggests that the proportion of tallow that is recovered from steers and heifers increases as the average dressed weight increases.

Table 13. The influence of factors affecting the supply of tallow

<table>
<thead>
<tr>
<th>Exogenous variable</th>
<th>Impact multiplier</th>
<th>Ratio of standard deviation to mean</th>
<th>Impact on supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fed cattle marketings</td>
<td>0.718</td>
<td>9.85</td>
<td>7.07</td>
</tr>
<tr>
<td>Nonfed steers and heifers</td>
<td>0.192</td>
<td>54.48</td>
<td>10.47</td>
</tr>
<tr>
<td>Cows</td>
<td>-0.084</td>
<td>25.90</td>
<td>2.17</td>
</tr>
<tr>
<td>Cows average dressed wt.</td>
<td>0.685</td>
<td>3.37</td>
<td>2.31</td>
</tr>
<tr>
<td>Steers and heifers dressed wt.</td>
<td>1.364</td>
<td>2.43</td>
<td>3.31</td>
</tr>
<tr>
<td>Hog slaughter</td>
<td>0.216</td>
<td>10.63</td>
<td>2.30</td>
</tr>
<tr>
<td>Hog average weight</td>
<td>-0.676</td>
<td>2.44</td>
<td>1.65</td>
</tr>
<tr>
<td>Beef imports</td>
<td>-0.074</td>
<td>22.50</td>
<td>1.66</td>
</tr>
</tbody>
</table>

The influence of exogenous variables upon tallow demand

Impact on tallow demand by soap industry of variation of exogenous variables. The demand for tallow by the soap industry was quite stable over the period of 1966-1975; thus, it would not be expected that the exogenous variables had a major impact upon the demand for tallow. Of the factors which influenced the demand for tallow, deflated disposable income per capita (DDYN) and fabric production (FABRIC) had the greatest impact upon demand. The impact multiplier of DDYN suggests that for a
one percent increase in DDYN the demand for tallow by the soap sector increased by 0.9995 percent. This could only happen if the demand for toilet-soaps increased by approximately one percent in response to a one percent increase in DDYN. If the soap consumption had actually been stimulated by income growth, it is possible that the demand for tallow had actually been this responsive. But if the population has reached the point where further increases in income will not increase consumption of soaps further, this impact multiplier would not be believable.

Table 14. The influence of factors affecting the demand for tallow by the soap industry

<table>
<thead>
<tr>
<th>Exogenous variable</th>
<th>Impact multiplier</th>
<th>Ratio of standard deviation to mean</th>
<th>Impact on demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabric production</td>
<td>0.4081</td>
<td>9.59</td>
<td>3.91</td>
</tr>
<tr>
<td>Deflated disposable income per capita</td>
<td>-0.1149</td>
<td>46.06</td>
<td>5.29</td>
</tr>
<tr>
<td>Trend 1966-1971</td>
<td>0.0227</td>
<td>151.41</td>
<td>3.437</td>
</tr>
</tbody>
</table>

Impact on tallow demand by feed sector of variation of exogenous variables

Of the exogenous variables affecting the demand for tallow by the feed sector, the price of corn had the greatest influence upon tallow demand. Changes in the price of corn affected the demand for tallow by an average of 4.48 percent. Changes in the quantity of broiler feed consumed caused the demand for tallow to change by 3.88 percent.
Table 15. The influence of factors affecting the demand for tallow by the animal feed industry

<table>
<thead>
<tr>
<th>Exogenous variable</th>
<th>Impact multiplier</th>
<th>Ratio of standard deviation to mean</th>
<th>Impact on demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn price</td>
<td>0.104</td>
<td>43.27</td>
<td>4.48</td>
</tr>
<tr>
<td>Ratio of soybean meal price to corn price</td>
<td>-0.0542</td>
<td>34.55</td>
<td>1.87</td>
</tr>
<tr>
<td>Broiler feed consumed</td>
<td>0.4263</td>
<td>9.11</td>
<td>3.88</td>
</tr>
<tr>
<td>Time</td>
<td>0.146</td>
<td>57.03</td>
<td>8.32</td>
</tr>
</tbody>
</table>

Impact on tallow demand by fatty acid sector of variation of exogenous variables

The factor which had the greatest effect upon the demand for tallow by the fatty acid industry was consumer income (DDYN). The impact multiplier of DDYN was estimated to be 3.324; that is, a one percent increase in DDYN resulted in a 3.324 percent increase in the demand for tallow. Although this impact multiplier is very large compared to other impact multipliers, it should not be rejected as incorrect. Because many of the items produced from fatty acids can be considered luxuries, the demand for the final goods which use fatty acids could conceivably be very responsive to changes in DDYN. Thus, the demand for tallow by the fatty acid sector would also be highly influenced by changes in DDYN.

The demand for tallow was also found to be highly responsive to fabric production (FABRIC). A one percent increase of FABRIC resulted in an increase in the tallow demand of 0.9178 percent.
Table 16. The influence of factors affecting the demand for tallow by the fatty acid industry

<table>
<thead>
<tr>
<th>Exogenous variable</th>
<th>Impact multiplier</th>
<th>Ratio of standard deviation to mean</th>
<th>Impact on demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean oil price</td>
<td>0.1657</td>
<td>58.43</td>
<td>9.68</td>
</tr>
<tr>
<td>Fabric production</td>
<td>0.9178</td>
<td>9.59</td>
<td>8.80</td>
</tr>
<tr>
<td>Unemployment</td>
<td>-0.1500</td>
<td>30.00</td>
<td>4.50</td>
</tr>
<tr>
<td>Deflated disposable income per capita</td>
<td>3.324</td>
<td>6.16</td>
<td>20.48</td>
</tr>
</tbody>
</table>

Impact on tallow demand by the food sector of variation of exogenous variables

In the food sector, the soybean oil price (SBOP) and deflated disposable income per capita (DDYN) had the greatest effect upon the demand for tallow. These two factors had a much greater effect upon the demand for tallow than the supply of tallow did. This suggests that the demand for tallow as a food product is determined by factors which influence the consumer and is not greatly constrained by the maximum amount of tallow that can be used for edible purposes.

The impact multiplier of DDYN was again found to be very large, 2.856. In this case, it is hard to accept the impact multiplier as correct because per capita shortening consumption did not increase dramatically over the period of 1966 to 1975 [29].
Table 17. The influence of factors affecting the demand for tallow by the food industry

<table>
<thead>
<tr>
<th>Exogenous variable</th>
<th>Impact multiplier</th>
<th>Ratio of standard deviation to mean</th>
<th>Impact on demand %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean oil price</td>
<td>0.2078</td>
<td>58.43</td>
<td>12.14</td>
</tr>
<tr>
<td>Deflated disposable income per capita</td>
<td>2.856</td>
<td>6.16</td>
<td>17.59</td>
</tr>
<tr>
<td>Total tallow supply</td>
<td>0.4990</td>
<td>7.58</td>
<td>3.78</td>
</tr>
<tr>
<td>Time</td>
<td>-0.0981</td>
<td>57.02</td>
<td>5.59</td>
</tr>
</tbody>
</table>

Impact on tallow exports of variation of exogenous variables

The level of Japanese industrial activity had the greatest effect upon exports of tallow. Stocks of tallow in the United States also had a significant effect on the quantity of tallow exported.

Table 18. The influence of factors affecting exports of tallow

<table>
<thead>
<tr>
<th>Exogenous variable</th>
<th>Impact multiplier</th>
<th>Ratio of standard deviation to mean</th>
<th>Impact on demand %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palm oil price</td>
<td>0.168</td>
<td>33.47</td>
<td>5.63</td>
</tr>
<tr>
<td>Japanese industrial production</td>
<td>0.5448</td>
<td>26.24</td>
<td>14.30</td>
</tr>
<tr>
<td>Stocks of tallow</td>
<td>0.6023</td>
<td>14.51</td>
<td>8.74</td>
</tr>
</tbody>
</table>

Determining the Price of Tallow

Because the supply and demand are both price inelastic, it would be expected that large fluctuations in the price of tallow occurred when supply or demand shifted. This was indeed the case for the tallow price. The variation of the tallow price, as indicated by the ratio of the standard deviation of the tallow price to the mean of the tallow price,
was 49 percent.

Although the lack of close substitutes in several of the domestic markets for tallow implies that the price of tallow is determined independently of the price of other fats and oils, the price of tallow actually is highly correlated with the price of other fats and oils. A correlation matrix of the prices of selected fats and oils (see Table 19) shows the correlation of the tallow price with the price of other fats and oils. The price of tallow had the highest correlation with the price of soybean oil. (The prices of other fats and oils also had the highest correlation with the price of soybean oil; thus, soybean oil appears to be the dominant force in determining the price of fats and oils.)

Table 19. Correlation matrix of selected fats and oils prices

<table>
<thead>
<tr>
<th></th>
<th>Tallow price</th>
<th>Lard price</th>
<th>Coconut oil price</th>
<th>Soybean oil price</th>
<th>Palm oil price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tallow price</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lard price</td>
<td>0.851</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coconut oil price</td>
<td>0.803</td>
<td>0.619</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean oil price</td>
<td>0.867</td>
<td>0.919</td>
<td>0.815</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Palm oil price</td>
<td>0.750</td>
<td>0.869</td>
<td>0.732</td>
<td>0.904</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Regressing the quarterly price of tallow upon the quarterly price of soybean oil further emphasizes the role of the soybean oil price in determining the price of tallow. The regression equation is:

\[ TP = 2.537 + 0.4492 \text{ SBOP.} \]

\[ (10.7) \]

\[ R^2 = 0.751 \quad F = 114.8 \quad S.E. = 2.36 \]
This equation implies that the price of soybean oil had a major impact upon the price of tallow even though soybean oil was not a major competitor of tallow in the domestic markets.

A second equation was estimated in which both the soybean oil price and the total consumption of tallow were explanatory variables of the variation of the tallow price. The results of the estimation are:

\[ TP = 2.9058 + 0.4515 - 0.00032 \text{ CONSUMPTION}. \]

\[ (9.09) \quad (0.09) \]

\[ R^2 = 0.751 \quad F = 55.9 \quad \text{S.E.} = 2.40 \] (16)

The addition of the consumption variable did not increase the percentage of variation in the tallow price that was explained by the regression equation.

The ability of the soybean oil price to explain the variation in the tallow price suggests that substitution of soybean oil and tallow caused the price of these commodities to move together. When the price of soybean oil would increase relative to the price of tallow, tallow would be substituted for soybean oil. The substitution of tallow for soybean oil would then cause the tallow price to increase.

The only markets in which soybean oil and tallow competed were the food and the export markets. Thus the substitution of soybean oil for tallow in these markets must have had a major impact on the tallow price.

Since tallow accounted for only 11 percent of the fats and oils traded on the world market, changes in domestic demand for tallow would have little effect upon the price of world fats and oils. However, if there was a general change in either the total production or total consumption of fats and oils, this change would affect the price of tallow.
It can then be concluded that the price of tallow is not determined independently of the prices of other fats and oils. Rather, the supply and demand for all fats and oils appears to simultaneously determine the prices of all fats and oils in order to clear the markets.
CHAPTER V. SUMMARY

This study analyzes the supply and demand for tallow. Factors which influenced the quantity of tallow supplied were identified and used in a linear supply equation which quantified the effects of changes in the values of exogenous variables. Demand was divided into five separate markets to permit a detailed analysis. For each market a separate linear demand equation was specified and statistically estimated.

The quantity of tallow supplied increased by 126 percent from 1950 to 1975. This increase was due to increased production of cattle for beef. Since beef and tallow are produced jointly, the production of tallow followed the increased production of beef. The price elasticity of the tallow supply was estimated to be 0.045. Thus the quantity of tallow supplied responded very little to changes in the price of tallow. Instead, the quantity of tallow supplied is determined largely by the number and weight of livestock being slaughtered.

Tallow is used as an intermediate product in the production of final goods. The demand for tallow, therefore, is derived from the demand for the final products. Products which use tallow as an intermediate good are soaps, fatty acids, animal feeds, and shortenings.

The utilization of tallow has changed drastically since 1950. In 1950, 60 percent of the domestic tallow was used to produce soaps. In 1975, only 12 percent of the domestic tallow was used in soap production. The animal feed market has become the largest domestic market for tallow. In 1975, 24 percent of the domestic tallow was used by this market. Exports of tallow have become the largest outlet for tallow.
Approximately 38 percent of the tallow produced in the United States was exported in 1975.

The elasticity of demand by the soap industry was estimated to be -0.03. The demand for tallow is inelastic because there are no good substitutes for tallow at moderate prices. Coconut oil has been the only other fat or oil that was used extensively in this market; however, coconut oil is a complement of tallow in soap manufacturing rather than a substitute for tallow. The quantity of tallow demanded decreased by 1.07 million pounds per quarter from 1966 to 1971. This was caused by synthetic detergents replacing tallow-based soaps in the detergent market. Since 1972, the quantity of tallow demanded increased by 1.07 million pounds each quarter. This increase was possibly caused by the replacement of synthetic detergents by tallow-based soaps because of pollution problems caused by the synthetic detergents.

Tallow is demanded by the animal feed industry because tallow is a concentrated source of energy for animal rations. Presently, the broiler industry is the greatest consumer of tallow in feeds. The demand by this sector was found to be price inelastic; the estimated elasticity was -0.138. No other fats or oils were reported as being used in animal feed rations. However, corn acts as a substitute for tallow because corn is high in energy. Thus changes in the price of corn affected the quantity of tallow demanded by the feed sector. The quantity demanded fell by 16.2 million pounds for every decrease in the price of a bushel of corn by one dollar. Other factors affecting the quantity of tallow demanded by this sector were the number of broilers being fed and the relative price of soybean meal to corn.
The quantity of tallow demanded by the fatty acid industry was not found to be responsive to changes in the price of tallow. The estimated price elasticity for this sector was -0.07. It was shown that the quantity of tallow demanded responded to changes in the production of fabrics and to changes in disposable income per capita.

As a food product, tallow competes with other edible fats and oils such as soybean oil, cottonseed oil, and lard. The availability of good substitutes for tallow suggests that the quantity of tallow demanded would be responsive to changes in the price of tallow. The estimated price elasticity indicated that the demand by this sector is more elastic than the demand by the soap, animal feed, and fatty acid sectors. The estimated price elasticity was -0.345.

Tallow competes with many fats and oils in the foreign trade sector. Soybean oil, palm oil, and coconut oil are some of the most important competitors. Thus the foreign demand for tallow would be more price elastic than the major domestic markets. Demand for tallow by the foreign sector was found to have an elasticity of demand of -0.211. Because of this size of this sector, the adjustments in the quantity exported due to changes in the price of tallow had a major impact on equating the quantity of tallow demanded with the quantity of tallow supplied. The productivity of foreign economies had a major effect upon the quantity of tallow exported. The quantity of tallow exported was found to be positively related to an index of Japan's industrial productivity. Exports increased by 0.545 percent for every one percent increase in the index of Japan's industrial productivity.
The price of tallow was shown to be highly correlated with the price of soybean oil. Substitution of soybean oil for tallow in the food and export sectors were responsible for this high correlation. In the other markets for tallow, soybean oil did not substitute for tallow.

Prospects for the Tallow Market

Continued expansion of the livestock sector in the United States will also expand the quantity of tallow produced. It will take intensified efforts by tallow producers to market the tallow.

The development of a tallow-based soap that functions in both hard and cold water and is also biodegradeable may lead to increased consumption of tallow by the soap industry. Such a soap has the potential to recover many of the markets that were lost to synthetic detergents. Such a soap would also be preferred to synthetic detergents in areas that have been heavily polluted by synthetic detergents.

The animal feed market has expanded steadily since 1954; however, the rate of growth of this market has slowed and further increases in the quantity of tallow demand may be dependent upon the adoption of high energy feeding practices by other livestock and poultry sectors. If the use of tallow can be successfully promoted as an ingredient in hog, cattle, and turkey rations, this sector can be expected to grow rapidly in the future. Otherwise, the consumption of tallow by this sector will be linked to the growth of the broiler industry.

In 1975, the quantity of U.S. exports of tallow fell dramatically in response to decreased demand caused by the recession and by the increased production of palm and coconut oils. It is likely that the U.S. will
recoup its exports that were lost due to the recession, but it does not seem likely that the exports which were lost to palm and coconut oil will be recovered. Therefore, it is necessary for the tallow exporters to adopt new marketing strategies and to seek new markets for tallow.

Efforts must be made to regain the major industrial markets of Western Europe and Japan. At the same time, efforts must be made to build old but small markets into major users of tallow. This could be accomplished through improving the technical servicing of customers, improving quality control, and reducing handling losses.

The rendering industry must also make an effort to increase the quantity of tallow being used in end products other than soap. Use of tallow in animal feeds seems to be the most promising growth market for tallow overseas. Countries in the Mideast and Africa which are developing their poultry industry are potential markets for U.S. tallow.

Countries in the Mideast which are considered the best prospective new markets are Iran, Iraq, Saudi Arabia, and Turkey. Countries that exhibit potential as new markets in Africa are Nigeria, Ghana, South Africa, Kenya, the Sudan, Algeria, and Morocco. Several South American countries--Venezuela, Brazil, Columbia, and Ecuador--also have the potential to become large markets for U.S. tallow [2, p. 12]. There may also be new opportunities to export tallow to the Soviet Union and China as trade agreements with these countries become more liberalized.
BIBLIOGRAPHY


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Last but not least, thanks go to my parents, Eugene and Lorraine Remmele, for their continued support of my graduate education.
APPENDIX A. COMPUTATION OF QUARTERLY CONSUMPTION OF FEED BY BROILERS

The quarterly feed consumption by broilers was computed by taking into account the broiler hatch and the quantity of feed consumed by a broiler at different periods of its life span.

Broilers are marketed approximately eight weeks after they are hatched. In the first week after hatch, male and female broilers consume approximately 0.15 pounds of feed. The weekly intake by both males and females increase for each additional week that they are fed. In the eighth week of their life, males consume approximately 2.01 pounds of feed and females consume 1.46 pounds of feed. Thus the age of the broiler flock will influence the quantity of feed consumed. Table 20 gives the weekly and cumulative feed consumption by male and female broilers.

Table 20. Weekly and cumulative feed consumption data for broilers

<table>
<thead>
<tr>
<th>Age in weeks</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feed consumed</td>
<td>Cumulative</td>
</tr>
<tr>
<td></td>
<td>(pounds of feed)</td>
<td>(pounds of feed)</td>
</tr>
<tr>
<td>1</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>2</td>
<td>0.44</td>
<td>0.59</td>
</tr>
<tr>
<td>3</td>
<td>0.99</td>
<td>1.58</td>
</tr>
<tr>
<td>4</td>
<td>0.94</td>
<td>2.52</td>
</tr>
<tr>
<td>5</td>
<td>1.42</td>
<td>3.94</td>
</tr>
<tr>
<td>6</td>
<td>1.53</td>
<td>5.47</td>
</tr>
<tr>
<td>7</td>
<td>1.64</td>
<td>7.11</td>
</tr>
<tr>
<td>8</td>
<td>2.01</td>
<td>9.12</td>
</tr>
</tbody>
</table>

Source: [20, p. 97].
The computation of feed consumed by broilers in the fourth quarter of 1975 is given as an example. Broilers which are hatched from August through December will affect the quantity of feed consumed in the fourth quarter. Broilers which are hatched in August will be marketed in October, the first month of the fourth quarter. On the average, these broilers will be six weeks old on October 1; therefore, they will consume feed for two weeks in the fourth quarter before they are marketed. In these two weeks, the males will consume 3.65 pounds of feed per bird and the females will consume 2.58 pounds of feed per bird. Assuming that 50 percent of the chick hatch is male and 50 percent is female, the quantity of feed consumed in the fourth quarter by male broilers that were hatched in August is computed by multiplying 3.65 pounds of feed consumed by one half of the reported broiler hatch of August. Add to this the result of multiplying 2.58 pounds of feed consumed by female broilers by one half of the reported broiler hatch to obtain the quantity of feed consumed in the fourth quarter by broilers hatched in August.

Broilers hatched in September will average two weeks old at the start of the fourth quarter. Thus they will be fed for six weeks in the fourth quarter. In this six week period, the males will consume 8.53 pounds of feed and the females will consume 6.70 pounds of feed. Multiplying these figures by the number of male and female broilers hatched in September and summing these two products gives the quantity of feed consumed in the fourth quarter by birds hatched in September.

Broilers hatched in October will consume feed for eight weeks in this quarter before being marketed. The male birds will consume 9.12
pounds of feed and the females will consume 7.28 pounds of feed in this period. Multiplying the number of male and female broilers hatched in October by the quantity of feed consumed by each sex and summing gives the quantity of feed consumed by broilers hatched in October.

The November hatch will be fed six weeks in the fourth quarter. The males will consume 5.47 pounds of feed and the females will consume 4.70 pounds of feed in these six weeks. The fourth quarter consumption of feed by the November hatch of broilers is computed by multiplying the pounds of feed consumed by the number of male and female broilers hatched in November. These two figures are summed to give total consumption.

Broilers hatched in December will on the average be fed for two weeks before the fourth quarter ends. In these two weeks, the males will consume 0.59 pounds of feed and the females will consume 0.58 pounds of feed. Multiplying these figures by the number of each sex which were hatched in December and summing gives the quantity of feed consumed in the fourth quarter by the December hatch of broilers.

Summing the quantities of feed consumed by the chicks hatched from August to December gives the total quantity of feed consumed by broilers in the fourth quarter. The actual data for the fourth quarter of 1975 is given in Table 21. The month of hatch is given in column one. The total hatch is given in column two. Column three gives the number of weeks that broilers hatched in a given month will be consuming feed in the fourth quarter. The amount of feed that each male bird will consume is given in column four. Multiplying column four by one half of the hatch of column one gives the feed consumed by males; this is reported
in column five. The quantity of feed consumed by females is given in column six. Multiplying this column by one half of column one gives the quantity of feed consumed by female broilers in each month; this is reported in column seven. Summing column five gives the total amount of feed consumed by males in the fourth quarter. Summing column seven gives the total amount of feed consumed by females. Totaling these two figures gives the total feed consumption by broilers in the fourth quarter of 1975.

Table 21. Procedure to compute broiler feed consumption for the fourth quarter of 1975

<table>
<thead>
<tr>
<th>Month</th>
<th>Hatch (millions)</th>
<th>Weeks on feed</th>
<th>Consumption by males (pounds)</th>
<th>Total (pounds)</th>
<th>Consumption by females (pounds)</th>
<th>Total (pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>August</td>
<td>266.7</td>
<td>2</td>
<td>3.65</td>
<td>486.73</td>
<td>2.58</td>
<td>344.04</td>
</tr>
<tr>
<td>September</td>
<td>245.9</td>
<td>6</td>
<td>8.53</td>
<td>1048.77</td>
<td>6.70</td>
<td>823.77</td>
</tr>
<tr>
<td>October</td>
<td>248.4</td>
<td>8</td>
<td>9.12</td>
<td>1132.71</td>
<td>7.28</td>
<td>904.18</td>
</tr>
<tr>
<td>November</td>
<td>254.1</td>
<td>6</td>
<td>5.47</td>
<td>694.97</td>
<td>4.70</td>
<td>597.14</td>
</tr>
<tr>
<td>December</td>
<td>271.0</td>
<td>2</td>
<td>0.59</td>
<td>79.94</td>
<td>0.58</td>
<td>78.59</td>
</tr>
</tbody>
</table>

Total feed consumption by broilers in the fourth quarter of 1975 6190.84
APPENDIX B. FIGURES
Figure 3. Estimated and actual production of tallow, 1966-1975

X Estimated
Z Actual
Figure 4. Estimated and actual consumption of tallow by the soap industry, 1966-1975

\( \bar{X} \) Estimated

Z Actual
Figure 5. Estimated and actual consumption of tallow by the animal feed industry, 1966-1975

\[ \bar{X} \text{ Estimated} \]

\[ Z \text{ Actual} \]
Figure 6. Estimated and actual consumption of tallow by the fatty acid industry, 1966-1975

\( \times \) Estimated

\( Z \) Actual
Figure 7. Estimated and actual consumption of tallow by the food industry, 1966-1975

\( \text{X} \) Estimated

\( \text{Z} \) Actual
Figure 8. Estimated and actual exports of tallow, 1966-1975

X Estimated

Z Actual