# THE ECONOMIC IMPACT OF MECHANICALLY DEBONING RED MEATS

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THE ECONOMIC IMPACT OF MECHANICALLY

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TABLE OF CONTENTS


| Chapter | | Page |
|---|---|---|
| I. | OVERVIEW | 1 |
| | Reason for the Study | 1 |
| | The Mechanical Deboning Issue | 2 |
| | The Technology | 2 |
| | Proposed Regulations | 4 |
| | The Pros and Cons of Adoption | 6 |
| | Objectives of the Study | 11 |
| | The Approach | 11 |
| | Selected Review of Previous Studies | 12 |
| | Summary | 15 |
| II. | THE MODEL | 17 |
| | The Institutional Framework | 17 |
| | The Theoretical Framework | 21 |
| | Primary Effects of Mechanical Deboning | 23 |
| | Secondary Effects of Mechanical Deboning | 25 |
| | The Empirical Framework | 27 |
| | The Model in Functional Form | 27 |
| | Data | 30 |
| | Estimation of the Parameters | 33 |
| | A Priori Hypotheses About the Parameters of the Variables | 35 |
| | Summary | 37 |
| III. | EMPIRICAL RESULTS | 38 |
| | Statistical Estimates of the Structural Equations | 38 |
| | Demand for Table Beef | 40 |
| | Supply of Table Beef | 41 |
| | Demand for Processed Beef | 43 |
| | Supply of Processed Beef | 43 |
| | Demand for Table Pork | 44 |
| | Supply of Table Pork | 46 |
| | Demand for Processed Pork | 46 |
| | Supply of Processed Pork | 47 |
| | Discussion of the Results | 48 |
| | A Comparison of Elasticities | 50 |
| | Summary | 53 |

Chapter | Page


IV. THE WELFARE EFFECTS OF ALTERNATIVE REGULATIONS ON THE USE OF MECHANICALLY DEBONED MEAT . . . . . . . . . . . 54

Simulation of the Consequences of Alternative Mechanical Deboning Regulations . . . . . . . . . . . . 54
Analysis and Measurement of the Welfare Effects of Alternative Mechanical Deboning Regulations . . . . . 71

V. SUMMARY AND CONCLUSIONS . . . . . . . . . . . . . . . . . . 78

A Brief Summary . . . . . . . . . . . . . . . . . . . . 78
Limitations . . . . . . . . . . . . . . . . . . . . . . 82
Policy Implications . . . . . . . . . . . . . . . . . . 84
Suggestions for Further Research . . . . . . . . . . . 85

BIBLIOGRAPHY . . . . . . . . . . . . . . . . . . . . . . . . . 87

APPENDIX - DATA . . . . . . . . . . . . . . . . . . . . . . . . 91

LIST OF TABLES


| Table | | Page |
|---|---|---|
| I. | Per Capita Consumption of Red Meat, by Type, Selected Years | 18 |
| II. | Shares of Table and Processed Meats - Technical Possibilities and Consumption Patterns | 32 |
| III. | Summary of Estimated Retail Demand and Supply Elasticities | 50 |
| IV. | Comparison of Selected Supply and Demand Elasticities for Table and Processed Beef | 52 |
| V. | Simulated Quantities of Processed Beef Under Alternative MDM Regulations | 58 |
| VI. | Simulated Prices of Processed Beef Under Alternative MDM Regulations | 59 |
| VII. | Simulated Quantities of Processed Pork Under Alternative MDM Regulations | 61 |
| VIII. | Simulated Prices of Processed Pork Under Alternative MDM Regulations | 62 |
| IX. | Simulated Quantities of Table Beef Under Alternative MDM Regulations | 64 |
| X. | Simulated Prices of Table Beef Under Alternative MDM Regulations | 65 |
| XI. | Simulated Quantities of Table Pork Under Alternative MDM Regulations | 66 |
| XII. | Simulated Prices of Table Pork Under Alternative MDM Regulations | 67 |
| XIII. | Simulated Effects of Alternative Mechanical Deboning Regulations on the Demand for Livestock | 70 |
| XIV. | Simulated Welfare Effects of Alternative Mechanical Deboning Regulations | 76 |

| Table | | Page |
|---|---|---|


XV. Summary of Price, Quantity and Welfare Effects Associated with Alternative MDM Regulations . . . . . . . 81

XVI. Time Series Data . . . . . . . . . . . . . . . . . . . . . . . . . . . . 94

LIST OF FIGURES

Figure | Page

1. Production Possibilities for Table Cuts and Processed Meats . . . . . . . . . . . . . . . . . . . . . . 22

2. Demand and Supply of Processed Meats . . . . . . . . . . . . . . 24

3. Demand and Supply of Table Cuts . . . . . . . . . . . . . . . . . 26

4. Demand and Supply of Livestock . . . . . . . . . . . . . . . . . 28

5. Demand and Supply of Processed Meats . . . . . . . . . . . . . . 73

# CHAPTER I

# OVERVIEW

## Reason for the Study

In a world of scarce resources and increasing population, many nations must be increasingly concerned about the provision of essential foodstuffs. Many of the world's people are chronically short of needed dietary nutrients, particularly protein. While the United States is fortunate to have an abundance and variety of protein sources, especially meat, economic efficiency demands that we be thrifty with our food supply and search for ways to cut down on waste. Recent technological advances have led to new methods for conserving meat that previously was not available for human consumption. One of these technologies, called mechanical deboning, may offer an opportunity to save millions of pounds of meat that is now wasted.

Mechanical deboning is a method, using special machines, for separating the particles of meat that cling to the bones of a carcass after they are hand trimmed in the processing plant. The United States Department of Agriculture (USDA) has proposed new regulations that would permit wider use of mechanically separated meat.[1]

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[1]While the Food and Drug Administration of the Department of Health, Education and Welfare is responsible for most of today's pure food and drug regulations, Congress singled out meat for the special separate attention of the USDA. For an excellent discussion of the many regulators of the livestock-meat industry see McCoy (24), Chapter 13.

This study is designed to determine, as nearly as possible, the economic impact which would result from the adoption of mechanical deboning techniques in the red meat industry. Economic impact is defined to mean changes in the retail prices and quantities of table and processed beef and pork and the associated welfare effects. All of this is with a view toward providing needed information for future policy decisions on regulations governing the production, use and labeling of mechanically deboned meat.

Briefly, the approach involves construction of an econometric model to describe in quantitative terms the supply and demand for table and processed beef and pork in the United States. This model is then used to take account of the economic impact of the increased meat production resulting from mechanically deboning red meats.

## The Mechanical Deboning Issue

### The Technology

Mechanical deboning is a technique for recovering the fragments of meat that remain on the bones of a carcass after hand trimming. In the mechanical deboning process, the bones and attached fragments of meat are ground up and fed into special deboning machines that act like a sieve. The bone bits are screened out while the meat passes through. The result is a paste-like product called mechanically deboned meat, hereafter referred to as MDM.

A deboning system consists of a grinder or bone cutter for breaking the meat covered bones into small enough pieces for the deboning equipment to handle, a deboning machine and some method for cooling the deboned protein material. A conveyor for bringing the bones and a transfer pump for moving the boney and lean material away are also necessary for an efficient system (26).

The mechanical deboning process is not new. It was developed for the Japanese seafood industry about 20 years ago and has been generally used in the United States poultry industry since 1965. Recent developments have established the technological feasibility of mechanically deboning red meats. It has been reported that red meats are being mechanically deboned in at least 29 foreign countries, including some major red meat producers and consumers such as Australia, New Zealand and Argentina (28).

Mechanical deboning techniques have not been widely adopted by United States red meat producers because the USDA has never clearly defined the term "meat".[2] The USDA recently proposed regulations which would expand the definition of meat and allow MDM to be used as an ingredient in certain processed meat products. But meanwhile, the additional meat that could be recovered via mechanical deboning is being wasted. It is either being thrown away or sent, along with the bones, for inedible rendering. This waste has been estimated to amount to 3-4 pounds of meat per pork carcass and 12-16 pounds per beef carcass.

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[2] For many years the Federal meat inspection regulations (9 CFR 301.2 (tt)) have defined meat as follows: "Meat. The part of the muscle of any cattle, sheep, swine, or goats which is skeletal or which is found in the tongue, in the diaphragm, in the heart or in the esophagus, with or without the accompanying and overlying fat, and portions of bone, skin, sinew, nerve and blood vessels which normally accompany the muscle tissue and which are not separated from it in the process of dressing. It does not include the muscle found in the lips, snout or ears. This term, as applied to products of equines, shall have a meaning comparable to that provided in this paragraph with respect to cattle, sheep, swine and goats" (39, p. 17560).

This means that each year the red meat industry could save millions of pounds of red meat by adopting the mechanical deboning process.

<u>Proposed Regulations</u>

The USDA's first move toward establishing regulations for the domestic production and use of mechanically deboned red meat came in November of 1974. In order to allow the Department to study many different procedures for mechanically deboning red meats, the USDA announced it would consider proposals from red meat packers and processors for preparing, labeling and distributing MDM. Red meat packers and processors whose proposals received USDA approval were allowed to produce MDM and use it in formulated meat food products. Approval was granted only to those proposals meeting certain temperature, calcium content and other quality control guidelines (35).

In April of 1976, the USDA formally proposed amending the meat inspection regulations to: (1) revise the definition of "meat" to include 13 different classes of meat, (2) provide for labeling these classes of meat in products and (3) regulate the production and use of certain classes of meat in products. Three classes of MDM were included in the proposed new definition of meat which, according to the proposal, would be revised as follows:

> Meat. Any edible portion of the carcass of any cattle, sheep, swine or goats, exclusive of lips, snouts, ears, caul fat, leaf fat and exclusive of all organs <u>except</u> the heart, tongue and esophagus; and including but not limited to the following classes of meat: (1) skeletal meat, (2) heart meat, (3) tongue meat, (4) esophagus meat, (5) meat trimmings, (6) fatty meat trimmings, (7) mechanically deboned meat, (8) mechanically deboned meat for processing, (9) mechanically deboned meat for rendering, (10) rendered meat, (11) rendered meat for processing, (12) cooked rendered meat and (13) cooked rendered meat for processing (39, p. 17562).

One reason for proposing the new classification of meat was to define the meat supply explicitly to include the new sources of edible meat protein which have become available as a result of advancing technologies such as mechanical deboning.

At the same time, the USDA published interim industry-wide regulations permitting the production and use of mechanically deboned red meat pending completion of final rulemaking. These regulations were developed by USDA for the purpose of acquiring factual data upon which to base the final regulations (39).

During the comment period which ended in August of 1976 a controversy developed over the regulations providing for the preparation, labeling and distribution of MDM (30). Ralph Nader's Health Research Group charged that "these proposed regulations should be seen for what they are - rules for turning garbage into money - and rejected" (20, p. 17A). After an unsuccessful appeal to the USDA to ban the production and use of MDM for human consumption, six consumer groups filed a suit in United States District Court contending that the USDA had failed to follow proper administrative procedure in issuing the temporary regulations. The Court concurred and issued an injunction against implementation of the interum rules. Subsequently, on September 14, 1976 the USDA ordered that the official mark of Federal inspection could no longer be placed on MDM. This in effect stopped domestic manufacture and distribution of mechanically deboned red meat (40).

Meanwhile, the broader proposal to redefine meat, including provisions for production and use of MDM, is still pending. At the Court's bidding, the USDA organized a panel with representatives from the Food and Drug Administration, Veterans' Administration and the National

Institute of Health to consider questions raised by the consumer groups about MDM. On the basis of recommendations provided by this Select Panel on Health and Safety Aspects of Use of Mechanically Deboned Meat, a revised proposal of standards and labeling requirements for MDM was issued in October of 1977 and is presently undergoing a public comment period (40).

The Pros and Cons of Adoption

Under the USDA's latest proposal, comminuted meat products such as bologna, hot dogs and sausage would be permitted to contain up to 20 percent MDM (40). The philosophy underlying the USDA's proposals to redefine meat and provide for the use of MDM as an ingredient in formulated meat products was expressed in the notice of proposed rulemaking.

> The first consideration in allowing any ingredient, new or traditional, is its wholesomeness. Secondly, the Department is becoming increasingly aware of its responsibilities in the field of nutrition. Meat and poultry are acknowledged as among the best sources of the complete protein needed by humans. To allow broad substitution of new products, which are wholesome and edible but greatly inferior to the traditional nutritional value of meat, would not serve the needs of the consumer . . . Implicit in the proposed new standards is an assurance to the consumer that . . . inclusion [of MDM] in formulated meat products will not dilute the nutritional quality normally and traditionally associated with meat (39, p. 17560).

The wholesomeness and nutritional value of MDM are two fundamental points of disagreement in the debate over MDM. Labeling of products containing MDM is a third issue to be addressed. The wholesomeness of MDM has been questioned because first, MDM contains small amounts of pulverized bone and second, the heat generated in the process of producing MDM could create bacterial problems. Nutritional questions about MDM concern its calcium content (which is an indication of bone content), the amount of fat, the amount of protein and the quality of protein. The labeling issue concerns specification of the ingredient statement, and whether the terms "beef" and "pork" (which are designations for hand-deboned meat) are appropriate for MDM products or whether labeling terminology more descriptive of the processing technique is more appropriate.[3] Some of the differing viewpoints on these issues are briefly summarized below.

In the mechanical deboning process, when the bones are crushed some pulverized bone powder is incorporated into the product. Is MDM adulterated, as some consumer groups contend, by the presence of this bone powder? The position taken by the USDA in its April, 1976 proposal was as follows:

> . . . the bone, if present in such a particle size or in such an amount as to be readily apparent to the taste or touch, would indeed be identifiable as bone and would be a reason for considering the product adulterated. However, modern equipment can minimize the particle size and level of bone to an extent that it cannot be detected by sensation in the mouth . . . As long as the particle size can be controlled, and the amount incorporated into the finished product [is] not detectable in any way, the Department is of the opinion that far from being objectionable, the presence of additional calcium may be of benefit (39, p. 17561).

According to the American Meat Institute (3), much of the confusion about MDM is the result of erroneous news reports that MDM could contain "bone chips".

> These reports are absolutely false . . . The design of mechanical deboning equipment prevents any bone chips, fragments or shards from entering the meat. The meat is separated from the bones by passing through minute holes

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[3] The Select Panel on Health and Safety Aspects of Use of MDM has recommended that the name of meat food products containing MDM be qualified by the phrase, "Tissue from Ground Bone Added." (40, p. 54441).

> in a screen or plate. The bones and cartilage are too large to go through the holes and are removed separately (pp. 1-2).

The American Meat Institute (3) acknowledges that a small amount of powder from the bones (calcium phosphate) remains in the meat, but argues that

> Individual particles are microscopic - less than 18/1000th of an inch in size - and cannot be felt or tasted in the final product . . . In form and quantity, the calcium content of mechanically deboned meat is not detrimental to human health and may be actually beneficial (p. 2).

Consumer groups contend that the presence of bone particles in MDM, however small, would be a "contaminant" which could have adverse effects on human beings. They argue that in some humans the pulverized bone could be an irritant to the digestive tract and harm those who might be sensitive to intake of excess calcium. Red meat producers argue that this position is inconsistent since mechanically deboned poultry and fish have been used for human consumption for many years and imported red meat products containing MDM are being sold in the United States as well.[4]

While the latest proposed regulations contain no specifications on the permissible particle size of the ground bone, a maximum size opening for the sieves used in processing MDM has been set at 0.5 mm. in diameter and the maximum amount of calcium to be permitted in MDM is .75 percent (40). By comparison, a choice grade sirloin steak contains 10 mg. of calcium per 100 gm. of meat, or .01 percent calcium; a choice grade T-bone steak contains 8 mg. per 100 gm., or .008 percent (32, p. 2).

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[4]United States processors currently produce about 135 million to 165 million pounds of mechanically deboned chicken and turkey each year (32, p. 1).

At the proposed 20 percent maximum allowable rate for inclusion of MDM in processed meat products, the final product would include .15 percent calcium. This is exclusive of the calcium supplied by other ingredients.

Dr. Robert Stokstad, president of the American Institute of Nutrition, has testified that from a nutritional standpoint the increased bone, which is made of calcium, would be a plus rather than a minus. According to Dr. Stokstad, many people have diets significantly low in calcium. A meat product containing calcium would be valuable, especially in ethnic groups who have lactose intolerance and whose consumption of milk is limited (23)(28). The Select Panel also concluded that "a slight nutritional benefit is to be expected for most people from the calcium in MDM . . ." (40, p. 54439).

With regard to the issue of fat content, the proposed regulations permit MDM to contain up to 30 percent fat. Some consumers believe that this figure is too high and that buyers should be getting more lean meat. By comparison, a broiled choice grade T-bone steak contains 44 percent fat; a broiled choice grade sirloin steak, 34 percent; the edible portion of a raw prime grade beef carcass, 46 percent and bacon 55 percent. Ground beef is permitted by existing USDA regulations to contain up to 30 percent fat (32).

The quality of the protein available in MDM is another point of contention. Protein quality, technically referred to as the Protein Efficiency Ratio (PER), is a measure of ability to maintain the body's growth. Lean beef has a PER of 2.85. The proposed regulations specify that MDM have a minimum PER of 2.5. Consumers object to the protein quality requirements for MDM being set lower than those of lean meat (32).

All meat is perishable and must be handled carefully to prevent spoilage. Consumer groups have voiced concern about bacterial problems with MDM. Since some heat is generated during the mechanical separating process, MDM must be thoroughly chilled to prevent bacterial growth. Consumer groups have requested that the chilling procedure be monitored so that consistently low bacterial numbers are maintained. After studying this issue, the Select Panel concluded that the "microbiology of MDM presents no unique hazards and should not be a problem if good manufacturing practices and quality control programs are employed" (40, p. 54439).

Another question raised by consumerists is whether antibiotics and other animal drugs might affect the bones of slaughtered animals and thus MDM also. In response to this question, Dr. Harry Mussman, USDA Associate Director of the Animal and Plant Health Inspection Service, says that the Food and Drug Administration tells him it "sees no problem with the presence of or the size of the bone particles in mechanically deboned meat" (28, p.1). After considering the results of an intensive analytical program of tests conducted in the laboratories of the USDA's Food Safety and Quality Service and other Government laboratories, the Select Panel concluded that no public health problem is posed by the presence or absence in bone of trace elements such as lead, fluorine, strontium-90, iron, nickel, zinc, nor chemical or pesticide residues. However, the Panel did urge caution and further research in several areas (40).

While evidence from studies of the nutritional and safety implications of MDM is being collected, little or no attention has been focused on the economic impact of the increased meat production which could result from mechanically deboning red meats (25)(2). This lack of economic analysis of the mechanical deboning issue is the reason for the present study.

## Objectives of the Study

The objectives of this study of the economic impact of mechanically deboning red meats involve testing two hypotheses:

1. Adoption of the mechanical deboning technology has a potential for affecting the prices, production and consumption of table and processed red meats.
2. Regulations prohibiting the adoption of mechanical deboning techniques result in an inefficient allocation of resources and an attendant welfare loss to society.

The first hypothesis is most crucial since if it is refuted the second hypothesis is also. Thus the greatest proportion of the study will be concerned with evaluating the first hypothesis, while the second will be examined more briefly. Quantification of the potential economic effect, if any, of mechanical deboning is the primary objective. This is to be achieved by building a model of the United States markets for table and processed beef and pork. Once accomplished, this model will be utilized to examine the two hypotheses.

## The Approach

To achieve the stated objectives, a model must be built which describes the markets for table and processed beef and pork in terms of demand and supply functions. This will allow measurement of the potential economic impact of adopting mechanical deboning techniques under alternative assumptions about the additional amount of MDM that can be recovered and utilized in processed meats.

Changes in efficiency, and thus welfare, result from changes in either price or quantity. These changes can be assessed by estimating the changes in the areas of consumer and producer surplus formed by the demand and supply curves. Methods for measuring these changes have been developed by Currie, Murphy and Schmitz (8), Schmitz and Seckler (31), Akino and Hayami (1) and others. They are reasonably straightforward, at least in their basic form, and are discussed later in Chapter IV.

## Selected Review of Previous Studies[5]

A number of previous studies have estimated demand relationships for beef, veal, pork, lamb and mutton, but few have attempted to estimate demand relationships at more disaggregated levels in these markets (4) (5)(13)(43)(44). An exception to this statement is the work by Duewer (9) estimating demand relationships for eight retail cuts of pork. However, neither this study nor the ones referenced earlier take account of the interdependence of both sides of the market, supply as well as demand. Rather, the demand relationships are estimated in isolation and the supply relationship, if included at all, is specified in terms of some assumed elasticity--usually perfectly inelastic.

Adequate economic analysis of a number of problems requires further disaggregation of the markets of the composite products called "beef"

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[5]Studies of the beef and pork subsectors of the meat-livestock economy are too numerous and wide ranging to be discussed here. Only those studies which involve disaggregating these composite markets or simultaneous estimation of demand and supply relationships in these markets are discussed.

and "pork". Tracing the economic impacts of a technological advancement such as mechanical deboning, or of a policy change, such as increasing meat import quotas, are but two examples where useful economic analysis requires further disaggregation of the traditionally analyzed composite markets for beef and pork. However, the lack of published data at more disaggregated levels presents a roadblock to researchers seeking to proceed in this direction.

Two studies which attempt simultaneous estimation of demand and supply relationships at more detailed levels in the market for beef are one by Langemeier and Thompson (22) and another by Hunt (17). No previous studies have been found which involve simultaneous estimation of demand and supply relationships at more detailed levels of the market for pork.

Hunt (17), in analyzing the economic impact of beef import quotas, attempted to disaggregate the market for beef by estimating separate demand and supply relationships for table beef and processed beef at both the farm and retail levels. Disaggregation of the market for beef was based on the assumption that all fed beef is converted into table beef and all nonfed beef and imported beef go into processed beef. The USDA (36) reports data on fed and nonfed beef, which Hunt converted into retail equivalents of table and processed beef.

While Hunt's assumption may be permissible for certain time periods, it cannot be considered acceptable over the entire 23 years of time series data used for estimation. According to the data reported by Hunt (17, p. 172), in 1946, the initial year of his time series, nonfed and fed beef comprised 67 and 33 percent of the beef market respectively. By 1968, the last year of Hunt's time series, these shares had practically reversed themselves to 37 and 63 percent respectively. Information from surveys of household consumption patterns indicates that it is very unlikely that such a significant shift occurred in the shares of table and processed beef consumed (Table II)(34)(41). In fact, while available information on beef consumption patterns is certainly less than adequate, it appears that beef consumption patterns have been fairly stable, with perhaps some trend toward increased consumption of processed products.

This inconsistency in the data used by Hunt casts some doubt on the reliability of the resulting estimates of the disaggregated retail demand and supply relationships for table and processed beef. In fact, Houck (15) later felt compelled to adjust the elasticities estimated by Hunt before using them in an analysis of the short-run impact of beef imports on United States meat prices. Hunt's study is notable, however, for its effort to disaggregate the traditionally analyzed composite market for beef and to estimate both supply and demand relationships simultaneously at two market levels.

An earlier study by Langemeier and Thompson (22) also divides the market for beef into table and processed components. It too is based on the assumptions that all fed beef is used for table cuts and all nonfed beef is used in processed meats. As explained above, these assumptions appear to be inconsistent with reported consumption patterns over the time period analyzed. This is because the quantities of fed and nonfed beef marketed are responsive to different forces than are the quantities of table and processed beef demanded by consumers. Information available on table and processed beef consumption patterns indicates fairly stable relationships over time. On the other hand, the relationship between fed and nonfed beef has changed dramatically over the same period in response to changing feed-livestock prices and other factors.

Another shortcoming of the Hunt-Langemeier-Thompson assumptions for disaggregating the retail market for beef is that they cannot be applied in a parallel manner to disaggregate the pork market into table and processed submarkets. These studies do, however, demonstrate that analysis of a number of economic problems requires disaggregating the beef and pork markets and that demand and supply relations may be estimated simultaneously rather than in isolation.

An alternative path around the data roadblock is used in this study. The basic assumption is that table and processed meats are supplied in relatively fixed proportions. Evidence to support this view is provided by the household consumption surveys, which indicate a fairly stable relationship between table and processed meats over the last two or three decades. Regardless of the long term trend, it is fairly safe to assume relatively stable proportions over shorter periods of time. Thus, the present study is based on monthly data for the period 1970 to 1976. The data on beef and pork consumption are disaggregated by the weighted average shares of home and away-from-home consumption of table and processed meats in the latest period for which survey data on consumption patterns are available. The methodology used is explained in more detail in the following chapter and in the Appendix.

## Summary

In the following chapter the institutional, theoretical and empirical background for the study is developed. Using this background, an empirical model is estimated in Chapter III which describes the supply and demand for table and processed beef and pork. In Chapter IV, this model is used to simulate the economic impact of alternative policies toward the use of MDM in processed meat products.

# CHAPTER II

# THE MODEL

This chapter contains three sections. The first section describes the institutional framework in which the potential impact of mechanical deboning will be analyzed. The second develops a theoretical framework from the knowledge of the institutional framework and attempts to describe the retail supply and demand for table and processed meats in economic terms. Several graphs are used in presenting the theoretical analysis. An empirical framework is developed in the third and final section. A model is hypothesized in a series of equations written in functional form. Data and estimation methods are discussed along with a priori hypotheses about the signs of the coefficients of the variables in the model.

## The Institutional Framework

Several types of red meat can easily be distinguished - beef, veal, pork, lamb and mutton. As Table I shows, beef and pork are by far the most important sources of red meat. Together they represent over 95 percent of per capita red meat consumption. Veal, lamb and mutton are relatively insignificant sources of red meat in comparison with beef and pork, and are omitted from the analysis that follows for reasons of simplicity and limitations in the data. Further references to the potential impact of the adoption of mechanical deboning techniques by red meat producers will not include mechanically deboned veal, lamb or mutton. This omission will tend to understate the potential impact of mechanical deboning.

TABLE I

PER CAPITA CONSUMPTION OF RED MEAT, BY TYPE, SELECTED YEARS

| Year | Pounds Per Capita - Retail Weight | | | | |
|---|---|---|---|---|---|
| | Beef | Pork | Veal | Lamb & Mutton | Total |
| 1976 | 95.4 | 54.1 | 3.4 | 1.7 | 154.6 |
| 1975 | 88.9 | 51.0 | 3.6 | 1.8 | 145.3 |
| 1970 | 84.1 | 61.8 | 2.4 | 2.9 | 151.2 |
| 1965 | 73.6 | 54.6 | 4.3 | 3.3 | 135.8 |
| 1960 | 64.3 | 60.4 | 5.2 | 4.3 | 134.2 |
| 1955 | 64.0 | 62.1 | 8.4 | 4.1 | 138.6 |
| 1950 | 46.9 | 64.4 | 6.6 | 3.6 | 121.5 |
| | Percent of Total | | | | |
| 1976 | 61.7 | 35.0 | 2.2 | 1.1 | 100.0 |
| 1975 | 61.2 | 35.1 | 2.5 | 1.2 | 100.0 |
| 1970 | 55.6 | 40.9 | 1.6 | 1.9 | 100.0 |
| 1965 | 54.2 | 40.2 | 3.2 | 2.4 | 100.0 |
| 1960 | 47.9 | 45.0 | 3.9 | 3.2 | 100.0 |
| 1955 | 46.2 | 44.8 | 6.1 | 2.9 | 100.0 |
| 1950 | 38.6 | 53.0 | 5.4 | 3.0 | 100.0 |

Source: United States Department of Agriculture (36).

Red meats reach consumers in two basic final forms, as table cuts and as processed meats. If red meat packers and processors utilized mechanical deboning techniques, the additional meat recovered would reach consumers as an ingredient in processed meat products. Consumers would not purchase MDM directly, but only to the extent it is included as an ingredient in processed meats.

Even though mechanical deboning is a processing technology, its impact is analyzed at the retail level. MDM is a manufacturing meat-- an intermediate meat product which is used in manufacturing other processed meat products. While mechanical deboning will increase the supply of manufacturing meat, it is very difficult to assess the impact in this market. Little information, in terms of prices and quantities of manufacturing meat traded, is available. This is due to the vertically integrated nature of meat packing and processing. Most firms produce and internally utilize their own manufacturing meats, so few market transactions occur and even fewer are publicly recorded.

The potential effects of mechanical deboning are assessed at the retail level in this study by assuming that the inclusion of MDM in processed meat products results in a pound for pound increase in the supply of processed meats. This is not an unrealistic assumption since: (1) as a processed meat ingredient, MDM is subject to little or no shrinkage; and (2) the proposed regulations for utilizing MDM stipulate that it not be detectable in the final product, so product homogeneity will be maintained.

Since MDM would enter the market as an ingredient in processed meat products, adoption of the technology may be expected to have differential impacts in the markets for table and processed meats.

For this reason, the markets for beef and pork must each be separated into submarkets for table and processed meats. Since the distinction between these terms is by no means uniformly clear, the definition accorded each in this study is set forth below.

The term table cuts, as used in this study, refers to meats which are consumed in whole muscle form, except for cutting or slicing. Steaks and roasts are the two principle types of beef table cuts. Pork loins, hams, roasts, chops, spareribs, bacon, butts and picnics are classified as pork table cuts.

The term processed meats refers to meats not consumed in whole muscle form. Included are processed products in which meat ingredients are ground, flaked, extruded or mixed with other ingredients of animal and/or vegetable origin to form a new product. Processed meat products include ground beef and pork; sausages, hotdogs and luncheon meat; canned products, such as stews and chillis; frozen products, such as pizzas; entrees, such as beef and gravy; and specialty foods, such as egg rolls. MDM is a potential ingredient for most of these processed meat products.

The classification of ground beef (hamburger) and ground pork (sausage) as processed meats is the principle departure between the definitions used in this study and those found elsewhere. Ground beef and pork are placed in the processed meat category because they are also candidates for receiving MDM as an ingredient. Final rulemaking by the

USDA will determine the extent to which MDM can be used in each of these processed meat products.[1]

## The Theoretical Framework

To analyze the economic impact of mechanical deboning, the markets for beef and pork are divided into submarkets for table cuts and processed meats. This division enables us to look more directly at the economic effects of mechanical deboning, since the additional meat recovered by the technique will be used as an ingredient in processed meats and will effect table cuts only indirectly. To avoid repetition, the graphical analysis below is presented generally without regard to species of meat (beef or pork). Perfectly competitive markets are assumed throughout.

The production possibilities for transforming slaughtered carcasses into table cuts and processed meats are shown in Figure 1, line XZY. The element of joint production and the technical limits to conversion of processed meats into table cuts are depicted by the kink in the transformation curve at Z. The maximum number of pounds of table cuts that a carcass will yield is oX. Jointly produced along with this quantity of table cuts will be a quantity of processed meats, XZ, which cannot be substituted for additional pounds of table cuts. But the limit on

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[1]The rules proposed by the USDA in October of 1977 would allow up to 20 percent MDM to be incorporated in the following products: beef patties, canned corned beef, fresh pork sausage, fresh beef sausage, breakfast sausage, whole hog sausage, smoked pork sausage, franks, bologna, braunschweiger, liver sausage, luncheon meat, meat loaf, scrapple, knockwurst, chillie con carne with beans, hash, corned beef hash, tamales, spaghetti with meatballs, spaghetti sauces with meat, chow mein, chop suey, pizza, potted meat and deviled meat (40).

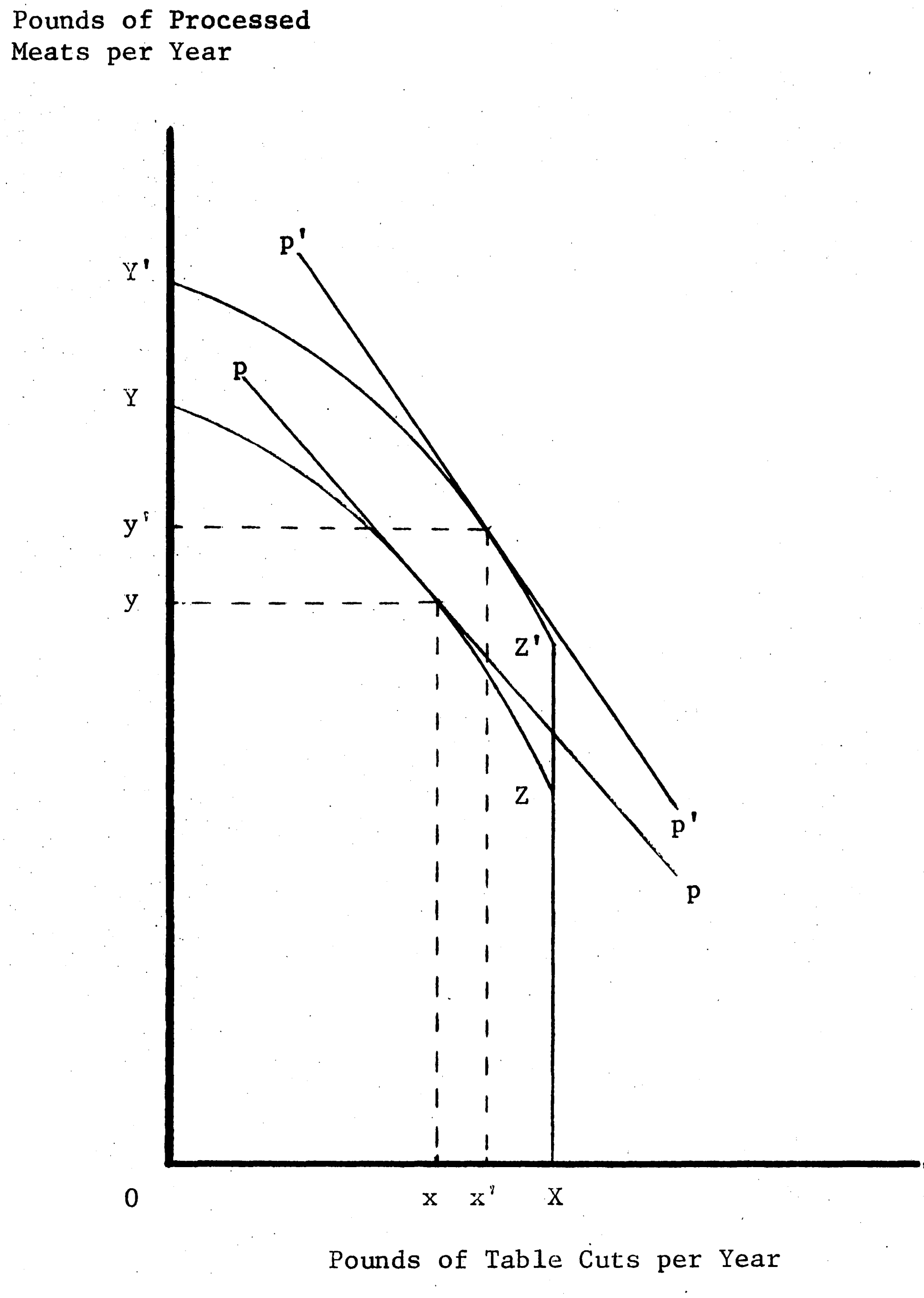


Figure 1. Production Possibilities for Table Cuts and Processed Meats

the transformation of processed meats into table cuts is not symmetrical; table cuts can be completely converted into processed meats.

Assuming competitive market conditions, the equilibrium distribution of carcass production between table cuts and processed meats will be such that the marginal rate of transformation of table cuts for processed meats (reflected by the slope of XZY in Figure 1) is equal to the marginal rate of substitution of table cuts for processed meats (reflected by the slope of the price line pp). The equilibrium conditions are satisfied in Figure 1 when ox pounds of table cuts and oy pounds of processed meats are produced.

## Primary Effects of Mechanical Deboning

If mechanical deboning techniques were adopted, each carcass mechanically deboned would yield, in addition to the previous amount of table cuts, more pounds of processed meats. As shown in Figure 2, the increase in the supply of processed meats from ss to s's' would, given demand, be accompanied by a reduction in the equilibrium price (from p to p') and an increase in the equilibrium quantity (from q to q') of processed meats.

In Figure 1, adoption of mechanical deboning techniques is reflected by: (1) a shift in the transformation curve to XZ'Y'; (2) an increase in the relative price ratio of table cuts to processed meats to p'p'; and (3) if the original marginal rate of substitution is less than the marginal rate of transformation at the maximum quantity of table cuts (oX), there will be a change in the distribution of production between processed meats and table cuts to oy' and ox' respectively.

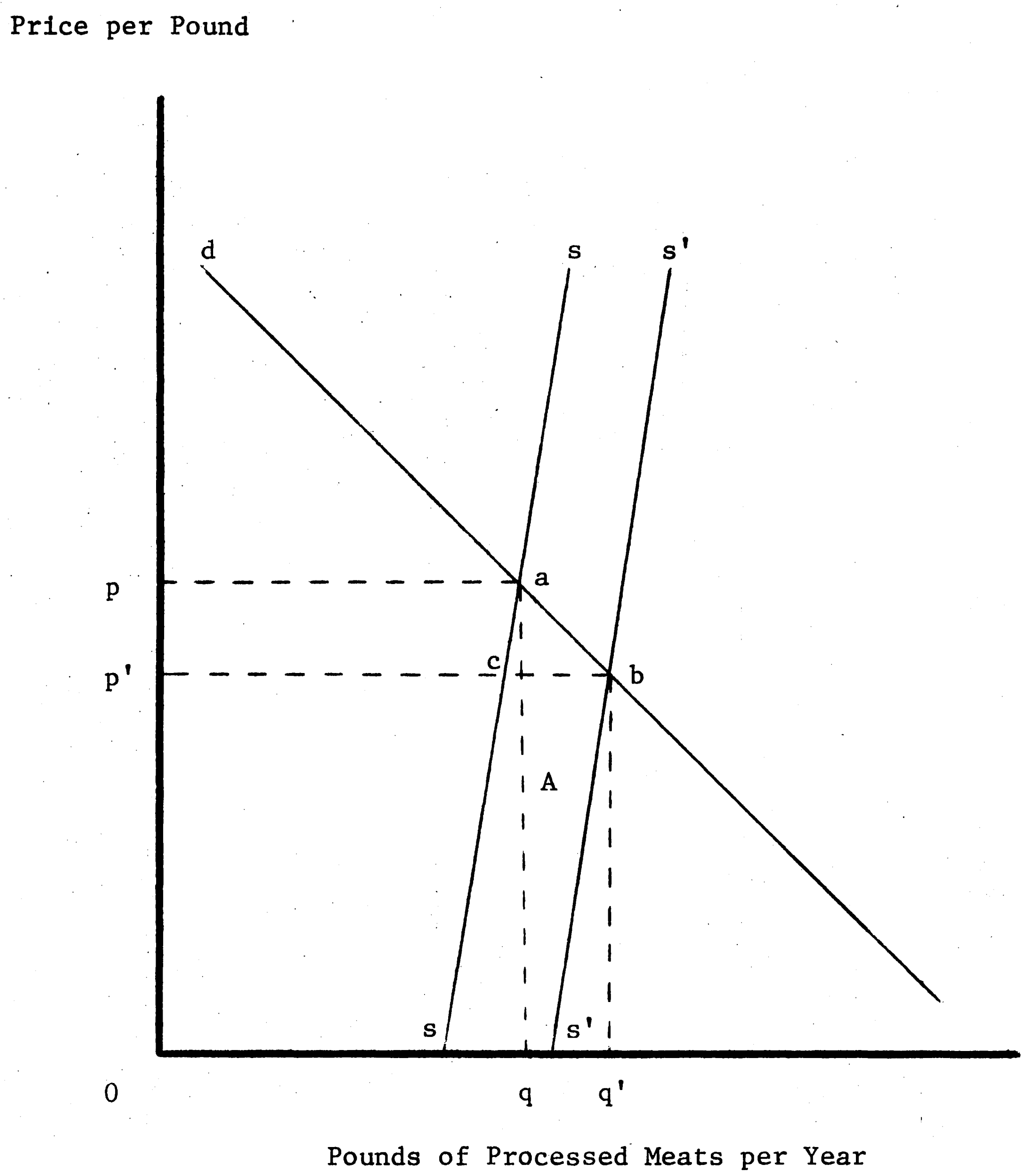


Figure 2. Demand and Supply of Processed Meats

Returning to Figure 2, if mechanical deboning of red meats is permitted, the welfare gain to consumers can be measured by the area p'pab. Part of this welfare gain, area p'pac, is transferred from producers to consumers. At the same time, producers also gain the welfare measured by the area between the two supply curves and below line cb, area A. Thus, the net gain to society can be measured by area abc plus area A.

Secondary Effects of Mechanical Deboning

As implied by Figure 1, if less than the maximum possible amount of table cuts were initially being produced, adoption of mechanical deboning techniques and the attendant change in the relative prices of table cuts and processed meats could lead to a change in the production of table cuts as well as processed meats. The degree of impact on table cuts depends on the cross price elasticities of supply and demand between table cuts and processed meats.

To the extent that consumers regard table cuts and processed meats as close substitutes, the decrease in the price of processed meats will induce consumers to substitute their consumption in favor of the less expensive product. This would be reflected by a leftward shift in the demand for table cuts in Figure 3 from dd to d'd'. On the supply side, as the price of table cuts rises relative to the price of processed meats, producers will shift production toward the now relatively more profitable table cuts. Technical constraints permitting, the result will be an increase in the supply of table cuts from ss to s's' in Figure 3. While the net effect on the equilibrium quantity of table cuts is uncertain, depending on the relative cross price demand and

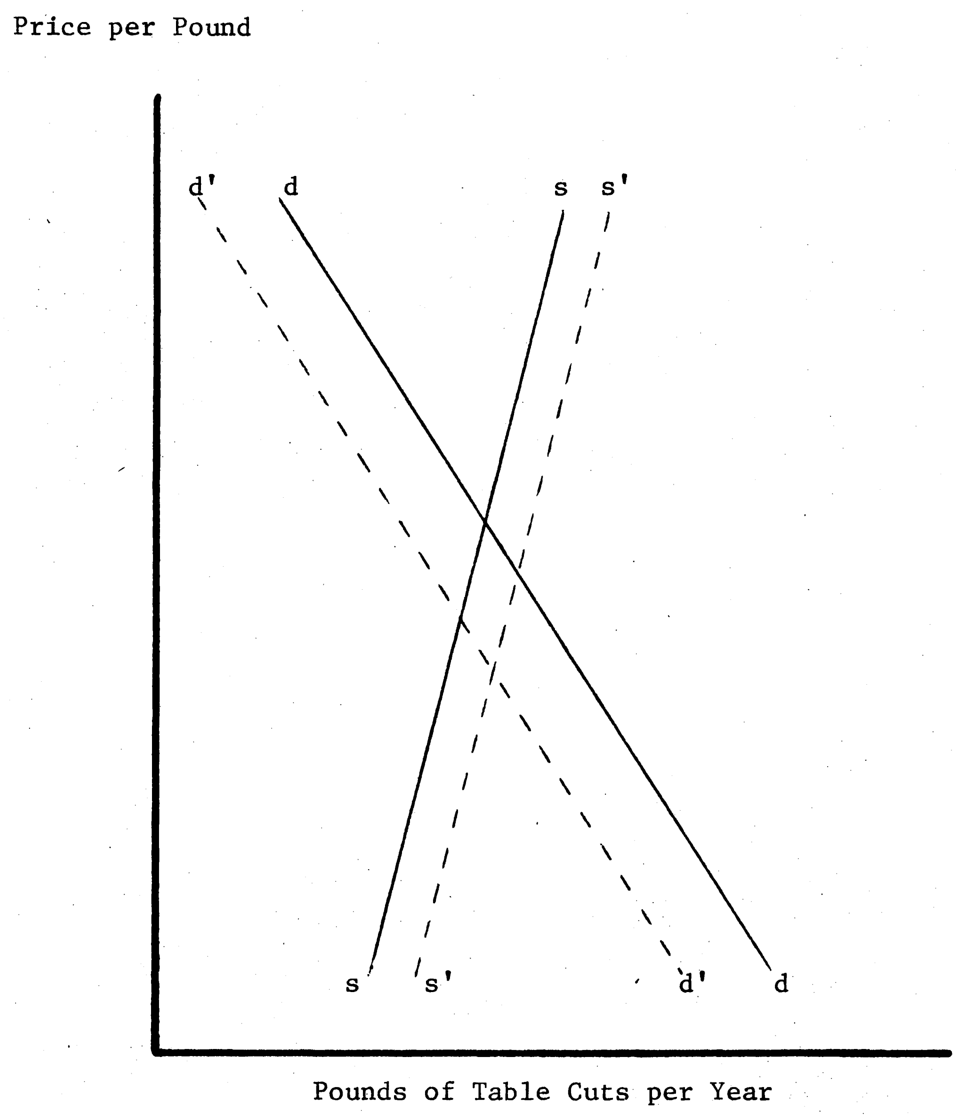


Figure 3. Demand and Supply of Table Cuts

supply elasticities, the price of table cuts may be expected to fall. A decrease in the price of table cuts, again depending on the cross price elasticities, may in turn reduce the demand and increase the supply of processed meats. When all of the cross effects have been accounted for, economic theory would cause us to expect lower prices for both processed meats and table cuts.

Changes in the equilibrium prices and quantities of table cuts and processed meats associated with the adoption of mechanical deboning may also influence the demand for livestock. Assuming conditions of pure competition, the derived demand for slaughter livestock in Figure 4 is dependent upon: (1) the demand for meat - table and processed - or more specifically on the price of meat, and (2) the marginal physical product of livestock in producing meat. Since the prices of both table and processed meats are expected to decline as a result of the adoption of mechanical deboning, this will have a depressing influence on the demand for livestock. On the other hand, mechanical deboning allows increased production of meat per unit of livestock slaughtered, thus having an expansionary impact on the demand for livestock. The a priori net effect on the demand for livestock is uncertain, but with estimates of the price elasticities for table and processed meats as well as estimates of the additional product recovered by mechanical deboning, the effect on the demand for livestock can be estimated.

## The Empirical Framework

### The Model In Functional Form

In order to estimate empirically the economic impacts associated with mechanically deboning red meat, the relationships hypothesized in

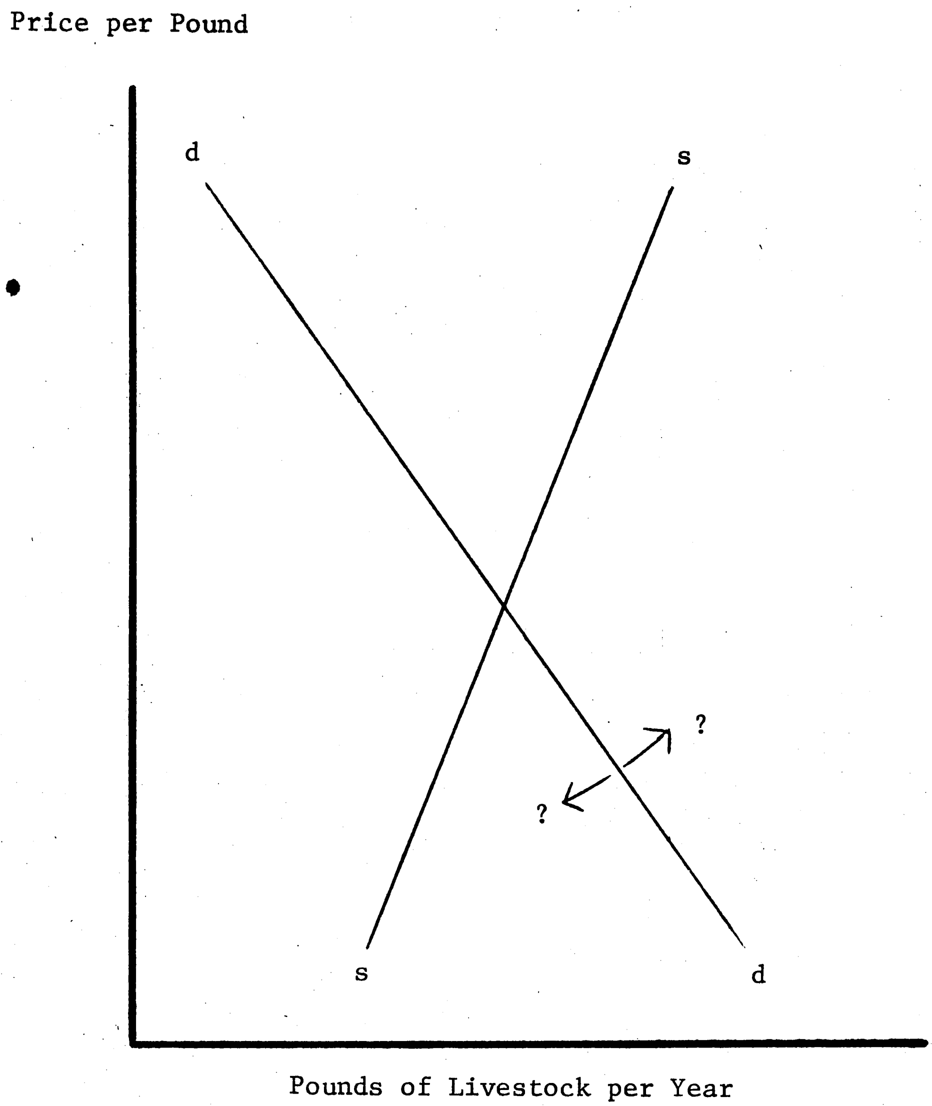


Figure 4. Demand and Supply of Livestock

the theoretical framework must be quantified. Parameters of the demand and supply functions for table and processed meats must be estimated along with the appropriate own and cross price elasticities.

The demand for a particular type of meat can be specified as a function of its own price, the prices of related goods, income and population. The general functional form of the demand relations to be estimated for table beef, processed beef, table pork and processed pork is as follows:

Qdi = f(PTBi, PPBi, PTPi, PPPi, PLi, PPOi, PFi, PIi, POPi)

where i = the time period

Qd = quantity of meat demanded

PTB = retail price of table beef

PPB = retail price of processed beef

PTP = retail price of table pork

PPP = retail price of processed pork

PL = retail price of lamb

PPO = retail price of poultry

PF = retail price of fish

PI = personal income

POP = population.

The supply of a particular type of meat can be specified as a function of its own price, the prices of related goods, the levels of inputs considered fixed for any production period and the prices of any inputs whose level of use may be varied during the production period. The general functional form of the four supply functions is as follows:

Qsi = f(PTBi, PPBi, PTPi, PPPi, PCi, SLi)

where i, PTB, PPB, PTP and PPP are specified above, and

Qs = quantity of meat supplied

PC = price of corn (or other feed grains)

SL = number of animals available for slaughter.

In constructing the model reported in the following chapter, relationships between the dependent and independent variables listed in the general functional form equations were explored. The coefficients of a number of the explanatory variables suggested by economic theory were found to be not statistically different from zero and these variables were subsequently dropped from the model. The final forms of the estimated demand and supply equations are reported in the next chapter.

## Data

A particularly troubling problem in analyzing the markets for table and processed beef and pork is that data on the prices and quantities of table and processed meats produced and consumed are not published. However, several reasonable and logical assumptions can be applied to data from both published and unpublished sources to yield the necessary proxies. The underlying assumptions and calculations necessary to develop these data series are outlined briefly below and in more detail in the Appendix.

The quantities of beef and pork consumed are reported in Livestock and Meat Statistics (37). These data must be disaggregated into two components, table cuts and processed meats, for both beef and pork.

Typical retail beef and pork carcass cutout percentages (10) could be applied to disaggregate total beef and pork production into table cuts and processed meats if consumption was at point Z in Figure 1. But even though the amount of table cuts is constrained by the carcass composition, there is evidence to suggest that meat is not actually consumed in these proportions (34)(41). Certain table cuts are usually ground and used in processed meats - i.e., production is at some point to the left of point Z on the production possibilities curve in Figure 1. Therefore, the cutout proportions would have to be adjusted to reflect the shares of table cuts and processed meats actually consumed.[2]

An alternative method of disaggregation is used in this study. Estimates of the shares of table and processed home consumption of beef and pork are obtained from household consumption surveys (34). An away-from-home food survey provides data on the shares of table and processed meats consumed in restaurants and institutions (41). These percentages are shown in Table II for comparison with typical retail carcass cutout shares. The percentages from the food consumption surveys are weighted by the shares of meat consumed at home and away from home, combined, and applied to the aggregate consumption data to disaggregate it into a series for table cuts and a series for processed meats.

Price series for table cuts and processed meats are constructed from the retail meat prices of individual retail cuts published by the Bureau of Labor Statistics (38) and from unpublished USDA data.[3] The prices of individual retail cuts are weighted by their market basket shares to form retail price series for table and processed beef and pork (11).

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[2]This is the methodology employed by Duewer (9) in analyzing demand relationships for eight retail cuts of pork.

[3]A retail meat price survey of about 40 retail chain divisions throughout the United States is conducted on a weekly basis by the Economic Research Service of the USDA (11, p. 27).

TABLE II

SHARES OF TABLE AND PROCESSED MEATS
--TECHNICAL POSSIBILITIES AND
CONSUMPTION PATTERNS

| | Beef | | Pork | |
|---|---|---|---|---|
| | Table | Processed | Table | Processed |
| | (percent of retail weight) | | | |
| Typical Retail Carcass Cutout (a) | 64.2 | 35.8 | 84.5 | 15.5 |
| At Home Consumption (b) | | | | |
| 1942 | 61.6 | 38.4 | 72.2 | 27.8 |
| 1948 | 62.4 | 37.6 | 69.0 | 31.0 |
| 1955 | 58.9 | 41.1 | 71.2 | 28.8 |
| 1965-1966 | 67.4 | 32.6 | 68.1 | 31.9 |
| Away-From-Home Consumption (c) | 49.3 | 50.7 | 80.4 | 19.6 |
| Weighted Shares Used In this Study (d) | 60.8 | 39.2 | 77.6a | 22.4a |

(a) Duewer (10, pp. 25, 26).
(b) USDA (34).
(c) Van Dress (41).
(d) Assumed shares of total meat consumed at home and away from home are 63.4 percent and 36.6 percent respectively (34)(41).

Since the shares applied to disaggregate the beef and pork markets are assumed to be constant over time, it was decided that monthly time series data for a relatively short period, 1970 through 1976, would be most appropriate for estimating the parameters of the supply and demand equations.

Estimation of the Parameters

A system of eight interdependent supply and demand equations evolve from the theoretical and empirical frameworks outlined above. When more than one relationship has to be considered simultaneously - i.e., when an equation cannot be solved independently but has to be solved with other equations in a simultaneous equations model - it may happen that two or more of the equations consisting of the same variables cannot be distinguished from each other (7, p. 96). The question of whether or not it is possible to determine or identify unique values for the parameters of the structural (behavioral) equations is called the identification problem.

In order to determine unique estimates of the parameters, each equation in the system must be either just-identified or over-identified. Two criteria known as the order condition and the rank condition are used to determine the identification status of any system of linear equations. These criteria are discussed in econometric texts such as Johnston (19, pp. 352-365), Kmenta (21, pp. 539-550), and Huang (16, pp. 213-221) and will not be discussed in detail here. Briefly, however, the order condition states that an equation will be under-, just-, or over-identified as the total number of variables excluded from that equation is less than, equal to, or greater than the total number of endogenous variables in the simultaneous-equation system minus one (7, pp. 96-106). In practice, the rank condition cannot be determined and its status is of necessity rather academic. According to Christ (6, p. 322), it is usually safe to say that an equation is identified if it fulfills the order condition.

Each of the eight equations in the model estimated in the next chapter contains at least two endogenous variables, own price and quantity. Since an equation can have only one dependent term, regardless of which endogenous variable is chosen as the dependent variable, the remaining one(s) will be related to the error term. As a result, ordinary least squares (OLS) estimators will be biased and inconsistent (18, p. 253).

If the system of eight equations was just-identified, indirect least squares could be applied to give consistent estimates. It is much more likely, however, that the equations will be over-identified. This means that the options for obtaining consistent estimates of the parameters include Full Information Maximum Likelihood (FIML), Limited Information Maximum Likelihood (LIML), Two-Stage Least Squares (2SLS), and Three-Stage Least Squares (3SLS). The 3SLS estimation method is selected over FIML and LIML because the latter two methods involve relatively more complex calculations. 3SLS is preferred to 2SLS because all the parameters are estimated simultaneously with 3SLS rather than equation by equation as with 2SLS. Finally, 3SLS estimates also tend to have lower standard errors and are therefore more efficient than 2SLS estimates (16, pp. 222-240).

A brief and simplified explanation of the 3SLS method developed by Zellner and Theil (45) is as follows. As the name implies, there are three basic stages or steps in the estimation process. The first stage involves finding the OLS estimated values of the explanatory endogenous variables in each structural equation, where each explanatory endogenous variable is regressed on all of the exogenous variables in the system. The second stage involves using the first stage estimates of the explanatory endogenous variables in place of the observed values of these variables and applying OLS to find the 2SLS's estimates of the coefficients of each structural equation. Finally, in the third stage, the 2SLS estimates of the coefficients are used to calculate residuals for each structural equation. These 2SLS residuals are used to estimate the variance-covariance matrix of the structural disturbances. Then the coefficients of all the structural equations are estimated simultaneously by means of Aitken's generalized least-squares method, using the estimated variance-covariance matrix and the identifying restrictions on all the coefficients in the model (6, p. 446)(16, pp. 237-238).

## A Priori Hypotheses About the Parameters of the Variables

The general a priori hypotheses about the signs of the parameters in the equations estimated in the next chapter are based on theoretical considerations. In the case of demand curves, a negative sign is expected on the parameter of the own price of the good demanded, assuming it to be an ordinary good. A positive sign is anticipated for the parameters of substitute good prices, income and population. Were the prices of any complementary goods included, a negative sign would be expected on the parameters of these variables. But in the case of table and processed beef and pork, the only complements which easily come to mind are condiments and these readily exemplify Stigler's (33) proposition that complementary goods are not very common, or where they are, their cost as a proportion of the composite good (the good in question plus the complement) is so low that the cross elasticity is likely to be very small and so negligible.

For the supply curves, a positive sign is hypothesized for the parameter of the own price of the good supplied. A negative sign is expected for the parameters of input prices and a positive sign is expected for the parameters of input quantities.

The inclusion of commercial cattle and hog slaughter in the supply functions can be expected to have a very definite effect on the nature of these functions. These variables are likely to explain much if not most of the variation in the supply of table and processed beef and pork. Both variables are exogenous to the system and thus not subject to influence within the model. This together with their high explanatory values will give rise to quite inelastic supply functions. The outcome of this is of course that results derived from the analysis utilizing the estimated model will have greatest application in the short run. This is important to bear in mind since it implies that predictions of price and quantity changes or estimates of welfare costs grow more inaccurate the further away from the base period such predictions are made. To avoid such inaccuracy, these short run supply functions would have to be converted to long run supply functions. This would mean explaining commercial cattle and hog slaughter which would require them to be converted to endogenous variables with the addition of two new markets to the system. This enlarged system is beyond the scope of this study. With such long run supply functions the own price elasticity of supply would be much greater than the ones likely to emerge from the estimates of the supply functions in this study. This in turn allows for greater adjustment of the supply to price. Such lack of adjustment in the short run functions to be estimated here results in over estimation of price changes and under estimation of quantity changes if used in the long run.[4]

## Summary

This chapter has presented institutional, theoretical and empirical background in preparation for estimating the model presented in the following chapter. This model will be used in Chapter IV to evaluate the economic impact of several alternative mechanical deboning regulations.

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[4]Hunt (17) encountered similar supply inelasticities in modeling the demand and supply of table and processed beef. His explanation is the one presented above. It also seems applicable to the present study.

# CHAPTER III

# EMPIRICAL RESULTS

This chapter is composed of three sections. In the first, the statistical estimates of the structural equations are presented along with the elasticities of the relevant variables. The second section contains a general discussion of the results and the third compares the estimated elasticities with those from other studies.

## Statistical Estimates of the Structural Equations

Each of the eight structural demand and supply equations was estimated with three different procedures, Ordinary Least Squares (OLS), Two-Stage Least Squares (2SLS) and Three-Stage Least Squares (3SLS). The OLS estimates are the results of the preliminary investigations of the system. The 2SLS estimates were generated in the computation of the 3SLS estimates.

For each OLS estimated equation, the coefficient of multiple determination (R-Square) is presented. In the parenthesis below each coefficient is the estimated standard error for that coefficient. Tests of statistical significance are made on all of the OLS coefficients estimated. The number of asterisks below the estimated standard error indicate the confidence level at which the coefficient is significantly different from zero. One asterisk implies significance at the 90 percent level; two, the 95 percent level; and three, the 99 percent level.

No tests of significance are performed on the coefficients of the 2SLS and 3SLS estimates as no theoretical tests have been developed for testing the significance of coefficients estimated from small samples. This is due to a lack of knowledge about the properties of small samples. The asymptotic properties of these estimates have been well explored, but not very much is known about their finite sample distributions. The asymptotic properties of 2SLS and 3SLS estimates mean that large sample tests of significance are the same as for OLS coefficients. Sometimes small samples are assumed to have large sample properties and the coefficients are tested for significance using the standard t-test, but this is generally not done formally. The size of the coefficient relative to its standard error is, however, usually taken as an informal indication of its strength in the estimated equation.

The elasticities with respect to the individual variables are calculated at the mean for the 3SLS estimates only. The 3SLS estimates were chosen since they represent in theory the best (in the sense of their unbiasedness and asymptotic efficiency) estimates of the three types.

Coefficients of the variables should be interpreted in a ceteris paribus fashion. Each coefficient represents the change in the dependent or left hand side variable for a unit change in the right hand side variable to which the coefficient is attached, assuming all other variables are held constant.

All eight structural equations in the model are over-identified. The system of eight equations contains eight endogenous variables and five exogenous variables which are listed below.

Endogenous variables:

QTB: Quantity of Table Beef

QPB: Quantity of Processed Beef

QTP: Quantity of Table Pork

QPP: Quantity of Processed Pork

PTB: Price of Table Beef

PPB: Price of Processed Beef

PTP: Price of Table Pork

PPP: Price of Processed Pork

Exogenous variables:

PI: Personal Income

POP: Population

CCS: Commercial Cattle Slaughter

SC: Steer-Corn Price Ratio - Lagged One Year

Demand for Table Beef

The quantity of table beef demanded was found to be inversely related to the price of table beef and directly related to the price of table pork and population. This is consistent with economic theory, assuming table beef is an ordinary good and table beef and table pork are substitutes in consumption. Two additional substitute relationships were also anticipated, but no significant cross effects were found between the quantity of table beef demanded and the prices of processed beef and processed pork.

OLS QTB = -3135.5151 - 4.5118 PTB + 2.3850 PTP + .0213 POP

(669.8112) (.7826) (.5609) (.0036)

*** *** *** ***

R-Square = .5864

2SLS QTB = -6448.8212 - 11.3959 PTB + 4.8886 PTP + .0406 POP

(1434.8882) (1.9973) (1.0681) (.0079)

3SLS QTB = -5389.9361 - 11.1429 PTB + 5.4511 PTP + .0351 POP

(1109.6717) (1.5325) (.8874) (.0061)

Since the population and personal income variables are so highly correlated, inclusion of both variables in each demand equation was deemed inappropriate. The population variable performed statistically better than the personal income variable in three of the four demand equations, and so was included. The personal income variable was included in the fourth for its superior performance.

The signs on the coefficients are as hypothesized in Chapter II. All OLS coefficients were found significant at the 99 percent level and all 2SLS and 3SLS coefficients are large relative to their standard errors. The elasticities of demand for table beef with respect to own price (Ed PTB), the price of table pork (Ed PTP), and population (Ed POP) are computed below using the 3SLS coefficients:

Ed PTB = -11.1429 x 140.5833 / 910.6920 = -1.7201

Ed PTP = 5.4511 x 106.9167 / 910.6920 = .6400

Ed POP = .0351 x 207,732.6786 / 910.6920 = 8.0064

Supply of Table Beef

The quantity of table beef supplied was found to be positively related to its own price, commercial cattle slaughter, and the steer-corn price ratio lagged one year. Anticipations of finding that table beef and processed beef are substitutes in production were not realized. No cross effects could be detected between the quantity of table beef supplied and the prices of processed beef, table pork or processed pork. This is not surprising for table and processed pork, since these are short-run supply equations estimated at the retail market level. Relative supplies of beef and pork are more likely to respond to long-run relative prices, and primarily at the farm level.

$$\text{OLS}\quad QTB = -78.6552 + .1434\ PTB + .2804\ CCS + 4.5966\ SC$$
$$(49.7643)\ (.1347)\quad (.0117)^{***}\quad (.6916)^{***}$$

R-Square = .9228

$$\text{2SLS}\quad QTB = -105.0665 + .3856\ PTB + .2760\ CCS + 4.8692\ SC$$
$$(51.2323)\ (.1514)\quad (.0120)\quad (.7091)$$

$$\text{3SLS}\quad QTB = 28.6730 + .3380\ PTB + .2485\ CCS + 2.9534\ SC$$
$$(38.2221)\ (.1407)\quad (.0092)\quad (.5148)$$

While the signs of all the variables are as expected by economic theory, the OLS estimate of the coefficient for the price of table beef is significant only at the 71 percent level. The 2SLS and 3SLS estimates are, however, large relative to their standard errors, with the exception of the 3SLS intercept term. Elasticities of supply (Es) for table beef are calculated as follows:

Es PTB = .3380 x 140.5833 / 910.6920 = .0522

Es CCS = .2485 x 3100.5095 / 910.6920 = .8460

Es SC = 2.9534 x 21.7274 / 910.6920 = .0705

## Demand for Processed Beef

The quantity of processed beef demanded was found to vary inversely with the price of processed beef, and directly with the price of processed pork and population. No cross effects were detected between the demand for processed beef and the price of table beef or the price of table pork.

OLS QPB = -1164.0904 - 2.8530 PPB + 1.7134 PPP + .0089 POP

(433.9503) (.5429) (.6853) (.0023)

*** *** ** ***

R-Square = .5672

2SLS QPB = -1890.4523 - 4.0962 PPB + 1.4167 PPP + .0130 POP

(673.7891) (.6827) (1.0042) (.0036)

3SLS QPB = -303.6920 - 4.5415 PPB + 3.7087 PPP + .0046 POP

(504.2903) (.5928) (.7789) (.0027)

All coefficients have the expected signs. All OLS coefficients are highly significant and only the 3SLS intercept term has a relatively large standard error. Own price, cross price and population elasticities of demand for processed beef are:

Ed PPB = -4.5415 x 81.6786 / 587.8961 = -.6310

Ed PPP = 3.7087 x 85.2381 / 587.8961 = .5377

Ed POP = .0046 x 207,732.6786 / 587.8961 = 1.6254

## Supply of Processed Beef

The quantity of processed beef supplied was found to be positively related to its own price and commercial cattle slaughter and negatively related to the price of table beef. These relationships are consistent with economic theory, since table and processed beef are substitutes in production. No statistically significant cross effects with table or processed pork were detected. This is not surprising for the retail market level, especially in the short-run. All OLS coefficients are highly significant. With the exception of the 2SLS intercept term, the second and third stage coefficients have relatively small standard errors.

OLS QPB = 53.7930 + 1.9695 PPB - 1.2215 PTB + .1758 CCS

(18.0581) (.2546) (.1731) (.0064)

*** *** *** ***

R-Square = .9315

2SLS QPB = 20.5744 + 2.6478 PPB - 1.5115 PTB + .1818 CCS

(21.9633) (.3722) (.2431) (.0078)

3SLS QPB = 27.3252 + 2.5795 PPB - 1.4997 PTB + .1808 CCS

(18.1884) (.2845) (.1821) (.0061)

All coefficients have the expected signs. The supply elasticities of processed beef with respect to own price, the price of table beef, and commercial cattle slaughter are computed as follows:

Es PPB = 2.5795 x 81.6786 / 587.8961 = .3584

Es PTB = -1.4997 x 140.5833 / 587.8961 = -.3586

Es CCS = .1808 x 3100.5095 / 587.8961 = .9535

Demand for Table Pork

The quantity of table pork demanded was found to be inversely related to the price of table pork and directly related to the price of processed beef and personal income. No statistically significant cross effects could be detected between the demand for table pork and the prices of processed pork or table beef.

| | | | | | |
|---|---|---|---|---|---|
| OLS | QTP = 838.5997 | - 5.4072 PTP | + 1.6061 PPB | + .3832 PI | |
| | (47.5048) | (.5959) | (.7094) | (.0760) | |
| | *** | *** | ** | *** | |
| | R-Square = .6131 | | | | |
| 2SLS | QTP = 837.6700 | - 9.6079 PTP | - 1.0183 PPB | + 1.0089 PI | |
| | (74.1469) | (1.2176) | (1.2768) | (1.1639) | |
| 3SLS | QTP = 874.1090 | - 6.4472 PTP | + .2950 PPB | + .5553 PI | |
| | (66.2273) | (.8348) | (1.1512) | (.1149) | |

The OLS coefficients are highly significant and have the hypothesized signs. The coefficient for the price of processed beef switches from positive to negative in the second stage and back to positive again in the third stage. This coefficient also has a relatively large standard error in the second and third stage. Although the 3SLS coefficient for the price of processed beef is small relative to its standard error, the variable was retained in the relation because of the appropriate positive sign of the coefficient and the desire in the next chapter to simulate as many of the cross effects between the markets for table and processed meats as possible. Own price, cross price and income elasticities of demand for table pork are calculated below.

Ed PTP = -6.4472 x 106.9167 / 798.6164 = -.8631

Ed PPB = .2950 x 81.6786 / 798.6164 = .0302

Ed PI = .5553 x 1061.9369 / 798.6164 = .7384

Supply of Table Pork

The quantity of table pork supplied was found to be positively related to the price of table pork and commercial hog slaughter. No statistically significant cross effects could be detected between the quantity of table pork supplied and the prices of processed pork, table or processed beef.

OLS QTP = 143.7965 + .1630 PTP + .0946 CHS

(51.2310) (.1822) (.0052)

*** ***

R-Square = .8929

2SLS QTP = 63.0906 + .4874 PTP + .1014 CHS

(57.3715) (.2088) (.0057)

3SLS QTP = 92.0725 + .3982 PTP + .0985 CHS

(53.3948) (.1976) (.0052)

The OLS coefficient of the commercial hog slaughter variable is highly significant, but the OLS coefficient of the price variable becomes significant only at the 63 percent level. The coefficients of both variables have the expected signs and relatively small standard errors for the second and third stage coefficients. The relevant elasticities of supply for table pork are:

Es PTP = .3982 x 106.9167 / 798.6164 = .0533

Es CHS = .0985 x 6737.9607 / 798.6164 = .8310

Demand for Processed Pork

The quantity of processed pork demanded was found to vary inversely with the price of processed pork, and directly with the price of processed beef and population. Cross effects not found statistically significant were those with table pork and table beef.

OLS QPP = -513.1594 - 2.4694 PPP + 1.0040 PPB + .0042 POP

(257.2542) (.4062) (.3218) (.0013)

** *** *** ***

R-Square = .4340

2SLS QPP = -1990.8494 - 4.4011 PPP + .7358 PPB + .0122 POP

(472.3925) (.7041) (.4786) (.0025)

3SLS QPP = -1121.9326 - 3.2330 PPP + .6885 PPB + .0076 POP

(278.9884) (.4313) (.4424) (.0015)

All of the OLS coefficients are highly significant and have the hypothesized signs. The standard errors of all 2SLS and 3SLS coefficients are relatively small, with the possible exception of those for the price of processed beef. Own price, cross price and population elasticities of demand for processed pork are computed below.

Ed PPP = -3.2330 x 85.2381 / 230.6611 = -1.1947

Ed PPB = .6885 x 81.6786 / 230.6611 = .2438

Ed POP = .0076 x 207,732.6786 / 230.6611 = 6.8445

<u>Supply of Processed Pork</u>

The quantity of processed pork supplied was found to vary directly with the price of processed pork and commercial hog slaughter, but varied inversely with the price of table pork.

OLS QPP = 36.3142 + .9174 PPP - .5265 PTP + .0256 CHS

(13.3541) (.2041) (.1361) (.0014)

*** *** *** ***

R-Square = .9145

$$\text{2SLS QPP} = 16.0967 + .8248\ \text{PPP} - .3852\ \text{PTP} + .0275\ \text{CHS}$$
$$(14.9309)\ (.2722)\qquad (.1819)\qquad (.0016)$$

$$\text{3SLS QPP} = 13.9843 + .2805\ \text{PPP} - .0321\ \text{PTP} + .0291\ \text{CHS}$$
$$(13.5097)\ (.0995)\qquad (.0815)\qquad (.0013)$$

All OLS coefficients have the expected signs and are highly significant. In the third stage, however, the standard errors of the intercept term and coefficient of the price of table pork are large relative to the size of the coefficients. Since economic theory supports the sign of the coefficient of the price of table pork, this variable is retained for simulation of the indirect effects of allowing mechanical deboning in Chapter IV. The elasticities of supply of processed pork are:

$$\text{Es PPP} = .2805 \times 85.2381 / 230.6611 = .1037$$

$$\text{Es PTP} = -.0321 \times 106.9167 / 230.6611 = -.0149$$

$$\text{Es CHS} = .0291 \times 6737.9607 / 230.6611 = .8501$$

## Discussion of the Results

In general, the statistically estimated results appear to be quite consistent with the theoretical model developed in Chapter II. All 3SLS coefficients have the hypothesized signs, i.e., the signs economic theory would lead us to expect for the coefficient of each variable.

To judge from the OLS R-Square values, the equations describing the supply side of the model are stronger than those describing the demand side. The relatively higher R-Square values on the supply side are accounted for by the inclusion of the commercial cattle and hog slaughter variables in these equations. To judge from the number of significant coefficients and their level of significance (in the OLS form), the equations describing the demand side of the model may be stronger than those describing the supply side. Cross price elasticities are detected in only two of the supply equations, those for processed beef and pork. This is not too surprising, since the equations are estimated at the retail level and most of the discretionary supply decisions have already been made at the farm or processing levels in an earlier time period. The primary decision left to the discretion of the retail supplier of meat is not whether to supply more beef and less pork or vice-versa, but rather how to divide production between table cuts and processed meats. This is borne out in the estimated supply equations. No cross species supply effects were detected. But cross effects were detected between table and processed meat of the same species in only two of the estimated supply relations. This may be due to the limitations inherent in the way the data series for table and processed meats were derived.

Limitations in the data may also have adversely affected the number of cross effects detected on the demand side of the model. At the retail level, one might expect consumers to make substitutions not only between table and processed meats of the same species, but also between species. This expectation is born out by the estimated demand equations. The demand for table beef is found to depend on the price of table pork as well as the price of table beef. Similar cross species price effects are found in the other three demand equations as well, but none capture all of the hypothesized cross price effects.

## A Comparison of Elasticities

Table III summarizes the estimated retail demand and supply elasticities. Both the own and cross price elasticities of demand and supply are reported. Elasticities with respect to the other exogenous variables are deleted since they are not as meaningful from the viewpoint of economic theory.

TABLE III

SUMMARY OF ESTIMATED RETAIL DEMAND AND SUPPLY ELASTICITIES

| | Elasticity of | |
|---|---|---|
| | Demand | Supply |
| Table Beef | | |
| Price of Table Beef | -1.72 | .05 |
| Price of Table Pork | .64 | |
| Processed Beef | | |
| Price of Processed Beef | -.63 | .36 |
| Price of Processed Pork | .54 | |
| Price of Table Beef | | -.36 |
| Table Pork | | |
| Price of Table Pork | -.86 | .05 |
| Price of Processed Beef | .03 | |
| Processed Pork | | |
| Price of Processed Pork | -1.19 | .10 |
| Price of Processed Beef | .24 | |
| Price of Table Pork | | -.01 |

All elasticities estimated generally conform to the expectations of economic theory with respect to sign: own price elasticities of demand are negative; the cross price elasticities of demand for substitutes in consumption are positive; own price elasticities of supply are positive; and cross price elasticities of supply for substitutes in production are negative.

The relative magnitudes of the estimated elasticities for table and processed beef are generally consistent with those reported elsewhere in the literature (see Table IV). The demand for table beef is relatively more own price elastic than the demand for processed beef. On the supply side, the quantity of processed beef is relatively more responsive to price changes than is the quantity of table beef. This may be a reflection of the technical constraints on the production of table cuts noted in Chapter II. The relative price inelasticity of the estimated supply equations is consistent with the consensus in the literature that major supply decisions are made at the farm level rather than the retail market level.

The levels (actual magnitudes) of the elasticities from the other studies are not directly comparable because of differences in the studies. As noted in Chapter I, the Hunt (17) and Langemeier and Thompson (22) estimated elasticities are based on data series differing substantially from the present study. These studies assumed that the shares of table and processed beef consumed are directly proportional to the shares of fed and nonfed beef marketed. In the present study, the shares of table and processed beef are estimated from the latest surveys of consumption patterns. Hunt and Langemeier and Thompson both used annual data, but for different time periods. The present estimates are based on monthly data. Finally, the Hunt and Langemeier and Thompson estimates are derived from models considering only submarkets of the beef market, while the present study attempts to consider relationships between submarkets of both the beef and pork markets. Houck's (15) estimates of the supply and demand elasticities for table and processed beef are the result of adjustments made to those estimated by Hunt.

TABLE IV

COMPARISON OF SELECTED SUPPLY AND DEMAND ELASTICITIES FOR TABLE AND PROCESSED BEEF

| Own Price Elasticities | This Study | Hunt | Houck | Langemeier-Thompson |
|---|---|---|---|---|
| Table Beef | | | | |
| Demand | -1.72 | -2.03 | -1.156 | -.978 |
| Supply | .05 | .156 | | .232 |
| Processed Beef | | | | |
| Demand | -.63 | -1.35 | -.850 | -1.243 |
| Supply | .36 | .332 | | -.552 |

In the case of table and processed pork, the relative magnitudes of the demand elasticities are somewhat unexpected. The demand for processed pork was found to be relatively more price elastic than the demand for table pork. The supply of both table and processed pork is very price inelastic. Once again, this is consistent with the fact that meat is highly perishable and has a very limited shelf life. Once the livestock producer makes the decision to market the animal, the wholesaler and retailer have little short-run discretion for increasing or reducing the quantity of meat supplied in response to variations in retail prices. The relatively higher supply elasticity for processed pork than table pork is consistent with the longer shelf life and less restrictive technical constraints on the production of processed meat products.

## Summary

This chapter has presented estimates of the parameters of the theoretical and empirical model developed in Chapter II. Parameters of the structural equations were estimated with three different procedures--ordinary least squares, two-stage least squares and three-stage least squares. Coefficients estimated by the latter technique were used in computing elasticities for each variable. In the following chapter, the model will be used to simulate the economic impact associated with several alternative policies toward the use of MDM as an ingredient in processed meat products.

# CHAPTER IV

# THE WELFARE EFFECTS OF ALTERNATIVE REGULATIONS ON THE USE OF MECHANICALLY DEBONED MEAT

The first section of this chapter presents the results of several simulations designed to demonstrate the economic consequences of alternative regulations of the use of mechanically deboned meat. The simulations are designed to show the effects of these alternative regulations on prices and quantities in the markets for table beef, processed beef, table pork and processed pork.

The second section analyzes the changes in economic welfare associated with each of the alternative regulations. The analysis is based on the concepts of economic surplus.

## Simulation of the Consequences of Alternative Mechanical Deboning Regulations

Conditions associated with four alternative policies toward the use of mechanically deboned meat are simulated using the model developed in Chapters II and III. These alternative policies are:

1. Continuation of the present ban on the use of MDM in products for human consumption.
2. Regulations allowing the use of up to 20 percent MDM as an ingredient in <u>all</u> processed meat products.

3. Regulations allowing the use of up to 20 percent MDM as an ingredient in all processed meat products _except_ ground beef and pork.

4. Regulations allowing the use of all MDM recoverable by existing technology in processed meat products.

Simulations of 1976 monthly prices and quantities of table beef, processed beef, table pork and processed pork are presented for each of the alternative policies. The policies allowing varying degrees of utilization of MDM in processed meat products are compared with the policy of banning MDM to assess the potential welfare gains to society. Changes in the prices and quantities associated with each policy will be used to assess the effect on economic welfare in the final section of this chapter.

The prices and quantities associated with a ban on the use of MDM for human consumption are simulated using the empirical model as estimated in Chapter III. The model was estimated for a time period during which the ban was in effect, and hence no changes in the parameters are necessary to account for its influence.

Conditions associated with the three remaining policies are simulated by shifting the supply functions for processed beef and pork to account for the addition of MDM to the supply of processed meats. An increase in the supply of processed meats leads to changes in the equilibrium prices and quantities of table meats as well as processed meats. This is due to the cross price effects included in the system of simultaneous demand and supply equations estimated in Chapter III.

The second and third policies simulated are variations of the USDA's proposed regulations for the use of MDM (40). The second policy is designed to illustrate the consequences of allowing all processed meats, including ground beef and pork, to contain up to 20 percent MDM. This policy is simulated by increasing the supplies of processed beef and processed pork by 20 percent of the 1976 average monthly production. The supply of processed beef is increased by 132.705 million pounds per month and the supply of processed pork by 43.041 million pounds per month. While recovery of MDM in sufficient quantities to meet the assumptions of this policy is probably not technologically feasible at the present time (see the description of policy number four below), the simulation is presented to illustrate an upper bound to potential future impacts of utilizing up to 20 percent MDM in all processed meat products.

The third alternative most closely approximates the USDA proposal, which would not allow MDM to be used as an ingredient in fresh ground beef or pork. It is estimated that 7.42 percent of all beef and 10.3 percent of all pork is consumed in processed form, excluding ground beef and pork (34)(41). This means that the supply of processed beef would be increased by 9.850 million pounds per month and the supply of processed pork by 4.433 million pounds per month. This simulation is the most restrictive of the three alternatives to the ban.

The fourth alternative policy is designed to simulate a free market policy of what is feasible, given the present state of the mechanical deboning technology, if red meat producers are allowed to utilize all the MDM they can economically recover. Industry tests of the technology indicate that an additional 8-16 pounds of MDM per beef carcass and 3-6 pounds per pork carcass could be economically recovered given present technology (12). With an assumed MDM recovery of 12 pounds per beef carcass, four pounds per pork carcass and average annual beef and pork slaughter of 40 million head and 80 million head, the increase in the supply of processed beef and pork will be 40 million pounds per month and 26.667 million pounds per month respectively. Note that the free market simulation of what is technically feasible at the present time is more restrictive than the simulation of the impact of including 20 percent MDM in all processed meats.

The results from the four simulations are presented in the following eight tables. The three simulations of policies allowing varying amounts of MDM to be used as an ingredient in processed meat products are compared with the simulation of the conditions associated with a continuation of the present ban on the use of MDM in products for human consumption. Examination of the results of these simulations confirms the economic analysis of the direct effects of mechanical deboning presented in Chapter II, and also provides answers to some of the theoretical uncertainties about the indirect effects of the technology.

As noted above, the direct effects on the markets for processed beef and pork are as predicted by economic theory. Tables V and VI show that the simulations of the use of MDM as an ingredient in processed beef products indicate an increase in the quantity of processed beef traded of 61.366 million pounds per month accompanied by a 28 cent reduction in price when the 20 percent maximum MDM content rule is applied to all processed beef and pork products. If the same rule is applied to processed meat products excluding ground beef and pork, the indicated increase in the quantity of processed beef traded is only 4.029 million pounds per month and the price falls by only 2.3 cents per pound. The free market adoption simulation indicates an increase in the quantity of processed beef traded of 12.698 million pounds

TABLE V

SIMULATED QUANTITIES OF PROCESSED BEEF UNDER ALTERNATIVE MDM REGULATIONS (MILLIONS OF POUNDS)

| Month of 1976 | Use of MDM Banned | Maximum of 20 Percent MDM in Processed Meats | | Use of All MDM Recoverable by Existing Technology |
|---|---|---|---|---|
| | | Including Ground Meat | Excluding Ground Meat | |
| January | 678.506 | 739.872 | 682.535 | 691.204 |
| February | 627.825 | 689.191 | 631.854 | 640.523 |
| March | 679.329 | 740.695 | 683.358 | 692.027 |
| April | 624.337 | 685.703 | 628.366 | 637.035 |
| May | 614.696 | 676.062 | 618.725 | 627.394 |
| June | 657.703 | 719.069 | 661.732 | 670.401 |
| July | 647.289 | 708.655 | 651.318 | 659.987 |
| August | 664.603 | 725.969 | 668.632 | 677.301 |
| September | 671.847 | 733.213 | 675.876 | 684.545 |
| October | 656.777 | 718.143 | 660.806 | 669.475 |
| November | 633.598 | 694.964 | 637.627 | 646.296 |
| December | 639.190 | 700.566 | 643.219 | 651.888 |
| Change in the Quantity Traded | | 61.366 | 4.029 | 12.698 |

TABLE VI

SIMULATED PRICES OF PROCESSED BEEF
UNDER ALTERNATIVE MDM REGULATIONS
(CENTS PER POUND)

| Month of 1976 | Use of MDM Banned | Maximum of 20 Percent MDM in Processed Meats | | Use of All MDM Recoverable by Existing Technology |
|---|---|---|---|---|
| | | Including Ground Meat | Excluding Ground Meat | |
| January | 81.631 | 53.624 | 79.347 | 70.919 |
| February | 100.000 | 71.993 | 97.716 | 89.288 |
| March | 74.615 | 46.608 | 72.331 | 63.903 |
| April | 93.707 | 65.700 | 91.423 | 82.995 |
| May | 102.797 | 74.790 | 100.513 | 92.085 |
| June | 91.385 | 63.378 | 89.101 | 80.673 |
| July | 96.730 | 68.723 | 94.446 | 86.018 |
| August | 83.833 | 55.826 | 81.549 | 73.121 |
| September | 78.983 | 50.976 | 76.699 | 68.271 |
| October | 78.803 | 50.796 | 76.519 | 68.091 |
| November | 83.342 | 55.335 | 81.058 | 72.630 |
| December | 87.045 | 59.038 | 84.761 | 76.334 |
| Change in the Price per Pound | | -28.007 | -2.284 | -10.712 |

per month, accompanied by a price decrease of about 10.7 cents per pound.

The direct effects in the processed pork market are, as shown in Tables VII and VIII, also consistent with the economic theory of Chapter II. Under the 20 percent maximum MDM content rule applied to all processed beef and pork products, the simulation indicates a 38.101 million pound per month increase in the quantity of processed pork traded each month, and a 17.7 cents per pound reduction in the price of processed pork. The simulation applying the same rule but excluding MDM as an ingredient in ground beef and pork indicates the quantity of processed pork traded would increase by only 3.957 million pounds per month and its price fall by only 1.7 cents per pound. Simulation of the unrestricted use of MDM indicates an increase in the quantity of processed pork traded of 23.963 million pounds per month, accompanied by a 9.7 cents per pound reduction in its price.

The a priori indirect effects suggested by the economic theory developed in Chapter II were in some instances uncertain. The underlying economic theory indicated that one of the anticipated indirect effects from the adoption of mechanical deboning techniques by red meat producers would be a reduction in the price of table meats. The simulation results presented in Tables X and XII are consistent with this hypothesized relationship. However, the economic theory in Chapter II led to the conclusion that the effect of the adoption of mechanical deboning on the quantity of table meats traded could not be determined a priori. It was noted that this is an empirical question depending on the cross price demand and supply elasticities and the relative changes in the demand and supply of table meats which they induce--see

TABLE VII

SIMULATED QUANTITIES OF PROCESSED PORK
UNDER ALTERNATIVE MDM REGULATIONS
(MILLIONS OF POUNDS)

| Month of 1976 | Use of MDM Banned | Maximum of 20 Percent MDM in Processed Meats | | Use of All MDM Recoverable by Existing Technology |
|---|---|---|---|---|
| | | Including Ground Meat | Excluding Ground Meat | |
| January | 204.486 | 242.586 | 208.442 | 228.448 |
| February | 189.836 | 227.937 | 193.793 | 213.799 |
| March | 229.054 | 267.154 | 233.010 | 253.016 |
| April | 215.847 | 253.948 | 219.804 | 239.810 |
| May | 195.803 | 233.903 | 199.759 | 219.765 |
| June | 197.125 | 235.226 | 201.082 | 221.088 |
| July | 190.163 | 228.263 | 194.119 | 214.125 |
| August | 219.013 | 257.114 | 222.970 | 242.976 |
| September | 230.374 | 268.474 | 234.330 | 254.336 |
| October | 246.015 | 284.115 | 249.971 | 269.977 |
| November | 252.981 | 291.081 | 256.937 | 276.943 |
| December | 237.539 | 275.640 | 241.495 | 261.502 |
| Change in the Quantity Traded | | 38.101 | 3.957 | 23.963 |

TABLE VIII

SIMULATED PRICES OF PROCESSED PORK
UNDER ALTERNATIVE MDM REGULATIONS
(CENTS PER POUND)

| Month of 1976 | Use of MDM Banned | Maximum of 20 Percent MDM in Processed Meats | | Use of All MDM Recoverable by Existing Technology |
|---|---|---|---|---|
| | | Including Ground Meat | Excluding Ground Meat | |
| January | 104.005 | 86.256 | 102.295 | 94.312 |
| February | 112.701 | 94.952 | 110.991 | 103.008 |
| March | 95.386 | 77.637 | 93.676 | 85.693 |
| April | 103.799 | 86.050 | 102.089 | 94.106 |
| May | 112.195 | 94.446 | 110.485 | 102.502 |
| June | 109.657 | 91.908 | 107.947 | 99.964 |
| July | 113.242 | 95.493 | 111.532 | 103.549 |
| August | 101.930 | 84.181 | 100.220 | 92.237 |
| September | 97.750 | 80.001 | 96.040 | 88.057 |
| October | 93.262 | 75.513 | 91.552 | 83.569 |
| November | 92.400 | 74.651 | 90.690 | 82.707 |
| December | 98.279 | 80.530 | 96.569 | 88.586 |
| Change in the Price per Pound | | -17.749 | -1.710 | -9.693 |

Chapter II, Figure 3. Tables IX and XI present the simulations which attempt to provide answers to this empirical question for the table beef and table pork markets.

In the market for table beef, Tables IX and X, simulation of regulations allowing a maximum of 20 percent MDM as an ingredient in all processed beef and pork indicates a decrease in the quantity of table beef traded of about 194 thousand pounds per month, accompanied by a price reduction of 0.57 cents per pound. Simulation of the 20 percent rule applied to all processed meats except ground beef and pork indicates a 16 thousand pound per month reduction in the quantity of table beef traded and a 0.05 cents per pound decrease in price. Simulation of free market adoption of mechanical deboning indicates a reduction in the quantity of table beef traded of 74 thousand pounds per month and a 0.22 cents per pound reduction in price. As expected, the indirect effects in the market for table beef (of using MDM in processed meats) are relatively small in comparison to the direct effects in the markets for processed meats. The decrease in the quantity of table beef traded is a result of the change in the relative prices of table and processed meats inducing a reduction in the demand for table beef which is relatively greater than the increase in the supply of table beef--see Chapter II, Figure 3. This follows from the fact that no cross price effects were picked up in the estimation of the equation for the supply of table beef. The demand equation for table beef, however, contains one cross price effect.

Indirect effects of alternative MDM regulations on the market for table pork are reported in Tables XI and XII. Simulations of the use of 20 percent MDM in all processed meat products indicate a decrease in

TABLE IX

SIMULATED QUANTITIES OF TABLE BEEF UNDER ALTERNATIVE MDM REGULATIONS (MILLIONS OF POUNDS)

| Month of 1976 | Use of MDM Banned | Maximum of 20 Percent MDM in Processed Meats: Including Ground Meat | Maximum of 20 Percent MDM in Processed Meats: Excluding Ground Meat | Use of All MDM Recoverable by Existing Technology |
|---|---|---|---|---|
| January | 1052.207 | 1052.013 | 1052.191 | 1052.133 |
| February | 953.314 | 953.120 | 953.298 | 953.240 |
| March | 1066.677 | 1066.483 | 1066.661 | 1066.603 |
| April | 963.060 | 962.866 | 963.044 | 962.986 |
| May | 944.358 | 944.164 | 944.342 | 944.284 |
| June | 1027.673 | 1027.479 | 1027.657 | 1027.599 |
| July | 1003.422 | 1003.228 | 1003.406 | 1003.348 |
| August | 1040.996 | 1040.802 | 1040.980 | 1040.922 |
| September | 1062.585 | 1062.391 | 1062.569 | 1062.511 |
| October | 1042.065 | 1041.871 | 1042.049 | 1041.991 |
| November | 1002.342 | 1002.148 | 1002.326 | 1002.268 |
| December | 1008.029 | 1007.835 | 1008.013 | 1007.955 |
| Change in the Quantity Traded | | -.194 | -.016 | -.074 |

TABLE X

SIMULATED PRICES OF TABLE BEEF UNDER ALTERNATIVE MDM REGULATIONS

| Month of 1976 | Use of MDM Banned | Maximum of 20 Percent MDM in Processed Meats | | Use of All MDM Recoverable by Existing Technology |
|---|---|---|---|---|
| | | Including Ground Meat | Excluding Ground Meat | |
| January | 159.841 | 159.268 | 159.794 | 159.622 |
| February | 173.919 | 173.346 | 173.872 | 173.700 |
| March | 153.435 | 152.862 | 153.388 | 153.216 |
| April | 167.603 | 167.030 | 167.556 | 167.384 |
| May | 175.558 | 174.985 | 175.511 | 175.339 |
| June | 168.059 | 167.486 | 168.012 | 167.840 |
| July | 173.043 | 172.470 | 172.996 | 172.824 |
| August | 162.444 | 161.871 | 162.397 | 162.225 |
| September | 158.159 | 157.586 | 158.112 | 157.940 |
| October | 156.984 | 156.411 | 156.937 | 156.765 |
| November | 160.037 | 159.464 | 159.990 | 159.818 |
| December | 164.801 | 164.228 | 164.754 | 164.582 |
| Change in the Price per Pound | | -.573 | -.047 | -.219 |

TABLE XI

SIMULATED QUANTITIES OF TABLE PORK UNDER ALTERNATIVE MDM REGULATIONS (MILLIONS OF POUNDS)

| Month of 1976 | Use of MDM Banned | Maximum of 20 Percent MDM in Processed Meats | | Use of All MDM Recoverable by Existing Technology |
|---|---|---|---|---|
| | | Including Ground Meat | Excluding Ground Meat | |
| January | 710.451 | 709.970 | 710.411 | 710.267 |
| February | 657.660 | 657.179 | 657.620 | 657.476 |
| March | 795.822 | 795.341 | 795.782 | 795.638 |
| April | 747.822 | 747.341 | 747.782 | 747.638 |
| May | 678.160 | 677.679 | 678.120 | 677.976 |
| June | 684.601 | 684.120 | 684.561 | 684.417 |
| July | 660.137 | 659.656 | 660.097 | 659.953 |
| August | 760.524 | 760.043 | 760.484 | 760.340 |
| September | 799.993 | 799.512 | 799.953 | 799.809 |
| October | 853.517 | 853.036 | 853.447 | 853.333 |
| November | 876.926 | 876.445 | 876.886 | 876.742 |
| December | 824.116 | 823.635 | 824.076 | 823.932 |
| Change in the Quantity Traded | | -.481 | -.040 | -.184 |

TABLE XII

SIMULATED PRICES OF TABLE PORK UNDER ALTERNATIVE MDM REGULATIONS (CENTS PER POUND)

| Month of 1976 | Use of MDM Banned | Maximum of 20 Percent MDM in Processed Meats | | Use of All MDM Recoverable by Existing Technology |
|---|---|---|---|---|
| | | Including Ground Meat | Excluding Ground Meat | |
| January | 142.886 | 141.679 | 142.788 | 142.425 |
| February | 152.828 | 151.621 | 152.730 | 152.367 |
| March | 131.141 | 129.934 | 131.043 | 130.680 |
| April | 140.373 | 139.166 | 140.275 | 139.911 |
| May | 152.490 | 151.283 | 152.392 | 152.028 |
| June | 151.615 | 150.408 | 151.516 | 151.153 |
| July | 156.550 | 155.343 | 156.451 | 156.088 |
| August | 140.794 | 139.587 | 140.695 | 140.332 |
| September | 134.984 | 133.777 | 134.885 | 134.522 |
| October | 127.750 | 126.543 | 127.652 | 127.289 |
| November | 125.809 | 124.602 | 125.710 | 125.347 |
| December | 135.728 | 134.521 | 135.630 | 135.267 |
| Change in the Price per Pound | | -1.207 | -.098 | -.462 |

the quantity of table pork traded of 481 thousand pounds per month accompanied by a 1.2 cents decrease in price. Simulations of the consequences of the same rule applied to all processed meats except ground beef and pork indicate a 40 thousand pound per month reduction in the quantity of table pork traded and a 0.10 cents reduction in price per pound. Finally, the free market use of MDM simulation results indicate a decline in the quantity of table pork traded of 184 thousand pounds per month accompanied by a reduction in price of 0.46 cents per pound. The indirect effects in the table pork market are relatively small in comparison to the direct effects of mechanical deboning in the markets for processed meats. Again, the simulated decrease in the quantity of table pork is a result of the change in the relative prices of table and processed meats inducing a reduction in the demand for table pork which is relatively greater than the induced increase in the supply of table pork--Chapter II, Figure 3. This results from the fact that the estimated demand equation for table pork contains one cross price effect, while no cross effects were detected in the supply equation.

In developing the theoretical background for the model in Chapter II, questions were also raised about the impact of mechanical deboning on the demand for livestock. It was noted that the derived demand for livestock to produce meat, table and processed, is dependent on the final demand for meat as well as the productivity of livestock in producing meat. In more technical terms, under conditions of pure competition, the demand for livestock = VMP = Pm x MPP;

where VMP = the value of the marginal product of livestock in producing meat,

Pm = the price of meat, and

MPP = the marginal physical product of livestock in producing meat.

While estimation of the derived demand for livestock is beyond the scope of this study, it is possible to estimate whether the adoption of mechanical deboning techniques by red meat producers will be associated with an increase or decrease in the demand for livestock. If the demand for livestock were actually estimated, changes in the welfare of producers could be allocated between livestock producers and meat packers and processors (42). The scope of the present study is limited to estimating the direction of any change in the demand for livestock and the associated change in prices received by livestock producers.

From the equation above, it follows that the

$$\text{change in the demand for livestock} = \Delta VMP = \Delta Pm \times \Delta MPP.$$

Adoption of mechanical deboning is associated with an increase in the marginal physical product of livestock in producing meat and a decrease in the price of meat. Consequently, the direction of the change in the demand for livestock is an empirical question dependent on whether the percentage decrease in the price of meat is greater than, less than or equal to the percentage increase in the marginal physical product of livestock in producing meat. Estimates of these percentage changes are presented in Table XIII. Under each of the alternative MDM regulations, estimates of the percentage decrease in the price of meat are

TABLE XIII

SIMULATED EFFECTS OF ALTERNATIVE MECHANICAL DEBONING REGULATIONS ON THE DEMAND FOR LIVESTOCK (PERCENT CHANGE)

| Percentage Change in the | Maximum of 20 Percent MDM in Processed Meats: Including Ground Meat | Maximum of 20 Percent MDM in Processed Meats: Excluding Ground Meat | Use of All MDM Recoverable by Existing Technology |
|---|---|---|---|
| Retail Price of Beef * | -8.44 | -.69 | -3.23 |
| Marginal Physical Product of Cattle in Producing Beef | 5.81 | .43 | 1.75 |
| Demand for Cattle | decrease | decrease | decrease |
| Retail Price of Pork * | -3.71 | -.35 | -1.91 |
| Marginal Physical Product of Hogs in Producing Pork | 4.17 | .43 | 2.58 |
| Demand for Hogs | increase | increase | increase |

* Weighted average of the percentage change in the prices of processed beef (pork) and table beef (pork).

compared with estimates of the percentage increase in the marginal physical product of livestock in producing meat. These estimates indicate that the adoption of mechanical deboning techniques by red meat producers may be associated with a decrease in the demand for beef cattle and an increase in the demand for hogs. This means that, given the supply of livestock, producers of beef cattle would receive lower prices for their animals while producers of hogs would receive higher prices.

The short-run direct and indirect effects of the alternative MDM regulations may be summarized as follows. Simulations of the use of MDM in processed meat products indicate more processed meat products being traded at lower prices and slightly smaller quantities of table cuts being traded at slightly lower prices. The demand for beef cattle is expected to decrease and the demand for hogs increase. Given supply, these changes would be accompanied by a decrease in the price of slaughter cattle and an increase in the price of slaughter hogs. The magnitude of these induced changes depends on the particular MDM regulation adopted. In the next section, the simulated changes in prices and quantities of processed beef and pork are used to assess the attendant welfare effects for producers and consumers of processed meat products.

## Analysis and Measurement of the Welfare Effects of Alternative Mechanical Deboning Regulations

The objective of this section is to analyze the welfare effects associated with a ban on the use of MDM. The partial equilibrium demand and supply model estimated in Chapter III was utilized in the previous section to simulate the changes in the prices and quantities of table and processed meats associated with alternative regulations on the use of MDM. In this section, the welfare effects attending these price and quantity changes are analyzed using the concepts of economic surplus.

A comprehensive survey of the concepts of economic surplus by Currie, Murphy and Schmitz (8) outlines the underlying theory of the approach as well as the difficulties of putting it into practice. Harberger's (14) three basic postulates for applied welfare economics are implicit assumptions of the methodology and are restated below.

1. The competitive demand price for a given unit measures the value of that unit to the demander.
2. The competitive supply price for a given unit measures the value of that unit to the supplier.
3. When evaluating the net benefits or costs of a given action (project, program or policy), the costs and benefits accruing to each member of the relevant groups . . . should normally be added without regard to the individual(s) to whom they accrue (p. 785).

Following Mishan's suggestion, only the direct welfare effects in the markets for processed beef and pork are analyzed. Changes in economic surplus in the markets for table beef and table pork are "simply the consequence of consumers' bettering themselves by switching from [table meats] to the new lower-priced [processed meats]" (27, p. 34).

Figure 5 (which is a duplication of Figure 2, Chapter II) shows the demand, dd, and supply, ss, of processed beef (pork) when the use of MDM in processed meat products is banned. Use of MDM as an ingredient in processed meats would lead to an increase in the supply

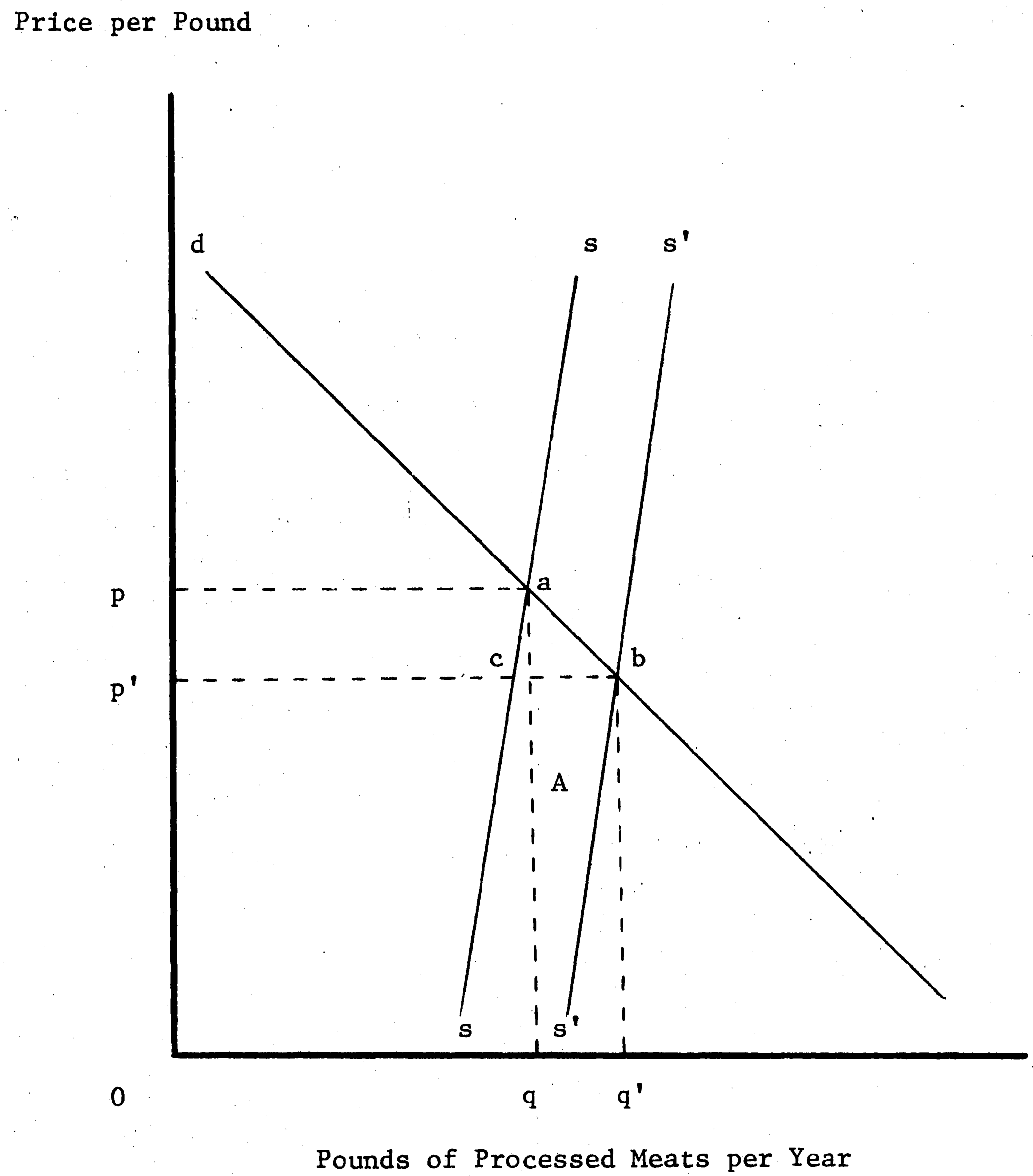


Figure 5. Demand and Supply of Processed Meats

of processed beef (pork) to s's', a reduction in the price of processed beef (pork) from p to p', and an increase in the quantity traded from q to q'. The welfare effects associated with these changes in the equilibrium price and quantity of processed beef (pork) are discussed below.

Regulations permitting MDM to be used as an ingredient in processed meats and the price and quantity changes they induce result in the economic welfare of consumers being increased by an amount measured by area p'pab in Figure 5. Part of this gain to consumers is a transfer from producers whose welfare is reduced by an amount measured by area p'pac. This loss to producers is at least partially offset by the welfare gain to producers measured by the area below line cb and between the two supply curves, aıea A.

Posing the question in a reciprocal manner, if the use of MDM in processed meat products is banned, the welfare effects are of equal but opposite magnitude. The economic welfare loss to consumers is measured by area p'pab. Part of this loss to consumers is gained by producers, area p'pac. But at least part of the producers' gains from consumers is cancelled out by the welfare loss to producers measured by area A.

Regardless of how the question is posed, the net welfare change for society (producers and consumers) is measured by area A plus area abc. This area represents the net economic welfare gain to society if use of MDM in processed meats is permitted, or conversely, the net loss in society's economic welfare if MDM is banned.

The linear demand and supply functions estimated in Chapter III and utilized to simulate the changes in equilibrium prices and quantities associated with the alternative MDM regulations, allow these welfare effects to be computed as follows:

Gains to Consumers = area p'pab = (p-p') (q+q')/2

Loss to Producers = area p'pac = (p-p') (q+q'-s)/2

Gain to Producers = area A = s (p')

Net Change in Social Welfare = area abc + area A = s (p+p')/2

where p and q are the original price and quantity, assuming MDM is banned; p' and q' are the new price and quantity under alternative simulated regulations allowing varying amounts of MDM to be incorporated in processed meats; and s is the shift in supply associated with each of the alternative regulations.

Estimates of the welfare gains and losses to consumers and producers of processed beef and pork under the three policy alternatives to a ban are reported in Table XIV. The annual welfare gain to consumers of processed beef and pork ranges from about $2,790 million, under the assumption that a maximum of 20 percent MDM is included in all processed meats; to about $224 million, when the same rule is applied to all processed meats except ground beef and pork; to about $1,110 million, under the free market assumption.

In the case of producers of processed beef, annual welfare losses exceed welfare gains under each of the simulated MDM policies. Just the opposite is found for producers of processed pork, whose welfare gains slightly exceed their losses when they are allowed to utilize MDM in processed pork, except when the 20 percent rule is applied to all processed meat products. Together, producers of processed beef and pork incur net welfare losses of about $1,130 million, $67 million and $401 million under each of the three alternative MDM policies examined.

TABLE XIV

SIMULATED WELFARE EFFECTS OF ALTERNATIVE MECHANICAL DEBONING REGULATIONS (MILLIONS OF DOLLARS PER YEAR)

| Welfare Gains (Losses) to: | | Maximum of 20 Percent MDM in Processed Meats: Including Ground Meat | Maximum of 20 Percent MDM in Processed Meats: Excluding Ground Meat | Use of All MDM Recoverable by Existing Technology |
|---|---|---|---|---|
| Consumers of: | | | | |
| Processed Beef | | 2,286.46 | 178.61 | 843.24 |
| Processed Pork | | 503.51 | 45.01 | 266.75 |
| Total | | 2,789.97 | 223.62 | 1,109.99 |
| Producers of: | | | | |
| Processed Beef: | Losses | (2,063.39) | (177.26) | (817.53) |
| | Gains | 951.53 | 101.01 | 369.73 |
| | Net | (1,111.86) | ( 76.25) | (447.80) |
| Processed Pork: | Losses | (457.67) | (44.55) | (251.24) |
| | Gains | 439.71 | 53.82 | 298.21 |
| | Net | ( 17.96) | 9.27 | 46.97 |
| Total | | (1,129.81) | (66.98) | (400.83) |
| Net Gain to Producers and Consumers of: | | | | |
| Processed Beef | | 1,174.61 | 102.36 | 395.44 |
| Processed Pork | | 485.55 | 54.28 | 313.72 |
| Total | | 1,660.16 | 156.64 | 709.16 |

The analysis indicates that the overall economic welfare of society in 1976 could have been increased by $1,660 million under the 20 percent rule applied to all processed meats; by $157 million when ground beef and pork are excluded from the 20 percent rule; and by about $709 million under free market conditions. These estimates also represent estimates of the economic cost to society of continuing the present ban on use of MDM for human consumption.

# CHAPTER V

# SUMMARY AND CONCLUSIONS

This chapter briefly summarizes the methodology and empirical results presented in earlier chapters. After noting several limitations of the analysis, policy implications are discussed and suggestions are made for future research.

## A Brief Summary

Mechanical deboning is a technique for recovering the fragments of meat that remain on the bones of a carcass after hand trimming. In the mechanical deboning process, the bones and attached fragments of meat are ground up and fed into special deboning machines that act like a sieve. The bone bits are screened out while the meat passes through. The result is a paste-like product called mechanically deboned meat (MDM).

The USDA has proposed regulations which would expand the definition of meat and allow MDM to be used as an ingredient in certain processed meat products. Interim regulations were also issued by USDA providing for immediate production and distribution of MDM in processed meat products for human consumption. However, several consumer groups filed a suit in United States District Court contending that the USDA failed to follow proper administrative procedures in issuing the interim regulations. When the Court concurred with the position of the consumer groups, the USDA was forced to withdraw the interim regulations pending further study. Meanwhile, the broader proposal to expand the definition of meat is still pending and the additional meat that could be recovered via mechanical deboning is being wasted. Recommendations of a Select Panel on Health and Safety Aspects of Use of Mechanically Deboned Meat have been incorporated into a revised MDM proposal which presently is undergoing a period of public comment.

The primary objective of this study was to determine, as nearly as possible, the economic impact of potential increases in meat production resulting from mechanical deboning of red meats. The economic impacts analyzed include changes in the retail prices and quantities traded, and the associated changes in the economic welfare of producers and consumers of red meats.

Red meats are consumed in two basic final forms, as table cuts and processed meats.[1] Since MDM reaches consumers as an ingredient in processed meat products, adoption of the technology may have differential impacts in the markets for table and processed meats. For this reason, the beef and pork markets were each separated into table and processed submarkets. The potential impacts of mechanical deboning were assessed under the assumption that inclusion of MDM as an ingredient in processed meat products results in pound for pound increases in the retail supply of processed meats.

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[1]Table cuts are defined as meats which are consumed in whole muscle form, except for cutting and slicing. The term processed meats refers to meats not consumed in whole muscle form, including ground beef and pork; sausage, hotdogs, and luncheon meats; and other processed products in which meat ingredients are ground, flaked, extruded or mixed to form a new product.

A simultaneous equations model describing the supply and demand for table and processed beef and pork was developed and estimated using 3SLS. This model was used to simulate the consequences, in terms of prices and quantities, of several alternative regulations regarding the use of MDM in processed meat products. Policies simulated range from a continuation of the present ban on the use of MDM in products for human consumption, to a free market approach allowing red meat packers and processors complete freedom to produce and distribute all the MDM existing technology will allow them to economically recover.

More specifically, the prices and quantities associated with continuation of the present ban were compared with prices and quantities associated with three other alternative policies:

1. Allowing a maximum of 20 percent MDM as an ingredient in all processed meats,
2. Allowing a maximum of 20 percent MDM as an ingredient in all processed meat products except ground beef and pork,
3. Allowing all MDM economically recoverable by existing technology to be used in processed meat products.

It should be recalled from Chapter IV that the last policy listed is actually more restrictive than the first. This is because the present state of the arts in mechanical deboning will not allow the recovery of MDM in sufficient quantities to provide 20 percent of the ingredients for all processed meat products. The price, quantity and welfare changes associated with each of these policies are summarized in Table XV.

The potential impact of mechanical deboning is highly dependent on the regulatory policy adopted. While the impact on the price of table

TABLE XV

SUMMARY OF PRICE, QUANTITY AND WELFARE EFFECTS ASSOCIATED WITH ALTERNATIVE MDM REGULATIONS

| | Maximum of 20 Percent MDM in Processed Meats | | Use of All MDM Recoverable by Existing Technology |
|---|---|---|---|
| Change in the | Including Ground Meat | Excluding Ground Meat | |
| Price of: | | (cents per pound) | |
| Processed Beef | -28.007 | -2.284 | -10.712 |
| Processed Pork | -17.749 | -1.710 | - 9.693 |
| Table Beef | - .573 | - .047 | - .219 |
| Table Pork | - 1.207 | - .098 | - .462 |
| Quantity of: | | (millions of pounds) | |
| Processed Beef | 61.366 | 4.029 | 12.698 |
| Processed Pork | 38.101 | 3.957 | 23.963 |
| Table Beef | - .194 | - .016 | - .074 |
| Table Pork | - .481 | - .040 | - .184 |
| Welfare of: | | (millions of dollars) | |
| Consumers | 2,789.97 | 223.62 | 1,109.99 |
| Producers | -1,129.81 | - 66.98 | - 400.83 |
| Consumers & Producers | 1,660.16 | 156.64 | 709.16 |

meats is relatively insignificant, even the most restrictive policy alternative simulated indicated that mechanical deboning could significantly reduce the price of processed meats.

From the welfare analysis, it is even more clear that consumers stand to gain considerably from policies permitting the use of MDM as an ingredient in processed meat products. Estimates of the annual welfare gain to consumers are about $2.8 billion when the 20 percent rule is applied to all processed meats, $224 million when ground meats are excluded from the 20 percent rule and $1.1 billion under a free market policy. While producers' welfare is reduced under all of the alternative regulations, simulated increases in the economic welfare of society as a whole for 1976 ranged from about $157 million when ground beef and pork were excluded from the 20 percent rule, to about $1.7 billion when the 20 percent rule was applied to all processed meats.

## Limitations

As with any study, the results summarized above should be applied with some caution based on an appreciation of the limitations of the underlying analysis. Data and methodology are rarely equal to the demands of economic theory. This study is no exception.

Perhaps the most serious limitation of the study is the lack of reliable data for disaggregating the retail markets for beef and pork into table and processed submarkets. Chapter II and the Appendix describe the steps taken to overcome this problem, but until more detailed and more timely data become available, researchers will continue to be plagued with the problem of using estimation techniques more sophisticated than the data which they utilize.

While it is plausible that the only short run cross effects which exist between the markets for table and processed beef and pork are those detected in the model in Chapter III, it is also plausible that the methods by which the data series for beef and pork were disaggregated into table and processed components precluded the detection of some cross effects.

Lack of data also precluded analysis of the impact of mechanically deboning veal, lamb and mutton. While consumption of these red meats is relatively insignificant in comparison to the consumption of beef and pork, this omission will tend to understate the potential impact of mechanical deboning in the red meat industry. For sheep, the mechanical deboning process could be particularly important since lamb and mutton carcasses are impractical to hand bone.

Results derived from the analysis utilizing the model estimated in Chapter III have greatest application in the short run. Predictions of price and quantity changes grow more inaccurate the further away from the base period such predictions are made. Therefore, temptations to extend these results to long run analysis should be avoided.

Finally, while the problems of operationalizing the concepts of economic surplus have been well documented elsewhere (8), it should be noted that measurement of increases in the welfare of producers (area A, Figures 2 and 5) involves projection of the supply curve well beyond the range of the data. For this reason, more confidence can probably be placed in the measures of changes in consumers' welfare than in those of producers' welfare.

## Policy Implications

The argument for regulating the use of MDM is not unlike the argument for most other governmental regulations in such areas as traffic control, drug control, registration of firearms, property zoning, licensing, etc. In each case, the basic justification for control or restriction of individual liberties is the enhancement of the general welfare. General welfare is a broad term construed to include such concerns as health, safety, economic well-being, social conditions, aesthetic values, humane consideration, etc. While this study of the economic impact of mechanically deboning red meats has been limited to consideration of economic welfare, this does not imply that other considerations are either less important or irrelevant.

Consumerists have raised legitimate concerns about the nutritional, health and safety implications of utilizing MDM in products for human consumption. Policymakers must weigh potential risks from MDM against the potential gains in economic welfare estimated above. In fact, the measures of potential economic welfare gain represent a part of the cost to society of continuing the present ban, which is not generally recognized. Policymakers should also consider these welfare losses as a cost of "proving" that mechanically deboned red meat is safe. This is particularly true in light of the fact that mechanically deboned fish and poultry have been consumed in this country for years, and mechanically deboned red meats are consumed in many foreign countries and imported to this country as ingredients in processed meat products. If no harmful effects from consumption of MDM can be demonstrated, policymakers must decide whether avoiding any potential risks from MDM is worth the economic cost to society of continuing the ban.

## Suggestions for Further Research

Additional research may be warranted to explore the possible complementarity between mechanical deboning and several other emerging meat packing and processing technologies. This is particularly true as meat packing and processing becomes more integrated with wholesale and retail distribution of meat and meat products.

In recent years there has been a trend toward centralized fabrication with more meat packers and processors shipping boxed wholesale and retail cuts rather than hanging carcasses. Centralized fabrication means that more bones are accumulated in one place for mechanical deboning.

Complementarities may also be found between mechanical deboning and hot boning. Hot boning involves the removal of bone and waste fat from freshly slaughtered carcasses prior to chilling. By doing this, energy and space required for refrigeration are reduced and shipping costs are incurred only for the edible portions of the carcasses. Plants designed to incorporate the hot boning technique into the total processing procedure could, for example, buy hogs in the morning, slaughter them, make sausage from the hot "pre-rigor" meat, chill and deliver the final product the same day. Widespread adoption of hot boning would also result in more bones accumulating in one place for mechanical deboning.

The impact of mechanical deboning may also be dependent on the development of a family of meat restructuring technologies. Restructuring meat involves the use of flaking, extruding, portioning, shaping and other processing techniques to produce restructured meat products which closely resemble the color, appearance, texture and flavor of whole muscle meats. Restructuring technologies could open up new uses for MDM as an ingredient in more processed meat products as well as in simulated table cuts.

Finally, research aimed at examining the impact of mechanical deboning in more detailed markets, such as those for hotdogs or luncheon meats, could prove very interesting and useful. This is especially true if regulations for the use of MDM as an ingredient vary substantially from product to product.

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APPENDIXES

# APPENDIX

## DATA

The data used in estimating the parameters of the empirical model reported in Chapter III are shown in the table that follows. Sources and procedures used in deriving each of the data series are described briefly below.

Monthly total civilian consumption of beef and pork is computed by summing monthly commercially produced civilian consumption and one-third of the appropriate quarterly consumption from farm slaughter. These figures are reported in annual supplements of Livestock and Meat Statistics (37). After conversion from carcass to retail weight basis, the data on beef and pork consumption are disaggregated into two components, table cuts and processed meats, for both beef and pork. Estimates of the shares of table and processed home consumption of beef and pork are obtained from the latest household consumption surveys (34). A survey of away-from-home food consumption patterns provides estimates of the shares of table and processed meats consumed in restaurants and institutions (41). These percentages are shown in Table II, Chapter II. The percentages from the two types of food consumption surveys are weighted by the shares of meat consumed at home and away from home, combined, and applied to the aggregate consumption data to disaggregate it into a series for table cuts and a series for processed meats.

Price series for table cuts and processed meats are constructed from the retail prices of individual retail cuts published by the Bureau of Labor Statistics (38) and from unpublished USDA data. The prices of individual retail cuts are weighted by their market basket shares to form retail price series for table and processed beef and pork (11).

The price of table beef is a weighted average of the USDA sales price of 22 retail cuts of table beef. The price of table pork is a weighted average of the USDA sales price of 19 retail cuts of table pork. The USDA sales price of ground beef is used as a proxy for the price of processed beef. The price of processed pork was computed as the average of the USDA sales price of sausage and the BLS prices of four other processed pork items--bologna sausage, salomi sausage, liver sausage and frankfurters.

## TABLE XVI

## TIME SERIES DATA

| MONTH | YEAR | $QTB_a$ | $QPB_b$ | $QTP_c$ | $QPP_d$ | $PTB_e$ | $PPB_f$ | $PTP_g$ | $PPP_h$ | $PI_i$ | $POP_j$ | $CCS_k$ | $CHS_l$ | $SC_m$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1970 | 906.141 | 584.959 | 773.541 | 223.419 | 110 | 64 | 86 | 67 | 774.2 | 200466 | 3033.7 | 6832.4 | 22.8 |
| 2 | 1970 | 786.072 | 507.448 | 678.292 | 195.908 | 110 | 65 | 86 | 67 | 778.8 | 200662 | 2652.1 | 6084.4 | 22.8 |
| 3 | 1970 | 860.722 | 555.638 | 782.200 | 225.920 | 112 | 65 | 86 | 68 | 784.6 | 200839 | 2830.6 | 7032.5 | 23.5 |
| 4 | 1970 | 842.734 | 544.026 | 786.530 | 227.170 | 112 | 66 | 84 | 68 | 803.9 | 201064 | 2898.8 | 7296.2 | 24.0 |
| 5 | 1970 | 811.255 | 523.705 | 723.030 | 208.830 | 112 | 67 | 84 | 69 | 799.5 | 201293 | 2816.9 | 6420.1 | 25.4 |
| 6 | 1970 | 869.716 | 561.444 | 756.223 | 218.417 | 111 | 65 | 83 | 68 | 799.0 | 201520 | 2957.4 | 6261.6 | 26.6 |
| 7 | 1970 | 876.911 | 566.089 | 767.769 | 221.751 | 114 | 66 | 85 | 68 | 803.8 | 201722 | 2994.1 | 6359.8 | 25.2 |
| 8 | 1970 | 851.278 | 549.542 | 763.439 | 220.501 | 113 | 67 | 83 | 68 | 808.7 | 201943 | 2868.1 | 6616.8 | 24.6 |
| 9 | 1970 | 907.940 | 586.120 | 844.978 | 244.052 | 111 | 65 | 80 | 68 | 815.1 | 202182 | 3086.7 | 7641.9 | 24.3 |
| 10 | 1970 | 914.686 | 590.474 | 919.302 | 265.518 | 111 | 65 | 78 | 67 | 812.5 | 202418 | 3141.5 | 8352.5 | 23.5 |
| 11 | 1970 | 804.510 | 519.350 | 883.222 | 255.098 | 110 | 64 | 75 | 67 | 814.3 | 202661 | 2773.7 | 8093.8 | 23.4 |
| 12 | 1970 | 877.810 | 566.670 | 985.688 | 284.692 | 109 | 64 | 73 | 66 | 820.8 | 202869 | 2971.3 | 8824.8 | 23.9 |
| 1 | 1971 | 868.817 | 560.863 | 922.188 | 266.352 | 110 | 65 | 72 | 66 | 831.8 | 203106 | 2921.2 | 8250.6 | 23.7 |
| 2 | 1971 | 774.830 | 500.190 | 809.621 | 233.839 | 114 | 66 | 74 | 65 | 834.0 | 203280 | 2619.4 | 7017.5 | 24.4 |
| 3 | 1971 | 892.651 | 576.249 | 953.938 | 275.522 | 115 | 67 | 74 | 65 | 840.7 | 203455 | 3046.6 | 8988.3 | 26.0 |
| 4 | 1971 | 835.989 | 539.671 | 886.109 | 255.931 | 116 | 67 | 73 | 66 | 845.1 | 203665 | 2888.5 | 8457.6 | 25.2 |
| 5 | 1971 | 831.941 | 537.059 | 847.143 | 244.677 | 118 | 68 | 72 | 65 | 850.1 | 203858 | 2873.2 | 7548.6 | 23.9 |
| 6 | 1971 | 909.289 | 586.991 | 888.274 | 256.556 | 121 | 68 | 73 | 66 | 869.1 | 204067 | 3155.0 | 7603.2 | 24.1 |
| 7 | 1971 | 880.509 | 568.411 | 834.155 | 240.925 | 118 | 68 | 75 | 66 | 860.0 | 204250 | 3067.6 | 6803.7 | 24.3 |
| 8 | 1971 | 882.757 | 569.863 | 898.376 | 259.474 | 120 | 68 | 75 | 66 | 865.6 | 204441 | 3071.0 | 7512.8 | 22.1 |
| 9 | 1971 | 935.372 | 603.828 | 920.023 | 265.727 | 119 | 70 | 75 | 66 | 868.6 | 204661 | 3140.1 | 7991.2 | 20.9 |
| 10 | 1971 | 867.467 | 559.993 | 888.995 | 256.765 | 118 | 68 | 75 | 65 | 872.6 | 204887 | 3009.0 | 7780.2 | 21.3 |
| 11 | 1971 | 847.681 | 547.219 | 940.949 | 271.771 | 120 | 69 | 75 | 66 | 880.3 | 205086 | 2923.5 | 8217.0 | 20.3 |
| 12 | 1971 | 854.426 | 551.574 | 965.483 | 278.857 | 122 | 69 | 80 | 66 | 891.3 | 205284 | 2870.0 | 8267.2 | 18.8 |
| 1 | 1972 | 868.817 | 560.863 | 857.245 | 247.595 | 125 | 71 | 79 | 66 | 902.4 | 205497 | 2888.4 | 7022.3 | 19.9 |
| 2 | 1972 | 841.385 | 543.155 | 822.609 | 237.591 | 130 | 73 | 85 | 70 | 914.6 | 205666 | 2772.6 | 6828.8 | 22.0 |
| 3 | 1972 | 894.000 | 577.120 | 955.381 | 275.939 | 129 | 74 | 83 | 71 | 920.1 | 205807 | 3037.3 | 8409.4 | 22.2 |
| 4 | 1972 | 826.095 | 533.285 | 791.581 | 228.629 | 125 | 74 | 82 | 71 | 927.0 | 205978 | 2761.9 | 7256.1 | 22.7 |
| 5 | 1972 | 926.828 | 598.312 | 851.473 | 245.927 | 126 | 74 | 83 | 71 | 931.7 | 206146 | 3117.7 | 7323.8 | 22.9 |
| 6 | 1972 | 925.928 | 597.732 | 831.990 | 240.300 | 127 | 74 | 85 | 72 | 923.0 | 206321 | 3142.3 | 6809.0 | 21.9 |
| 7 | 1972 | 822.947 | 531.253 | 717.979 | 207.371 | 132 | 76 | 90 | 72 | 940.3 | 206457 | 2758.4 | 5686.5 | 23.0 |
| 8 | 1972 | 979.442 | 632.278 | 839.927 | 242.593 | 130 | 75 | 89 | 74 | 949.7 | 206583 | 3214.8 | 6946.8 | 26.7 |
| 9 | 1972 | 929.975 | 600.345 | 793.024 | 229.046 | 127 | 74 | 90 | 75 | 954.0 | 206727 | 3041.5 | 6807.9 | 28.3 |
| 10 | 1972 | 983.040 | 634.600 | 875.285 | 252.805 | 127 | 75 | 90 | 75 | 971.7 | 206878 | 3192.0 | 7492.5 | 28.3 |
| 11 | 1972 | 914.236 | 590.184 | 880.336 | 254.264 | 125 | 75 | 90 | 76 | 984.1 | 207005 | 2985.3 | 7460.6 | 29.0 |
| 12 | 1972 | 862.970 | 557.090 | 828.382 | 239.258 | 128 | 75 | 93 | 76 | 992.0 | 207142 | 2866.4 | 6663.4 | 27.7 |

TABLE XVI (Continued)

| MONTH | YEAR | $QTB_a$ | $QPB_b$ | $QTP_c$ | $QPP_d$ | $PTB_e$ | $PPB_f$ | $PTP_g$ | $PPP_h$ | $PI_i$ | $POP_j$ | $CCS_k$ | $CHS_l$ | $SC_m$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1973 | 934.472 | 603.248 | 865.904 | 250.096 | 139 | 82 | 98 | 76 | 1000.2 | 207306 | 3104.7 | 7099.5 | 28.5 |
| 2 | 1973 | 822.947 | 531.253 | 730.246 | 210.914 | 145 | 86 | 102 | 78 | 1012.6 | 207417 | 2672.8 | 6089.1 | 29.5 |
| 3 | 1973 | 854.426 | 551.574 | 797.354 | 230.296 | 150 | 93 | 107 | 84 | 1022.4 | 207531 | 2884.1 | 7036.0 | 28.6 |
| 4 | 1973 | 719.966 | 464.774 | 744.678 | 215.082 | 151 | 94 | 106 | 88 | 1031.1 | 207682 | 2407.2 | 6361.3 | 27.6 |
| 5 | 1973 | 893.100 | 576.540 | 829.825 | 239.675 | 149 | 95 | 106 | 89 | 1037.8 | 207821 | 2953.5 | 7043.1 | 28.1 |
| 6 | 1973 | 840.935 | 542.865 | 740.348 | 213.832 | 149 | 95 | 107 | 89 | 1045.7 | 207973 | 2794.4 | 6073.9 | 30.8 |
| 7 | 1973 | 836.438 | 539.962 | 697.775 | 201.535 | 151 | 95 | 110 | 90 | 1054.1 | 208102 | 2691.7 | 5327.9 | 31.0 |
| 8 | 1973 | 863.870 | 557.670 | 734.576 | 212.164 | 157 | 105 | 134 | 102 | 1064.0 | 208249 | 2696.6 | 5890.1 | 29.5 |
| 9 | 1973 | 805.859 | 520.221 | 673.962 | 194.658 | 158 | 108 | 129 | 109 | 1074.8 | 208422 | 2608.9 | 5656.8 | 27.1 |
| 10 | 1973 | 956.957 | 617.763 | 838.484 | 242.176 | 149 | 102 | 121 | 105 | 1086.2 | 208575 | 3152.0 | 6995.6 | 27.3 |
| 11 | 1973 | 886.804 | 572.476 | 813.950 | 235.090 | 148 | 100 | 119 | 102 | 1096.7 | 208701 | 2955.3 | 6933.8 | 25.1 |
| 12 | 1973 | 842.734 | 544.026 | 783.643 | 226.337 | 146 | 100 | 119 | 101 | 1103.6 | 208823 | 2765.6 | 6287.9 | 24.7 |
| 1 | 1974 | 963.703 | 622.117 | 901.984 | 260.516 | 155 | 104 | 120 | 100 | 1103.8 | 208951 | 3090.8 | 7237.4 | 27.1 |
| 2 | 1974 | 791.918 | 511.222 | 757.666 | 218.834 | 164 | 110 | 122 | 100 | 1109.3 | 209059 | 2546.9 | 5963.8 | 28.1 |
| 3 | 1974 | 905.692 | 584.668 | 860.853 | 248.637 | 155 | 106 | 116 | 100 | 1115.9 | 209163 | 2876.4 | 6948.3 | 30.6 |
| 4 | 1974 | 891.751 | 575.669 | 865.183 | 249.887 | 150 | 97 | 109 | 96 | 1125.3 | 209281 | 2901.4 | 7267.7 | 29.8 |
| 5 | 1974 | 928.626 | 599.474 | 922.188 | 266.352 | 148 | 96 | 104 | 92 | 1137.3 | 209410 | 3050.2 | 7478.3 | 24.9 |
| 6 | 1974 | 892.651 | 576.249 | 806.013 | 232.797 | 147 | 92 | 98 | 89 | 1147.9 | 209561 | 2865.9 | 6268.4 | 20.8 |
| 7 | 1974 | 923.680 | 596.280 | 788.695 | 227.795 | 153 | 94 | 108 | 89 | 1164.0 | 209683 | 3184.6 | 6095.4 | 20.5 |
| 8 | 1974 | 952.460 | 614.860 | 824.774 | 238.216 | 160 | 94 | 113 | 90 | 1172.2 | 209833 | 3169.4 | 6729.2 | 19.5 |
| 9 | 1974 | 898.497 | 580.023 | 822.609 | 237.591 | 158 | 93 | 114 | 91 | 1181.5 | 210006 | 3088.6 | 6880.5 | 19.0 |
| 10 | 1974 | 1014.968 | 655.212 | 891.882 | 257.598 | 153 | 90 | 114 | 91 | 1191.7 | 210170 | 3605.0 | 7430.8 | 17.9 |
| 11 | 1974 | 938.520 | 605.860 | 815.393 | 235.507 | 150 | 86 | 116 | 92 | 1191.7 | 210307 | 3277.8 | 6789.5 | 16.7 |
| 12 | 1974 | 910.189 | 587.571 | 817.558 | 236.132 | 149 | 86 | 118 | 92 | 1198.9 | 210429 | 3234.5 | 6672.6 | 15.8 |
| 1 | 1975 | 1037.004 | 669.436 | 845.700 | 244.260 | 149 | 85 | 120 | 93 | 1199.4 | 210555 | 3516.0 | 6763.8 | 17.4 |
| 2 | 1975 | 909.289 | 586.991 | 707.155 | 204.245 | 145 | 80 | 119 | 93 | 1201.6 | 210647 | 3083.7 | 5891.3 | 15.7 |
| 3 | 1975 | 926.378 | 598.022 | 725.195 | 209.455 | 143 | 78 | 118 | 93 | 1208.3 | 210740 | 3132.7 | 6104.5 | 15.5 |
| 4 | 1975 | 914.686 | 590.474 | 774.984 | 223.836 | 152 | 82 | 120 | 93 | 1213.5 | 210861 | 3207.8 | 6730.4 | 16.7 |
| 5 | 1975 | 889.503 | 574.217 | 697.775 | 201.535 | 181 | 86 | 127 | 95 | 1223.7 | 210993 | 3149.2 | 5691.6 | 16.1 |
| 6 | 1975 | 892.201 | 575.959 | 670.354 | 193.616 | 179 | 90 | 135 | 99 | 1253.7 | 211202 | 3193.5 | 5385.6 | 14.2 |
| 7 | 1975 | 932.674 | 602.086 | 632.832 | 182.778 | 184 | 93 | 149 | 103 | 1252.0 | 211355 | 3401.2 | 4955.5 | 13.7 |
| 8 | 1975 | 950.212 | 613.408 | 596.752 | 172.358 | 178 | 89 | 156 | 107 | 1267.5 | 211534 | 3467.3 | 4883.2 | 13.1 |
| 9 | 1975 | 993.383 | 641.277 | 649.428 | 187.572 | 175 | 88 | 159 | 108 | 1277.1 | 211719 | 3671.5 | 5467.8 | 12.0 |
| 10 | 1975 | 1072.979 | 692.661 | 671.076 | 193.824 | 174 | 90 | 164 | 109 | 1290.8 | 211878 | 3986.8 | 5637.0 | 10.9 |
| 11 | 1975 | 943.017 | 608.763 | 634.997 | 183.403 | 172 | 88 | 159 | 110 | 1300.2 | 212031 | 3470.0 | 5337.0 | 10.9 |
| 12 | 1975 | 960.105 | 619.795 | 746.121 | 215.499 | 172 | 88 | 153 | 109 | 1308.2 | 212147 | 3631.5 | 5839.1 | 11.1 |

TABLE XVI (Continued)

| MONTH | YEAR | $QTB_a$ | $QPB_b$ | $QTP_c$ | $QPP_d$ | $PTB_e$ | $PPB_f$ | $PTP_g$ | $PPP_h$ | $PI_i$ | $POP_j$ | $CCS_k$ | $CHS_l$ | $SC_m$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1976 | 1078.826 | 696.434 | 731.689 | 211.331 | 169 | 89 | 149 | 107 | 1320.8 | 212296 | 3761.9 | 5697.9 | 11.8 |
| 2 | 1976 | 933.573 | 602.667 | 636.440 | 183.820 | 164 | 86 | 147 | 105 | 1331.4 | 212404 | 3336.4 | 5122.0 | 12.5 |
| 3 | 1976 | 1116.600 | 720.820 | 778.592 | 224.878 | 155 | 84 | 144 | 104 | 1341.9 | 212499 | 3813.4 | 6611.7 | 13.1 |
| 4 | 1976 | 971.348 | 627.052 | 716.536 | 206.954 | 161 | 87 | 143 | 104 | 1352.5 | 212611 | 3354.5 | 6087.3 | 15.0 |
| 5 | 1976 | 955.159 | 616.601 | 626.338 | 180.902 | 160 | 89 | 144 | 104 | 1362.9 | 212722 | 3237.5 | 5331.4 | 17.6 |
| 6 | 1976 | 1052.743 | 679.597 | 679.735 | 196.325 | 160 | 88 | 145 | 106 | 1370.4 | 212851 | 3575.9 | 5400.3 | 18.2 |
| 7 | 1976 | 1022.613 | 660.147 | 653.758 | 188.822 | 158 | 85 | 147 | 106 | 1380.8 | 212976 | 3483.4 | 5132.1 | 17.2 |
| 8 | 1976 | 1078.376 | 696.144 | 751.172 | 216.958 | 155 | 87 | 143 | 105 | 1385.5 | 213129 | 3675.2 | 6214.5 | 15.0 |
| 9 | 1976 | 1094.565 | 706.595 | 764.882 | 220.918 | 153 | 85 | 138 | 104 | 1391.7 | 213286 | 3748.9 | 6638.5 | 16.6 |
| 10 | 1976 | 1065.784 | 688.016 | 847.143 | 244.677 | 150 | 85 | 131 | 102 | 1404.2 | 213452 | 3658.4 | 7210.9 | 17.4 |
| 11 | 1976 | 992.933 | 640.987 | 903.427 | 260.933 | 153 | 85 | 123 | 100 | 1421.4 | 213591 | 3490.8 | 7456.3 | 17.7 |
| 12 | 1976 | 975.845 | 629.955 | 851.473 | 245.927 | 156 | 85 | 123 | 98 | 1439.5 | 213725 | 3508.4 | 6880.3 | 17.6 |

(a) Quantity of Table Beef - millions of pounds retail weight.
(b) Quantity of Processed Beef - millions of pounds retail weight.
(c) Quantity of Table Pork - millions of pounds retail weight.
(d) Quantity of Processed Pork - millions of pounds retail weight.
(e) Price of Table Beef - cents per pound.
(f) Price of Processed Beef - cents per pound.
(g) Price of Table Pork - cents per pound.
(h) Price of Processed Pork - cents per pound.
(i) Personal Income - billions of dollars.
(j) Population - thousands.
(k) Commercial Cattle Slaughter - thousands of head.
(l) Commercial Hog Slaughter - thousands of head.
(m) Steer-Corn Price Ratio.

VITA

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Candidate for the Degree of

Doctor of Philosophy

Thesis: THE ECONOMIC IMPACT OF MECHANICALLY DEBONING RED MEATS

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