January 2007

GIPSA Livestock and Meat Marketing Study

Contract No. 53-32KW-4-028

Volume 5: Lamb and Lamb Meat Industries

Final Report

Prepared for

Grain Inspection, Packers and Stockyard Administration
U.S. Department of Agriculture
Washington, DC 20250

Prepared by

RTI International
Health, Social, and Economics Research
Research Triangle Park, NC 27709

RTI Project Number 0209230

RTI Project Number
0209230

GIPSA Livestock and Meat Marketing Study

Contract No. 53-32KW-4-028

Volume 5: Lamb and Lamb Meat Industries
Final Report

January 2007

Prepared for

Grain Inspection, Packers and Stockyard Administration
U.S. Department of Agriculture
Washington, DC 20250

Prepared by

RTI International
Health, Social, and Economics Research
Research Triangle Park, NC 27709

Abstract

Over time, the variety, complexity, and use of alternative marketing arrangements (AMAs) have increased in the livestock and meat industries. Marketing arrangements refer to the methods by which livestock and meat are transferred through successive stages of production and marketing. Increased use of AMAs raises a number of questions about their effects on economic efficiency and on the distribution of the benefits and costs of livestock and meat production and consumption between producers and consumers. This volume of the final report focuses on AMAs used in the lamb and lamb meat industry and addresses the following parts of the Grain Inspection, Packers and Stockyard Administration (GIPSA) Livestock and Meat Marketing Study:

- Part C. Determine extent of use, analyze price differences, and analyze short-run market price effects of AMAs.
- Part D. Measure and compare costs and benefits associated with spot marketing arrangements and AMAs.
- Part E. Analyze the implications of AMAs for the livestock and meat marketing system.

This final report follows the publication of an interim report for the study that used qualitative sources of information to identify and classify AMAs and describe their terms, availability, and reasons for use. The portion of the study contained in this volume of the final report is based on quantitative analyses using transactions data, Mandatory Price Reporting (MPR) data, other publicly available data, and the results of the industry survey and industry interviews.

This volume of the final report presents the results of analyses of the effects of AMAs on the markets for lambs and lamb products. Economic and statistical models were developed and estimated to examine the effects of AMAs on lamb prices, procurement costs, quality, price risk, and consumers and

producers. Results of analyses of the estimated effects of hypothetical restrictions on AMAs also are presented.

The principal contributors to this volume of the final report are the following:

- Gary Brester, PhD, Montana State University (Lamb Team Leader)
- Mary Muth, PhD, RTI International (Project Manager)
- Joseph Atwood, PhD, Montana State University
- John Marsh, PhD, Montana State University
- Kevin McNew, PhD, Cash Grain Bids, Inc.
- Sheri Cates, RTI International (Data Collection Manager)
- Michaela Coglaiti, RTI International
- Shawn Karns, RTI International
- Justin Taylor, MS, RTI International
- Catherine Viator, MS, RTI International

We would like to thank the anonymous peer reviewers and GIPSA staff who provided comments on earlier drafts, which helped us improve the report. We also thank Melissa Fisch and Sharon Barrell for editing assistance.

This report and the study on which it is based were completed under a contract with GIPSA, U.S. Department of Agriculture (USDA). Any opinions, findings, and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of GIPSA or USDA.

Contents

Figures

Tables

Number		Page

Executive Summary

As part of the congressionally mandated Livestock and Meat Marketing Study, this volume of the final report presents the results of analyses of the effects of alternative marketing arrangements (AMAs) on the lamb and lamb meat industries. This final report focuses on determining the extent of use of AMAs, analyzing price differences and price effects associated with AMAs, measuring the costs and benefits associated with using AMAs, and assessing the broad range of implications of AMAs. The analyses in this volume were conducted using the results of industry interviews, the industry survey, and analysis of Mandatory Price Reporting (MPR) data and other publicly available data sources. Transactions data from lamb packers were used to validate MPR data used in the analyses.

In this report, AMAs refer to all possible alternatives to cash or spot market. AMAs include arrangements such as forward contracts, marketing agreements, procurement or marketing contracts, packer ownership, custom feeding, and custom slaughter. Cash or spot market transactions refer to transactions that occur immediately, or “on the spot.” These include auction barn sales; video or electronic auction sales; sales through order buyers, dealers, and brokers; and direct trades.

Primary conclusions for this final report, as they relate to the lamb and lamb meat industries, are as follows:

- **Lamb packers procure fed lambs primarily through formula pricing arrangements and auctions.** According to MPR data, lamb packers procure 42.2% of fed lambs through formula pricing arrangements and 39.4% through auctions. Negotiated sales account for 12.0% of fed lamb procurement, and packer ownership represents 4.9%. Contracted procurement represents only 0.8% of lamb procurement, while imports represent only 0.7%. These data are similar to those obtained from the lamb packer survey.

- **The means and standard deviations of fed lamb prices from MPR data for formula pricing and cash arrangements were similar during the sample period.** The price series were highly correlated with an estimated correlation coefficient of 0.970. A reduced-form model of the difference between normalized formula pricing and cash fed lamb prices indicated that lamb inventories, lamb carcass price risk, and seasonality were the primary determinants of variations in the difference.

- **Changes in procurement methods for lamb would impose costs on the lamb marketing system by reducing efficiencies, but may also provide some benefits by altering potential market power effects.** If formula pricing procurement is restricted, lamb acquisition costs would rise. However, some of this increase in costs may be offset by a reduction in potential oligopsony power. Ultimately, a combination of these effects yields net changes in lamb prices, quantities, and producer surplus.

- **Given that lamb markets are relatively thin, the primary effect of MPR may have been to reduce price risk rather than to influence price levels.** The implementation of MPR in 2001 increased slaughter lamb price by only 0.129%.

- **AMAs were found to have statistically significant although economically small effects on lamb prices.** A 10% increase in formula pricing lamb procurement would increase the slaughter lamb price by an estimated 2.54%; this effect is likely due to risk reductions. A 10% increase in cash lamb procurement increases slaughter prices by an estimated 2.68%. A 10% increase in packer ownership reduces slaughter lamb prices by an estimated 0.23%.

- **Increases in formula pricing and cash procurement methods reduce lamb procurement costs, while increases in packer ownership increase procurement costs.** The effects of formula pricing and cash procurement methods on procurement costs for lambs were similar and not statistically different from one another.

- **Technological change has likely increased lamb quality over time.** However, there does not appear to be any statistically significant difference in the quality of lambs procured through formula pricing and cash procurement methods.

- **Price risk shifting from lamb producers to lamb packers and breakers has not occurred as a result of AMAs.** No statistical difference was found between the variances of prices for each type of AMA.
- **Restrictions on the use of AMAs cause almost every sector in the lamb industry to lose producer surplus, even if potential market power (if it exists) is reduced or eliminated.** Reductions in the use of AMAs have both positive and negative effects on the lamb industry. Reductions in potential market power (a positive effect) do not offset the increases in processing costs and reductions in lamb quality (negative effects).
- **Restrictions on the use of AMAs would likely reduce the competitiveness of the lamb industry.** Although lamb is not a strong substitute for beef and pork, restrictions on the use of AMAs would place it at a competitive disadvantage to these other meats. More importantly, however, it appears that imported lamb is a strong substitute for domestic lamb. Hence, the loss of competitiveness in response to restrictions on the use of AMAs is much more pronounced with respect to lamb imports.
- **AMAs may have multiple effects on accessing the lamb market.** Ease of entry may be affected by the availability of AMAs, because financing of production operations often depends on the assurance of market access and price risk management. However, for small producers, it may be more difficult to secure AMAs because it is more costly for packers to negotiate with many small producers relative to fewer large producers. Hence, if AMAs reduce the viability of public auctions, small producers may find that their market access is limited.
- **Restrictions on the use of AMAs may increase concentration of various segments of the lamb industry, but the effect of increased concentration on market power is unknown.** There are no clear effects of the changes in the use of AMAs on concentration in the lamb industry. Concentration in the lamb packing industry has remained relatively flat, even though the use of AMAs has increased. However, increased use of AMAs may reduce the viability of auctions and could lead to increased concentration in the lamb feeding sector. In addition, if restrictions on AMAs

reduce the competitiveness of domestic lamb meat relative to lamb imports, then concentration in the lamb packing and processing industry is likely to increase in response to declining domestic demand.

The analyses presented in this volume are based on the best available data, using methodologies developed to address the study requirements under the time constraints of the study. Some analyses were limited based on availability of transactions and profit and loss (P&L) statement data. However, secondary data were used, as available, to conduct the analyses.

1 Introduction and Background

AMAs include all possible alternatives to use of cash or spot markets for conducting transactions.

As part of the congressionally mandated Livestock and Meat Marketing Study, this volume of the final report presents the results of analyses of the effects of AMAs in lamb and lamb meat industries. The types of questions posed by the Livestock and Meat Marketing Study include the following: What types of marketing arrangements are used? What is the extent of their use? Why do firms enter into the various arrangements? What are the terms and characteristics of these arrangements? What are the effects and implications of the arrangements on participants and on the livestock and meat marketing system?

The overall study comprises five parts based on the performance work statement in the contract with the Grain Inspection, Packers and Stockyard Administration (GIPSA). An interim report released in August 2005 addressed the first two parts, Parts A and B, of the study (Muth et al., 2005). It described marketing arrangements used in the livestock and meat industries and defined key terminology.[1] Results presented in the interim report were preliminary because they were based on assessments of the livestock and meat industries using published data, review of the relevant literature, and industry interviews.

This final report describes the results of quantitative analyses addressing Parts C, D, and E of the study as follows:

- Part C. Determine extent of use, analyze price differences, and analyze short-run market price effects of AMAs.

[1] A glossary of terms used in the study is included in a separate document.

The interim report released in August 2005 addressed the first two parts of the study. This final report focuses on the final three parts of the study (Parts C, D, and E).

- Part D. Measure and compare costs and benefits associated with spot and AMAs.
- Part E. Analyze the implications of AMAs for the livestock and meat marketing system.

The analyses presented in this volume address these final three parts of the study using information from industry interviews,[2] data from the industry surveys (described in Volume 2), transactions data and profit and loss statements from packers and processors, and a variety of publicly available data. Analyses conducted for the Livestock and Meat Marketing Study are limited to economic factors associated with spot and AMAs and do not analyze policy options or make policy recommendations.

1.1 OVERVIEW OF THE LAMB AND LAMB MEAT INDUSTRIES

In this section, we describe the stages of lamb production and location of operations as background information for analyses described in later sections of this volume.[3]

1.1.1 Stages of Lamb Production

The specific stages of slaughter lamb production include feeder lamb production, backgrounding, feeding, packing, and processing or breaking.[4] In some cases, all of these stages are distinct production stages. However, production, backgrounding, and feeding are often combined at the livestock production stage, and packing and breaking are often combined at the meat production stage.

This biological cycle results in the majority of lambing occurring in the spring.

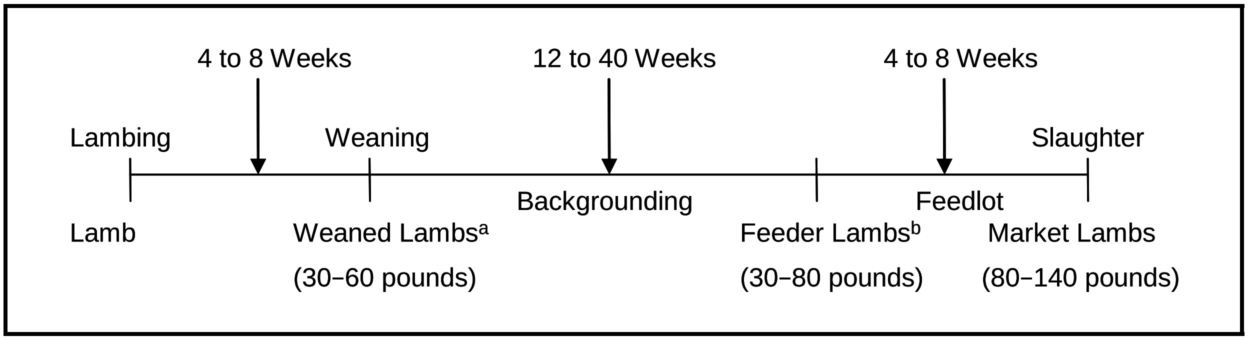
Most sheep can only be bred during specific times of the year. The breeding season tends to be induced by the shorter days of fall (Kott, 2004). This biological cycle results in the majority of lambs born in the spring. Newborn lambs will remain with ewes for 4 to 8 weeks before they are weaned (Figure 1-1). During the nursing period, lambs will gradually increase their intake of

[2] A description of the process for conducting the interviews and the complete findings from the interviews are provided in the interim report (Muth et al., 2005).

[3] A more complete overview of the lamb and lamb meat industries is provided in the interim report (Muth et al., 2005).

[4] Breaking refers to cutting carcasses into primal, subprimal, and other meat cuts. Although the term “breaking” has been used in the past for all meat species, it is now usually only used in the lamb industry.

Figure 1-1. Lamb Production Timeline
Lamb production time varies depending on the type of meat desired.



[a] Lambs sold for slaughter after weaning are referred to as milkfat lambs.
[b] Some feeder lambs are sold for slaughter after being backgrounded and are referred to as market lambs.

forages. After weaning, lambs can be sent directly to a feedlot, or they may be backgrounded. Lambs that go directly to feedlots are targeted to specific markets that desire young lambs. Backgrounding refers to providing lambs forages while they increase frame size and body mass. At this stage, lambs are referred to as feeder lambs. Feeder lambs are then placed in feedlots where they are fed a grain-based diet to bring them to slaughter weight and increase intramuscular marbling. Some lambs never enter a feedlot and are strictly grass fed; however, grain-fed lamb dominates U.S. production. The weight of finished market lambs varies, but the average liveweight is 135 pounds.

The production stages have remained relatively unchanged over time, but an increase in vertical integration within the industry has prompted several stages to be performed by a single entity or producer-owned cooperative.

Finished lambs are sent to a packer where they are slaughtered and the pelts and offal are separated from the fresh meat. Lamb carcasses are inspected by the U.S. Department of Agriculture/Food Safety Inspection Service (USDA/FSIS) or a state government inspection service. They are also usually quality graded by USDA/Agricultural Marketing Service (AMS).[5] Packers either sell carcasses to breakers or sell fabricated cuts. Breakers facilitate the distribution of lamb to consumers. Breakers exist in the industry because of geographical distances that separate packers from consumers and because of the relatively low volumes of lamb that are required by retail outlets. Increasingly, packers perform much of the initial breaking and boxing of cuts.

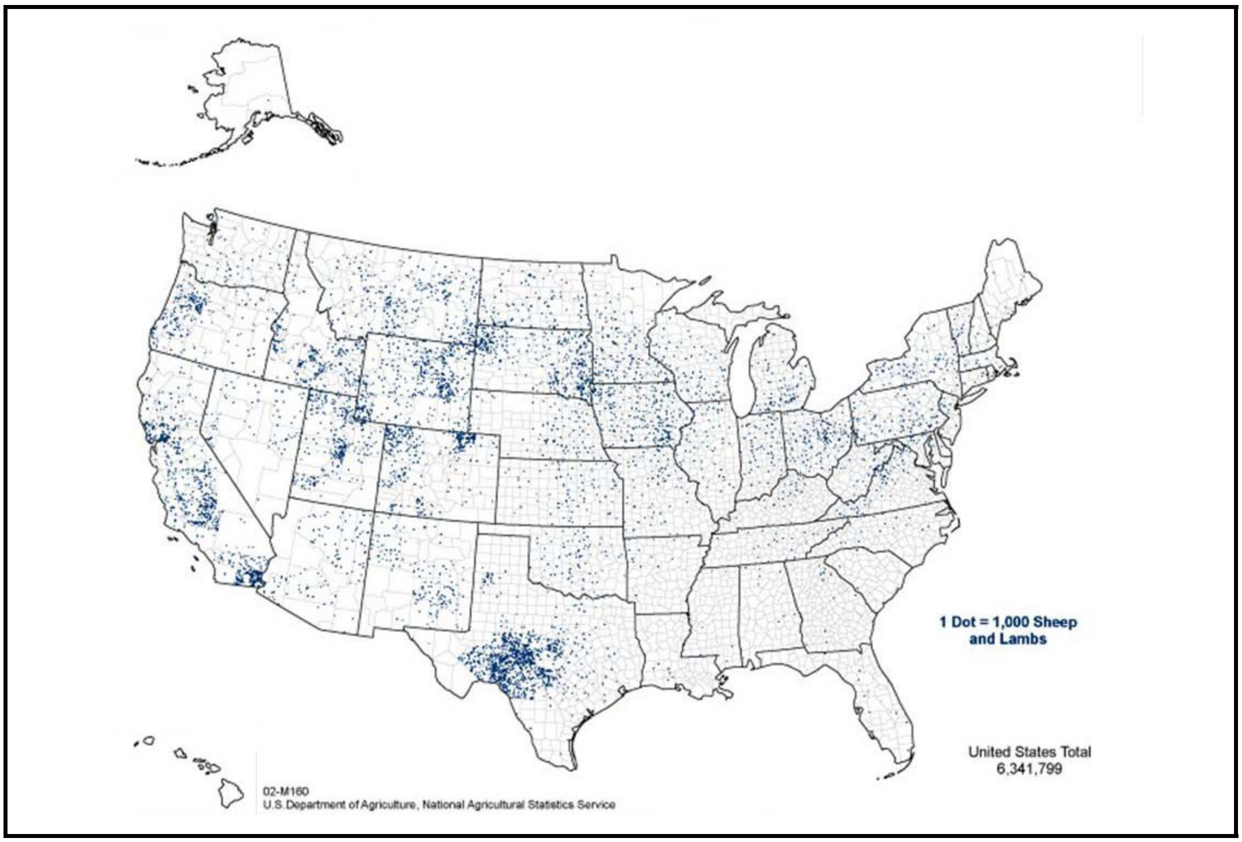
[5] The quality grades differ between lamb and beef, with lamb using Prime, Choice, Good, and Utility grades and beef using Prime, Choice, Select, and Standard (Other) grades.

The production stages have remained relatively unchanged over time, but an increase in vertical integration within the industry has prompted several stages to be performed by a single entity or producer-owned cooperative. Some producers not only sell feeder lambs to feedlots but also sell finished lambs to packers, carcasses to breakers, and meat products to retailers and food service providers.

1.1.2 Locations of Sheep and Lamb Operations

Lamb production occurs in all 50 states (Figure 1-2); however, flock sizes vary significantly by geographic location. Small flocks are located throughout the country, and many are part of diversified or hobby farms. Large flocks are typically located in the western part of the country, where large tracts of land are available for grazing. In 2002, 88% of sheep farms had fewer than 100 head, but these small farms represented only 22% of total sheep inventories.

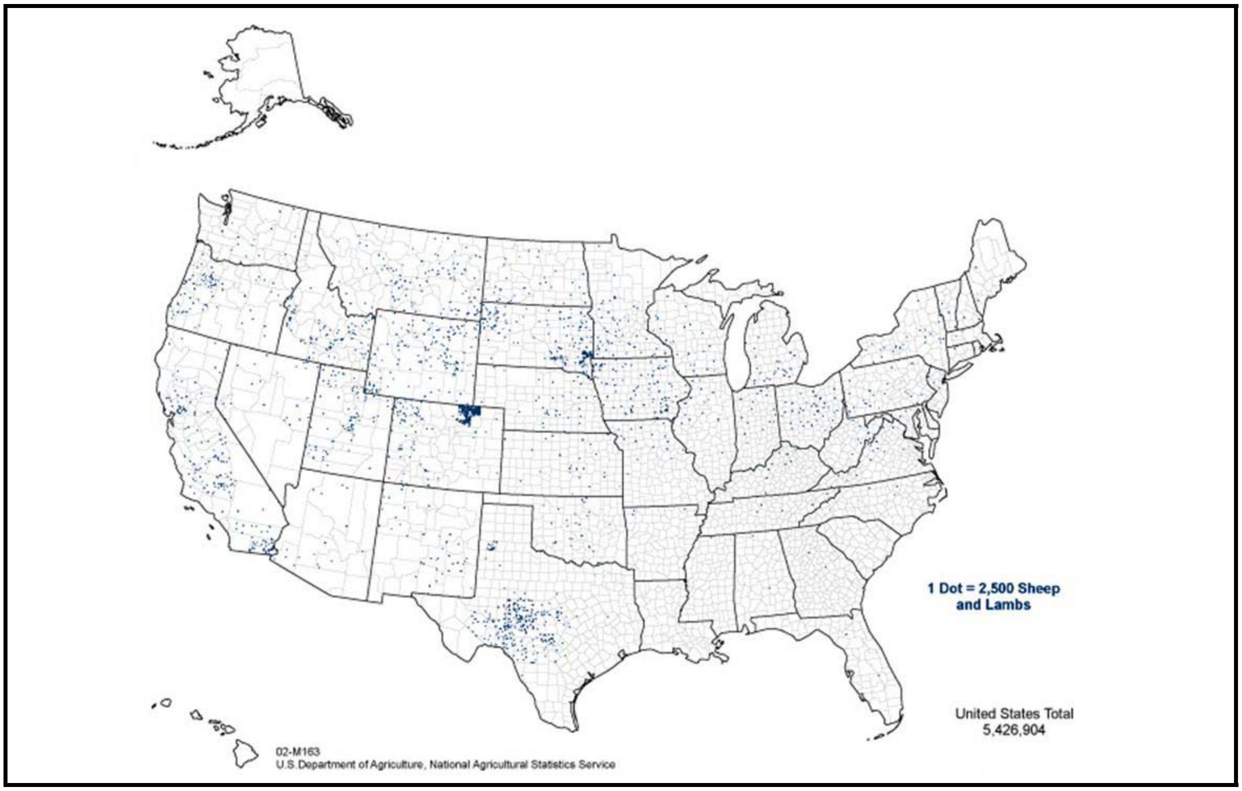
Figure 1-2. U.S. Inventory of Sheep and Lambs, 2002
Sheep are raised throughout the country.



Source: U.S. Department of Agriculture, National Agricultural Statistics Service. 2004b. "2002 Census of Agriculture." Washington, DC: USDA. <http://www.nass.usda.gov/research/atlas02/>.

The number of producers and sheep inventories has declined steadily in the United States since 1884, when there were 51 million sheep in the country (USDA/Economic Research Service [ERS], 2004c). In 2002, there were 6.68 million sheep (USDA/National Agricultural Statistics Service [NASS], 2002) raised on slightly more than 64,000 operations (USDA/NASS, 2003). Figure 1-3 shows that the largest concentration of lamb sales is in the Plains States where several large feedlots are located.

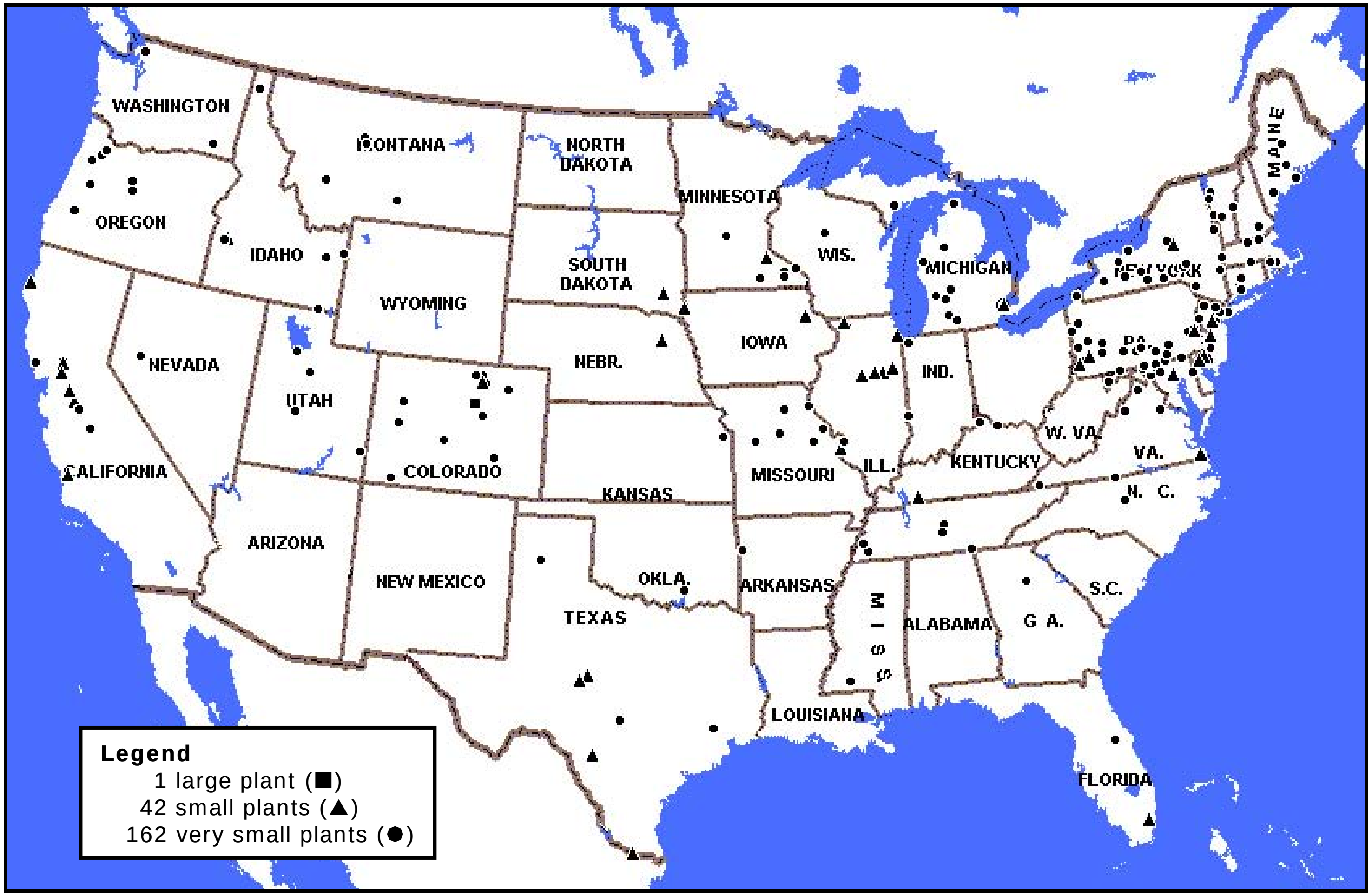
Figure 1-3. Number of Sheep and Lambs Sold, 2002
Few regions specialize in large-scale sheep or lamb production, but sales are concentrated in California, Texas, and Colorado.



Source: U.S. Department of Agriculture, National Agricultural Statistics Service. 2004b. “2002 Census of Agriculture.” Washington, DC: USDA. <http://www.nass.usda.gov/research/atlas02/>.

As with lamb producers, lamb packers are located throughout the country (Figure 1-4). However, most facilities are located strategically near lamb feeders, consumers, or both. The only large lamb packer (defined as a plant with 500 or more employees) is located close to large feedlots. Several small plants (defined as plants with 10 to 499 employees) and very small plants (defined as plants with fewer than 10 employees) are located in the Northeast, where consumption of lamb tends to be higher. Several plants are also located on the West coast.

Figure 1-4. Location of Federally Inspected Lamb Slaughter Plants[a]



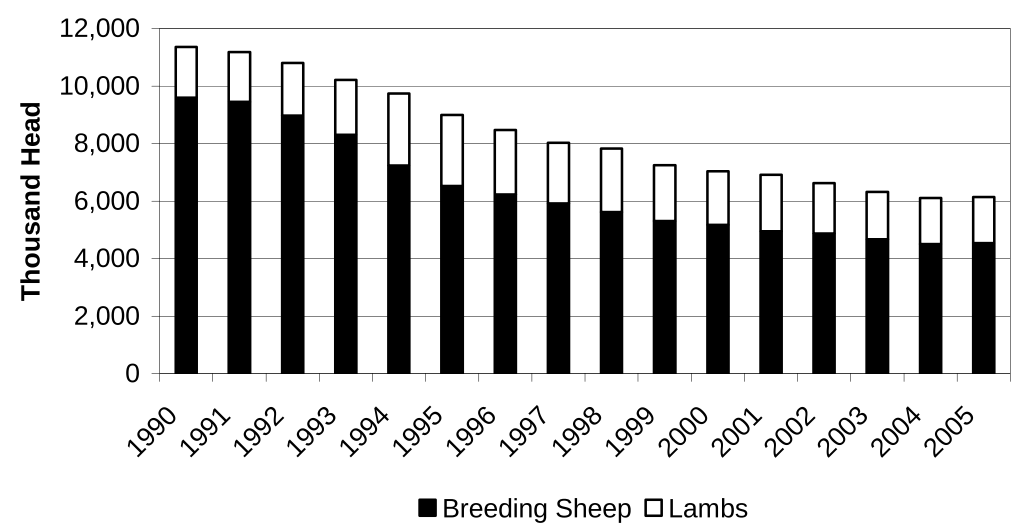
[a] Plants that slaughtered at least 50 head of lambs in FY2004 (October 1, 2003 through September 30, 2004) are included. Of 205 plants, 1 is classified by FSIS as large, with 500 or more employees; 42 are classified as small, with 10 to 499 employees; and 162 are classified as very small, with fewer than 10 employees or less than $2.5 million in annual sales. One plant in Hawaii is not shown.

Source: RTI International. 2005. Enhanced Facilities Database. Prepared for the U.S. Department of Agriculture, Food Safety and Inspection Service. Research Triangle Park, NC: RTI.

1.1.3 Trends in Sheep and Lamb Operations

Sheep inventories have continued to decline in recent years. Figure 1-5 presents total sheep inventories and the size of the breeding herd. Between 1990 and 2005, the total inventory of sheep declined 46%, breeding sheep declined 53%, and lamb inventories declined 9%. Lamb inventories are subject to several environmental conditions including drought and predators. However, the smaller decrease in progeny inventories indicates that breeding herd efficiency is increasing. Selective crossbreeding and intensive breeding programs have allowed producers to alter estrus cycles and attempt to increase the frequency of multiple births.

Figure 1-5. U.S. Inventory of Sheep and Lambs, December 1, 1990–2005
Sheep and lamb inventory categories include breeding sheep (ewes, rams, and new crop lambs) and lambs.



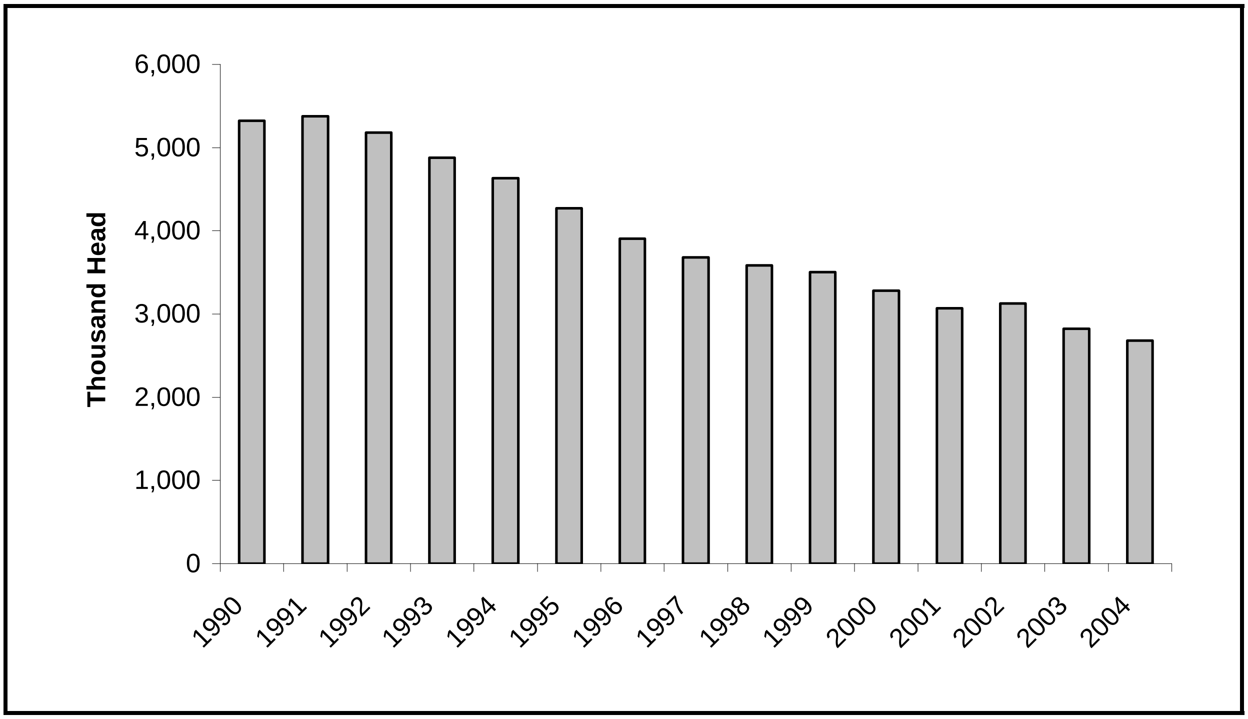
Sources: U.S. Department of Agriculture, National Agricultural Statistics Service. 2005. “Agricultural Statistics.” ISBN 0-16-036158-3. Washington, DC: USDA.

U.S. Department of Agriculture, National Agricultural Statistics Service. 1995-1996. “Agricultural Statistics.” ISBN 0-16-036158-3. Washington, DC: USDA.

The number of lambs slaughtered in the United States has declined dramatically over the past decade.

Federally inspected lamb slaughter volumes have decreased more rapidly than total commercial slaughter. The number of lambs slaughtered commercially decreased by 50% from 1990 to 2004 (Figure 1-6). During the same period, the percentage of lambs slaughtered at federally inspected facilities decreased from 97% in 1990 to 94% in 2002.

Figure 1-6. U.S. Commercial Lamb and Yearling Slaughter, 1990–2004
Commercial lamb and yearling slaughter includes animals slaughtered at federally inspected and nonfederally inspected plants but does not include animals slaughtered on the farm.

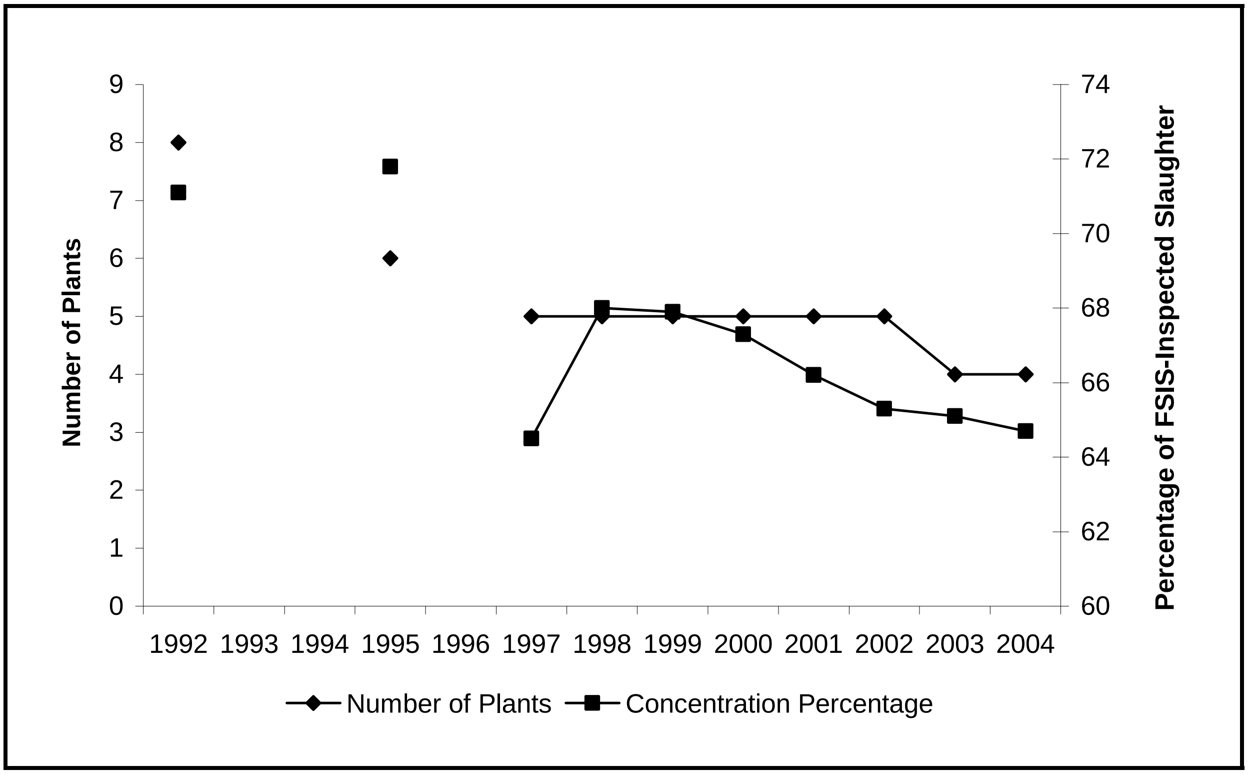


Source: U.S. Department of Agriculture, Economic Research Service, Market & Trade Economics Division. 2006. *Red Meat Yearbook*. Stock #94006. Washington, DC: USDA. <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354>.

The amount of meat produced per animal slaughtered has steadily increased. Between 1990 and 2003, the average liveweight of federally inspected slaughter lambs and sheep increased from 126 pounds to 135 pounds. During the same period, average lamb carcass weights increased from 64 to 68 pounds. About 70% of the carcass weight is saleable cuts, with fat and bones making up 30% (Boland, Bosse, and Brester, 2005).

Unlike lamb production, the lamb-packing phase is highly concentrated. From 1992 to 2004, the four largest slaughtering companies processed, on average, 67% of all U.S. lambs under federal inspection (Figure 1-7). The total number of plants operated by these companies decreased by 50% since 1992. During fiscal year 2002, 220 federally inspected plants slaughtered 50 or more lambs.

Figure 1-7. U.S. Sheep and Lamb Packer Four-Firm Concentration Ratio (CR4), Selected Years, 1992–2004
The CR4s show the percentage of all sheep and lambs slaughtered at plants owned by the four largest firms during the respective year. The total number of plants operated by those firms is also included. Percentages are based on total federally inspected slaughter numbers.



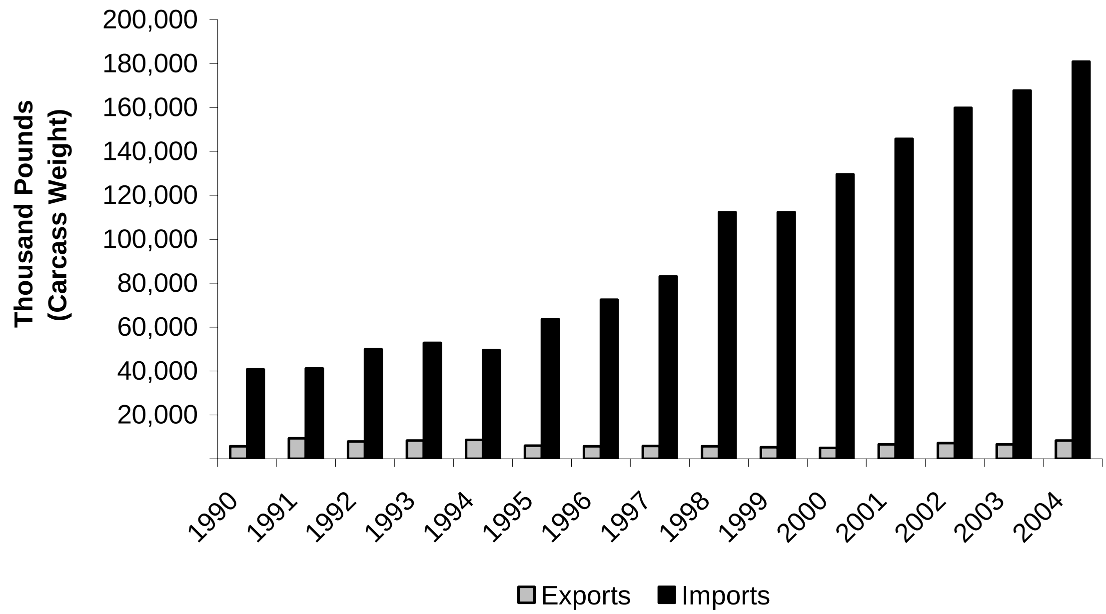
Source: U.S. Department of Agriculture, Grain Inspection, Packers and Stockyards Administration. 2006. *Packers and Stockyards Statistical Report*. SR-06-1. Washington, DC: GIPSA.

1.1.4 Imports and Exports of Lamb Meat

A substantial portion of the lamb consumed in the United States is imported.

The large decreases in U.S. production have been partially offset by increased imports of lamb meat (Figure 1-8). In 2003, lamb imports were approximately 46% of U.S. lamb consumption, and lamb exports were approximately 3% of U.S. lamb production (USDA/ERS, 2004b). Australia and New Zealand supply the majority of imported lamb to the United States. These countries account for 40% of U.S. consumption (Jones, 2004b). Traditionally, lamb exports have not been a large outlet for U.S. lamb production. Exports typically consist of mutton or lower-valued cuts that are not desired by domestic consumers. In 2002, more than 75% of U.S. lamb and mutton exports went to Mexico. Japan is the other main importer of U.S. lamb and purchased 7.2% of U.S. exports in 2002 (Jones, 2004b).

Figure 1-8. Total U.S. Lamb and Mutton Imports and Exports, 1990–2004
The United States is a net importer of lamb and mutton. Australia and New Zealand are the primary sources of imported lamb and mutton.



Source: U.S. Department of Agriculture, Economic Research Service, Market & Trade Economics Division. 2006. *Red Meat Yearbook*. Stock #94006. Washington, DC: USDA. <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354>.

Very few live sheep are imported or exported by the United States. Most of the existing trade occurs within North America, and the United States has generally been a net exporter of live animals. Live exports are usually culled breeding stock shipped to Mexico.

1.2 OVERVIEW OF MARKETING ARRANGEMENTS IN THE LAMB AND LAMB MEAT INDUSTRIES

In this report, cash or spot market transactions refer to transactions that occur immediately or "on the spot." These include auction barn sales; video or electronic auction sales; sales through order buyers, dealers, and brokers; and direct trades. The terms "cash market" and "spot market" are used interchangeably. "Alternative marketing arrangements" refer to all possible alternatives to the cash or spot market. In the lamb industry, these include arrangements such as forward contracts, marketing agreements, procurement or marketing contracts, packer owned, custom feeding, and custom slaughter. For AMAs at the producer level, livestock may be owned by the individual(s) that owns the farm or facility, or they may be owned by a different party.

Figure 1-9 illustrates the types of marketing arrangements used for sale of feeder lambs by producers to feedlots and for sale of fed lambs by producers or feedlots to lamb packers. The key dimensions of marketing arrangements at each stage include the **ownership method** for the animal or product while it is at the establishment (e.g., sole ownership, shared ownership, or owned by another entity) and the **pricing method** used. If formula pricing is used, a **formula base price** must also be specified. The **valuation method** for carcasses might be on a per-head basis or liveweight or carcass weight basis. Carcass weight valuation might be based on a grid that offers premiums or discounts based on weight range and carcass quality grade. If animals or products are shipped from one establishment to another owned by the same company, an **internal transfer pricing method** must also be specified.

Figure 1-10 illustrates the types of marketing arrangements used for sales or transfers of all types of meat products (including lamb) by packers. In addition to ownership method, pricing method, formula base, valuation method, and internal transfer pricing methods, **other pricing practices** might also be a key dimension of marketing arrangements for packer sales. Other pricing practices used for meat products might include two-part pricing, volume discounts, exclusive dealings, and bundling.

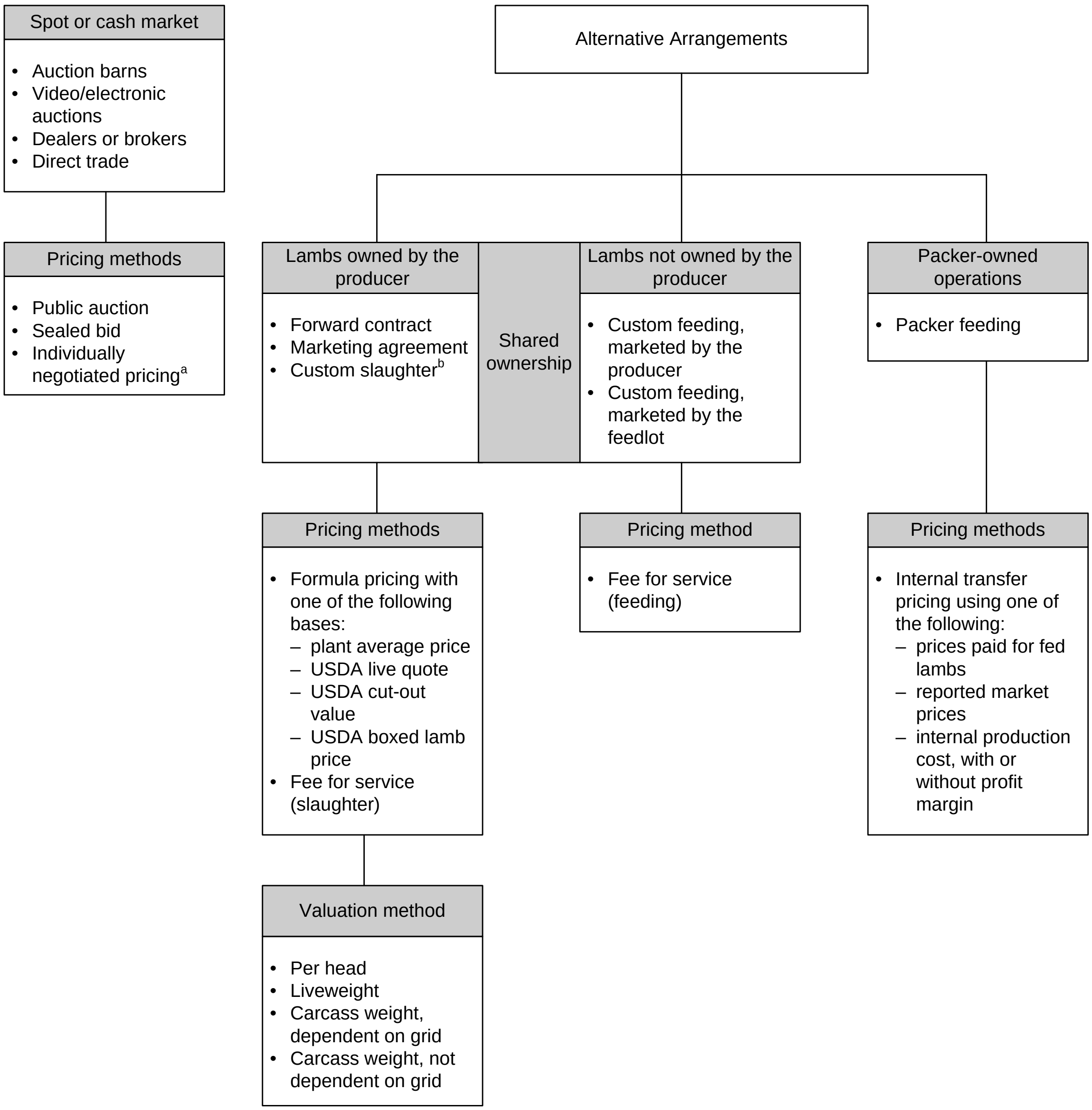
Whether lamb packers sell carcasses, cuts, or processed products, the types of sales transactions they use are similar. They generally have informal relationships with their buyers in which they anticipate some level of weekly orders. In some cases, they may have established marketing agreements with breakers or with distributors that purchase product for retail grocery and food service sales.

1.3 DATA ISSUES FOR THE EMPIRICAL ANALYSES OF THE LAMB INDUSTRY

The statistical analyses presented in this volume have intensive data requirements. It was anticipated that transactions data obtained from lamb packers and processors would be the primary source of data for evaluating the impact of AMAs on

Figure 1-9. Marketing Arrangements for Sale or Transfer of Feeder and Fed Lambs, by Lamb Producers

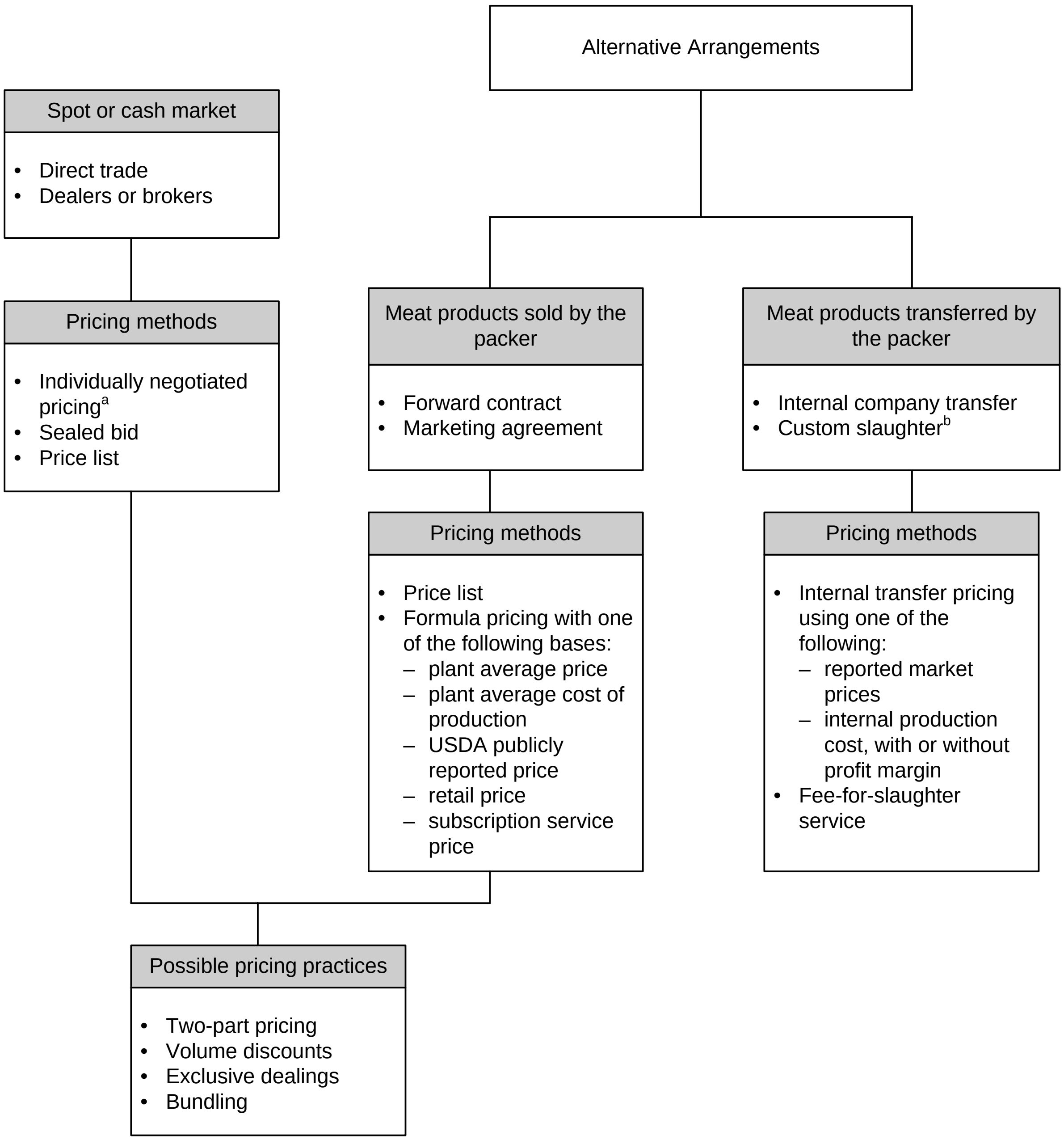
Different types of pricing methods are associated with each type of marketing arrangement used in the industry.



[a] Individually negotiated pricing is often benchmarked against reported prices.

[b] Custom slaughter may be coordinated by a cooperative that schedules slaughter of lambs for its producer-members.

Figure 1-10. Marketing Arrangements for Sale or Transfer of Meat Products from Packers
Meat products are sold or transferred to breakers, processors, wholesalers, exporters, food service operators, or grocery retailers.



[a] Individually negotiated pricing is often benchmarked against reported prices.

[b] Custom slaughter may be coordinated by a cooperative for its producer-members.

the lamb industry. However, little electronic transactions data were received from lamb packing plants that perform slaughtering and processing functions. Some data from a few packing plants were reported for the October 2002 to March 2005 period.

Because the transactions data received from lamb packers were very limited and had many deficiencies, the analyses presented in this volume are based primarily on other data sources.

In general, the transactions data contained information on total weight, total costs, gross prices, and net prices for live lambs, lamb carcasses, boxed (cut-out) lamb, wholesale lamb cuts, and lamb by-products. Each plant used different product description codes for wholesale lamb cuts, which reduced our ability to formulate homogeneous product categories among the plants. Furthermore, the data did not provide information regarding pricing, purchasing, and sales methods. No information was provided regarding the quality of live lamb purchases or product sales.

Because of these data problems, all of the statistical and econometric analyses presented in this volume use mandatory price reporting (MPR) data. Although the time periods differed for some of the variables, the longest consistent period for which at least some of the data were reported was October 2001 through May 2005. The MPR data were supplemented with data provided by the American Sheep Industry Association (ASIA) (2003–2004) and Tom McDonnell, ASIA Director of Natural Resources and Policy (McDonnell, 2005–2006).

1.4 DESCRIPTION OF THE LAMB TRANSACTIONS DATA

Some electronic transactions data were available for partial comparisons with MPR data. Four different data sets obtained from a few plants contained some observations on the following types of transactions: packer lamb purchases, packer product sales, breaker product purchases, and breaker product sales. The obtained data are described below.

- The fed lamb purchase data from packing plants included weekly information on total live weight, total carcass weight, and total lamb costs. Weekly data were aggregated into monthly data. These data allowed for the calculation of per-unit live and carcass prices. No data were reported on the quality of either live lamb or lamb carcasses.

- The sales data from packing plants included information on weekly total weight and gross prices of lamb carcasses, lamb cuts (loin, rib, shoulder, breast, leg, and chops), and lamb by-products (head, liver, intestines, kidney).
- The carcass purchase data from lamb breakers included information on total weight and total costs of carcasses, primals, subprimals, wholesale cuts, and by-products (loin, rack, and liver) purchases.
- The sales data from lamb breakers included weekly total weight and gross (list) prices for lamb product sales. No information, however, was provided in terms of sales method or on disaggregated lamb cuts.

Weekly data for lamb packers and breakers were aggregated to monthly data, and per-unit prices were calculated from the total weight and gross lamb price data for conducting comparisons of the data discussed in Section 1.5.

1.5 COMPARISON OF LAMB MPR DATA TO TRANSACTIONS DATA

We compared the limited transactions data received with MPR data and found that price and weight variables were closely related.

Although the transactions data could not be used for statistical analyses, it is informative to compare these data with relevant MPR data where possible. If the limited amount of transactions data compare favorably with the MPR data, then inferences obtained from statistical analyses of the MPR data should be similar to those obtained from a comprehensive set of transactions data.

Enough usable observations from the transactions data regarding fed lamb, lamb carcasses, boxed lamb values, and weights were available to compare with corresponding MPR observations. Wholesale lamb cut prices for legs, shoulders, and breasts could also be compared with corresponding MPR data. We describe these comparisons below.

1.5.1 Comparison of Live Lamb Prices

Live monthly nominal lamb prices were obtained from MPR data. Weekly live nominal lamb prices from lamb packing plants were averaged and aggregated on a monthly basis for comparison to the MPR data. Plotting both prices for the October 2002 through March 2005 period shows that the transactions data on live lamb prices were consistently larger than the MPR live lamb prices.[6] A two-sample test of the differences in the means of the two price series rejects the null hypothesis of no differences in the means at the α = 0.5 level. In addition, the F-test of the null hypothesis of no differences in the variances of the two price series is also rejected at the $\alpha = 0.05$ level. The result that the means and variances of the two price series are statistically different could reflect differences in weight and/or quality of lamb purchases by these plants relative to the industry as a whole.

Although the variances of the two prices series are statistically different, the correlation coefficient (0.924) between the MPR and transactions fed lamb prices indicates that the two price series are highly correlated. In addition, an ordinary least squares (OLS) regression of MPR lamb prices onto transactions lamb prices resulted in an estimated parameter coefficient close to one. This indicates that a $1/cwt increase in lamb prices in the transactions data is associated with a similar increase in the MPR lamb prices.

1.5.2 Comparison of Carcass Lamb Prices

The relationship between nominal monthly transactions lamb carcass prices and MPR carcass prices is relatively strong. Weekly carcass prices from lamb packing plants were averaged and aggregated on a monthly basis for comparison with the MPR data. Plotting the two price series for the October 2002 through March 2005 period shows that the two prices series are nearly identical.[7] A two-sample t-test of the differences in the means of the two prices series cannot reject the null hypothesis of no differences in the means at the $\alpha = 0.05$ level. Similarly, an F-test of the null hypothesis of no differences in the variances of the two price series cannot be rejected at the $\alpha = 0.05$ level.

The correlation coefficient (0.947) between the MPR and transactions carcass prices indicates that the two price series are highly correlated. In addition, an OLS regression of MPR carcass prices onto transactions carcass prices resulted in an estimated parameter coefficient close to one. This indicates that a $1/cwt increase in carcass prices in the transactions data is associated with a similar increase in the MPR lamb carcass prices. In addition, the estimated coefficient is not statistically

[6] To protect confidentiality, the graph is not included in this report.
[7] To protect confidentiality, the graph is not included in this report.

different from 1.0, which indicates that the carcass price transactions data are a good predictor of MPR carcass prices.

1.5.3 Comparison of Cut-Out and Wholesale Cut Lamb Prices

The transactions cut-out price data contained a significant number of missing observations that made comparison with the MPR wholesale cut lamb prices tenuous. Because of these problems, the only possible comparison involves estimating correlation coefficients for boxed cut-out values, shoulder cuts, breast cuts, and leg cuts. These correlation coefficients range from 0.375 to 0.641. Thus, the price relationship between the transactions cut-out price data and MPR wholesale cut price data is relatively weak.

1.5.4 Summary of Comparisons

The statistical analyses conducted for this study require the use of data that are consistently reported. The transactions data that were obtained from packing plants suffered from numerous deficiencies. However, the price and weight data for fed lambs and carcasses were closely related to similar variables obtained from MPR data. Given that a consistent series of MPR data were available and that most of the statistical analyses involve the fed lamb and wholesale lamb markets, MPR data were used throughout the remainder of this study.

1.6 ORGANIZATION OF THE LAMB AND LAMB MEAT STUDY VOLUME

In the remaining sections of this volume, we present results of the study for the lamb and lamb meat industries. Section 2 provides results on volume differences, price differences, and market price effects associated with AMAs. Section 3 provides results on procurement cost differences associated with AMAs. Section 4 provides results on quality differences, and Section 5 provides results on risk shifting associated with AMAs. Section 6 provides results on the measurement of economic effects associated with restricting AMAs by simulating hypothetical scenarios. Finally, Section 7 describes the implications of AMAs, including the incentives associated with changing the use of AMAs and the expected effects of possible changes in use of AMAs over time.

Note that each section of this volume addresses the requirements of the study as defined in the performance work statement for the contract. Section 2 addresses Part C; Sections 3, 4, and 5 address Part D; and Sections 6 and 7 address Part E. In addition to these sections, Appendix A provides additional technical details on the modeling approach presented in Section 6.

2 Volume Differences, Price Differences, and Short-Run Spot Market Price Effects Associated with Alternative Marketing Arrangements

This section uses survey responses and MPR data to describe the extent of use of AMAs. MPR legislation required market participants to report price, volume, and terms of trade for domestic and foreign live animal and meat transactions. Monthly MPR data are available for the lamb industry from August 2001 to June 2005. We consider differences between formula and cash prices in the live lamb market and estimated an econometric model to determine if systematic factors account for differences among these prices. We also considered the stability of parameter estimates over time. Formula prices refer to prices reported for live lambs procured through both formula and forward contract pricing arrangements as reported in MPR data. Cash prices refer to prices reported for live lambs that are procured through both negotiations and auction markets.

2.1 EXTENT OF USE OF ALTERNATIVE MARKETING ARRANGEMENTS

To examine the number of lambs traded under different AMAs, we compared responses from the lamb producer survey on sales of fed lambs to MPR data. However, in making these comparisons, differences in terminology and definitions occurred.

Purchase and sales information collected for this study (i.e., survey and transaction data collection) contained three categories that allow for the marketing arrangement to be clearly defined. These categories are purchase method, pricing method, and valuation method. The purchase method classifies the marketing arrangement as either a cash or alternative marketing arrangement. Examples of cash marketing arrangements include auctions and direct trade. Marketing agreements and forward contracts are examples of AMAs. The pricing method provides additional information about transactions by specifying how the price was determined (e.g., individual negotiations and formula pricing). The valuation method further defines the transaction type by indicating how the price was applied (e.g., per head, per pound liveweight, or per pound carcass weight) and whether the price was subject to premiums or discounts.

The structure of MPR for the lamb industry uses some of the same terminology and collects some of the same data as the survey and transaction data collection. However, MPR data commingles purchase method and pricing methods to define marketing arrangements. For example, based on MPR definitions, “formula marketing arrangement means the advance commitment of lambs for slaughter by any means other than through a negotiated purchase or a forward contract, using a method for calculating price in which the price is determined at a future date,” and “forward contact means an agreement for the purchase of lambs, executed in advance of slaughter, under which the base price is established by reference to publicly available prices” (USDA/AMS, 2000, p. 75519). Including pricing methods within the definition of the purchase method decreases the clarity of the data and makes direct comparisons with the survey results difficult.

2.1.1 Survey Responses

As discussed in Volume 2 of this report, 302 lamb producers responded to the industry survey (267 small and 35 large). From the weighted industry survey results, lamb producer sales arrangements to packers were as follows:

- **Sales methods to packers.** An estimated 80% of producers in Eastern states used only the cash or spot market to sell lambs in the past year, compared with 76% of producers in Western states.[1] Western producers made more use of AMAs such as forward contracts, marketing agreements, packer ownership, internal transfers, and custom feeding and slaughtering (19% of head sold for Western producers and 11% for Eastern producers). For Western producers, the AMAs used most frequently were forward contracts (5.3% of head) and marketing agreements (3.9% of head).
- **Pricing methods.** Western producers used multiple pricing methods in the past year. The most common were individually negotiated pricing (54.6%), public auction (47.1%), and formula pricing (10.3%). In contrast, Eastern producers used primarily public auction (71.8%) and individually negotiated pricing (46.4%). An additional 6.2% of Eastern producers used formula pricing.
- **Valuation methods.** The most frequently used valuation method was liveweight, regardless of regional location. However, Western producers used carcass weight valuation (with and without a grid) more frequently than Eastern producers (32% and 11.3% of producers, respectively). Nearly twice as many Eastern producers (31.2%) used per-head valuation compared with Western producers (16.9%) in the past year.

The volumes of purchases by type of marketing arrangement from the survey responses differ somewhat from the MPR data discussed below. This difference is likely because MPR data are only collected from plants that slaughter or process at least 75,000 head annually, while the survey responses are from a range of sizes of lamb producers selling to packers. The largest packers are more likely to use AMAs.

[1] The following states were classified as Western states: Alaska, Arkansas, Arizona, California, Colorado, Hawaii, Idaho, Kansas, Louisiana, Minnesota, Missouri, Montana, North Dakota, Nebraska, New Mexico, Nevada, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming. All other states were classified as Eastern states.

2.1.2 Mandatory Price Reporting

Table 2-1 presents monthly numbers of federally inspected fed lamb slaughtered in the United States and the number of head procured by various marketing arrangements. The procurement methods consist of packer ownership, formula pricing, forward contracts, negotiated sales, imports, and auctions as follows:

- **Packer-owned lambs** may be owned and finished by a packing firm or owned by a packing firm and custom finished by another entity. In both cases, lambs in this category are internally priced by packing firms.
- **Formula-priced lambs** are those procured by packing firms in which final lamb prices are determined by a combination of a fixed (base) price with adjustments made on a prespecified formula. The most common adjustments are those associated with varying quality. However, formula (base) prices are often based on nearby spot prices.
- **Forward contracting** fed lambs for slaughter includes both formal and informal agreements between a lamb producer and a packer. Contracts often establish terms of transactions with respect to both quantity and price. In general, these arrangements tend to be of a shorter duration than formula-pricing arrangements, and they tend to establish a price in advance of lamb delivery.
- **Negotiated lamb sales** represent private treaty arrangements between lamb producers and packing firms. These direct purchases are often based on spot market prices established by formal auctions.
- **Auction sales** represent fed lambs procured at formal auction locations in which prices are discovered through open bidding by packing firms or their representatives.

A small number of lambs have occasionally been imported from Canada and Mexico. However, we do not know the methods used to procure these lambs.

Table 2-1 summarizes the volume of lambs slaughtered and the relative importance of each procurement method based on MPR data. Monthly, federally inspected lamb slaughter averaged 235,399 head during the 2001 to 2005 period. Note that the MPR data used to create Table 2-1 do not report the size or location of market participants.

Table 2-1. Monthly Federally Inspected Lamb Slaughter and Lamb Procurement by Method as Reported under MPR, August 2001–June 2005, Head

Year	Month	Federally Inspected Slaughter	Packer Owned	Formula	Contract	Negotiated	Imports	Auction
2001	August	216,728	16,575	82,675	1,335	3,300	0	112,843
2001	September	290,234	17,355	153,032	1,656	23,500	2,727	91,964
2001	October	237,658	10,080	131,783	2,538	25,100	2,311	65,846
2001	November	248,416	5,520	137,188	2,518	34,100	3,297	65,793
2001	December	317,120	8,382	192,573	2,235	31,600	0	82,330
2002	January	209,709	7,881	111,196	0	27,600	0	63,032
2002	February	171,400	9,360	124,666	7,762	28,700	677	235
2002	March	297,723	24,319	162,531	11,897	28,900	4,950	65,126
2002	April	299,334	17,957	161,376	5,592	25,900	5,446	83,063
2002	May	244,013	13,047	102,700	2,879	19,800	4,424	101,163
2002	June	211,275	5,444	104,731	4,894	18,700	7,513	69,993
2002	July	259,447	2,881	107,690	7,693	40,600	1,881	98,702
2002	August	219,915	3,409	92,344	12,235	24,800	811	86,316
2002	September	308,518	12,708	126,200	6,968	32,000	1,130	129,512
2002	October	245,562	10,813	107,656	3,649	28,900	3,591	90,953
2002	November	248,350	8,629	96,802	4,581	26,200	5,025	107,113
2002	December	297,567	10,049	116,884	2,300	38,900	7,665	121,769
2003	January	201,513	6,820	74,582	321	35,700	6,879	77,211
2003	February	202,915	2,104	70,510	798	50,200	7,770	71,533
2003	March	291,227	6,786	103,972	0	55,100	6,510	118,859
2003	April	264,112	8,777	97,153	1,436	30,300	5,842	120,604
2003	May	191,948	3,895	64,785	0	23,100	4,126	96,042
2003	June	253,884	8,329	83,362	1,717	55,000	679	104,797
2003	July	191,886	7,229	65,413	0	35,000	0	84,244
2003	August	213,624	7,312	78,789	0	30,100	0	97,423
2003	September	273,311	12,972	110,668	0	36,000	0	113,671
2003	October	216,708	11,887	90,258	0	20,300	0	94,263
2003	November	231,500	11,769	93,782	2,800	21,200	0	101,949
2003	December	262,701	13,704	103,219	2,538	27,100	0	116,140

(continued)

Table 2-1. Monthly Federally Inspected Lamb Slaughter and Lamb Procurement by Method as Reported under MPR, August 2001–June 2005, Head (continued)

Year	Month	Federally Inspected Slaughter	Packer Owned	Formula	Contract	Negotiated	Imports	Auction
2004	January	188,400	10,052	74,278	5,497	20,600	0	77,973
2004	February	196,837	8,248	75,252	4,380	15,200	0	93,757
2004	March	303,337	21,491	127,749	0	28,100	0	125,997
2004	April	235,379	20,077	82,158	267	22,800	0	110,077
2004	May	220,418	22,905	72,355	0	21,100	0	104,058
2004	June	188,835	8,667	64,109	0	24,900	0	91,159
2004	July	186,680	7,171	65,231	0	30,900	0	83,378
2004	August	250,673	9,675	101,730	0	35,400	0	103,868
2004	September	206,855	14,376	83,672	0	24,850	0	83,957
2004	October	215,484	13,357	84,389	0	21,000	0	96,738
2004	November	262,977	20,242	104,495	0	13,300	0	124,940
2004	December	204,184	16,498	89,116	0	18,700	0	79,870
2005	January	224,433	14,607	100,201	0	25,400	0	84,225
2005	February	204,981	7,019	94,005	0	24,500	0	79,457
2005	March	241,562	11,022	108,199	0	26,900	0	95,441
2005	April	189,425	14,722	83,613	0	17,500	0	73,590
2005	May	242,057	28,222	80,712	0	28,100	0	105,023
2005	June	182,918	16,652	69,321	0	23,300	0	73,645
	Average	235,399	11,723	100,194	2,138	27,665	1,771	91,907

Note: MPR data are based on AMA procurement volumes, which must sum to federally inspected slaughter totals. MPR federally inspected slaughter data do not necessarily equal total federally inspected slaughter volumes because only the largest firms are required to provide MPR data.

Table 2-2 presents the percentage of monthly federally inspected lamb slaughter by procurement method based on MPR data. Lamb packers procure fed lambs primarily through formula pricing arrangements (42.2%) and auctions (39.4%).

These two methods account for 81.6% of lamb procurement during the sample period. Negotiated sales account for about 12% of lamb procurement, and packer ownership averaged 4.9%. Forward contracting and live lamb imports were quite minor; together they account for only 1.5% of lamb procurement. Since March 2004, almost no lambs were procured using either of these two methods.

Table 2-2. Monthly Percentages of Lamb Procurement by Marketing Method as Reported under MPR, August 2001–June 2005, Percent

Year	Month	Packer Owned	Formula	Contract	Negotiated	Imports	Auction	Total
2001	August	2.8	41.0	1.0	7.6	0.0	47.5	100.0
2001	September	6.8	52.4	0.0	7.8	1.2	31.8	100.0
2001	October	4.2	55.4	1.1	10.6	1.3	27.5	100.0
2001	November	2.7	57.1	0.9	12.6	1.1	25.6	100.0
2001	December	2.2	59.7	0.7	10.5	0.0	26.9	100.0
2002	January	3.7	53.2	0.0	13.2	0.0	29.9	100.0
2002	February	4.0	52.9	3.2	12.3	0.3	27.3	100.0
2002	March	7.9	53.2	3.9	9.7	1.7	23.5	100.0
2002	April	5.6	55.9	1.5	8.4	1.7	26.9	100.0
2002	May	5.5	54.7	1.2	8.3	2.1	28.2	100.0
2002	June	1.3	47.3	2.7	8.9	3.0	36.8	100.0
2002	July	1.3	40.1	3.1	17.3	0.6	37.7	100.0
2002	August	2.0	42.5	5.5	10.8	0.4	38.8	100.0
2002	September	4.2	39.9	1.5	10.7	0.3	43.4	100.0
2002	October	4.4	43.9	1.5	11.8	1.5	37.0	100.0
2002	November	3.4	39.3	1.7	11.7	2.2	41.7	100.0
2002	December	3.7	38.9	0.6	12.1	2.4	42.2	100.0
2003	January	3.3	36.4	0.2	20.0	3.5	36.6	100.0
2003	February	0.7	36.3	0.3	23.2	3.4	36.1	100.0
2003	March	2.6	34.8	0.0	17.8	2.2	42.6	100.0
2003	April	3.3	36.6	0.6	11.4	2.2	45.8	100.0
2003	May	1.9	32.4	0.0	13.2	2.0	50.4	100.0
2003	June	3.8	34.2	0.8	22.6	0.0	38.7	100.0
2003	July	3.8	34.1	0.0	18.1	0.0	43.9	100.0
2003	August	3.5	36.9	0.0	14.4	0.0	45.2	100.0
2003	September	5.0	41.4	0.0	12.5	0.0	41.1	100.0
2003	October	5.6	40.9	0.2	9.1	0.0	44.2	100.0
2003	November	4.8	41.8	0.9	9.9	0.0	42.5	100.0
2003	December	5.3	38.2	1.3	10.2	0.0	45.0	100.0

(continued)

Table 2-2. Monthly Percentages of Lamb Procurement by Marketing Method as Reported under MPR, August 2001–June 2005, Percent (continued)

Year	Month	Packer Owned	Formula	Contract	Negotiated	Imports	Auction	Total
2004	January	5.3	39.3	2.7	10.6	0.0	42.0	100.0
2004	February	4.3	39.4	1.8	8.8	0.0	45.7	100.0
2004	March	7.4	41.6	0.0	8.6	0.0	42.4	100.0
2004	April	9.2	35.4	0.1	9.2	0.0	46.0	100.0
2004	May	10.5	31.8	0.0	10.1	0.0	47.6	100.0
2004	June	4.6	33.9	0.0	13.2	0.0	48.2	100.0
2004	July	3.9	35.6	0.0	16.0	0.0	44.5	100.0
2004	August	3.8	41.3	0.0	14.4	0.0	40.6	100.0
2004	September	6.9	40.5	0.0	11.9	0.0	40.7	100.0
2004	October	6.4	40.2	0.0	8.4	0.0	45.0	100.0
2004	November	7.8	38.6	0.0	5.8	0.0	47.8	100.0
2004	December	8.1	43.4	0.0	10.4	0.0	38.0	100.0
2005	January	6.7	44.7	0.0	11.5	0.0	37.2	100.0
2005	February	3.5	46.0	0.0	11.8	0.0	38.7	100.0
2005	March	4.7	44.8	0.0	11.1	0.0	39.4	100.0
2005	April	7.9	44.0	0.0	9.1	0.0	38.6	100.0
2005	May	11.8	33.4	0.0	11.7	0.0	43.1	100.0
2005	June	9.1	37.9	0.0	12.6	0.0	40.4	100.0
	Average	4.9	42.2	0.8	12.0	0.7	39.4	100.0

Formula and auction procurement methods demonstrate opposite trends over the sample period. The MPR data indicate that packers reduced their use of formula procurement and increased their use of auction procurement in an almost equivalent fashion. For example, formula-procured lambs declined about 0.28 of a percentage point each month, and auction-procured lambs increased about 0.29 of a percentage point each month during the MPR period. These changes were statistically significant based on simple regressions of procurement percentages onto a monthly time trend variable.

A similar regression using packer ownership percentages as the dependent variable revealed that packer ownership declined about 0.07 of a percentage point each month. However, there was not a statistically significant trend associated with negotiated sales.

There are at least three possible explanations for these opposite trends. First, a variety of market factors (e.g., consolidation, changing demands, logistical issues) may have caused this to occur. That is, the relative benefits versus costs of using AMAs may have been altered during the sample period by market forces. Second, packers may use proprietary information when designing contractual arrangements, and once this information became more transparent through additional reporting, packers may have lost their individual competitive advantages in lamb procurement through the use of AMAs. Hence, on the margin, they increased procurement through auctions and reduced procurement through formulas. Third, packers may have been manipulating prices through the use of AMAs, and the increased price transparency caused them to change their practices and return to using auctions.

Our research efforts are unable to distinguish among these possible alternatives. However, the survey data indicated that packers were not likely to radically alter their procurement methods in the future. Therefore, packers may have been adjusting their procurement methods toward an equilibrium during the sample period.

2.2 TESTS OF PRICE DIFFERENCES ASSOCIATED WITH ALTERNATIVE MARKETING ARRANGEMENTS

AMAs have evolved over time for a number of reasons. Whether these arrangements have caused systematic differences among prices is an empirical question. We conduct statistical tests for differences among the prices of two different market lamb categories: formula prices and cash prices (defined as prices reported for live lambs procured through both free-on-board [FOB] feedlot negotiations and auctions).[2] Each monthly price series is obtained from MPR data on a dollars/cwt liveweight basis and are deflated by the consumer price index (CPI) (1982 – 84 = 100). Because formula prices were not reported in the MPR data during 2001, a common sample period beginning in January 2002 and ending in June 2005 is used for

[2] Because of the limited amount of contracting, MPR contract price data were not available and could not be included in the analysis.

all tests. Table 2-3 presents the deflated data. Cursory observation of the data indicates that average real lamb prices for each series are similar. The variation in lamb prices (as indicated by standard deviations) also appears similar.

Figure 2-1 illustrates the relationship between the two price series. The prices have trended upward and are highly correlated. The estimated correlation coefficient between the formula and cash price series is 0.970.

Each price series was regressed onto a monthly time trend variable. The results indicate that real slaughter cash lamb prices increased an average of $0.433/cwt each month, and real formula prices increased an average of $0.435/cwt each month.

Unit root and cointegration tests were used to examine the time-series properties of the two price series. These tests are used to determine the stationarity of the data. If the data are found to be nonstationary and not cointegrated, then subsequent regression results could yield spurious results and incorrect inferences. The augmented Dickey-Fuller (ADF) unit root test failed to reject the null hypothesis of a unit root (or nonstationarity) at the $\alpha = 0.05$ level for both slaughter price series (Pindyck and Rubinfeld, 1998). The ADF tests indicated the price series were integrated of order one. The Trace Test statistic of the Johansen Cointegration Test indicated a cointegrated relationship among the two price series at the $\alpha = 0.05$ level (Greene, 2003).

Table 2-4 presents the results of sample t- and F-tests on the difference in mean values and variances of the two slaughter lamb price series. Two-sample t-tests of the null hypotheses of no difference in mean values could not be rejected at the $\alpha = 0.05$ level for the paired comparison. Similarly, an F-test and a Bartlett test both failed to reject the null hypothesis of no differences in the variances of the two price series at the $\alpha = 0.05$ level. Based on the results of these tests, the price series are not statistically different from each other. Data obtained from the American Sheep Industry Association indicate that slight differences exist in average live slaughter weights of fed lambs procured via formula methods (formulas and forward contracts) and cash methods (negotiations and auctions). These differences are illustrated in Figure 2-2. Live slaughter weights for lambs procured by formula pricing

Table 2-3. Monthly Real Prices of Fed Lamb by Procurement Method, January 2002–June 2005, Dollars/Cwt, Liveweight

Year	Month	Cash Procurement ($)	Formula Procurement ($)
2002	January	34.66	33.44
2002	February	36.28	35.61
2002	March	35.92	35.15
2002	April	34.03	34.51
2002	May	34.63	33.60
2002	June	41.67	41.63
2002	July	44.61	45.63
2002	August	42.34	42.99
2002	September	40.91	43.45
2002	October	43.35	44.73
2002	November	45.70	46.65
2002	December	47.38	47.56
2003	January	47.60	48.19
2003	February	49.69	48.84
2003	March	52.59	50.37
2003	April	51.70	51.65
2003	May	55.74	54.41
2003	June	54.08	55.13
2003	July	48.34	49.06
2003	August	46.09	46.86
2003	September	47.98	48.88
2003	October	48.70	48.92
2003	November	48.94	48.86
2003	December	48.06	48.84
2004	January	51.16	47.95
2004	February	53.94	51.68
2004	March	53.41	53.96
2004	April	51.92	50.34
2004	May	53.78	49.58
2004	June	54.40	54.12
2004	July	52.22	54.50
2004	August	48.91	51.64
2004	September	47.49	51.06
2004	October	46.06	48.81
2004	November	48.43	48.19
2004	December	50.97	50.84
2005	January	56.01	55.19
2005	February	57.58	57.08
2005	March	55.53	56.10
2005	April	54.77	53.45
2005	May	55.94	56.54
2005	June	59.78	58.32
Average		48.41	48.44
Standard Deviation		6.60	6.46
Maximum		59.78	58.32
Minimum		34.03	33.44

Figure 2-1. Real Formula and Cash Fed Lamb Prices, January 2002–June 2005

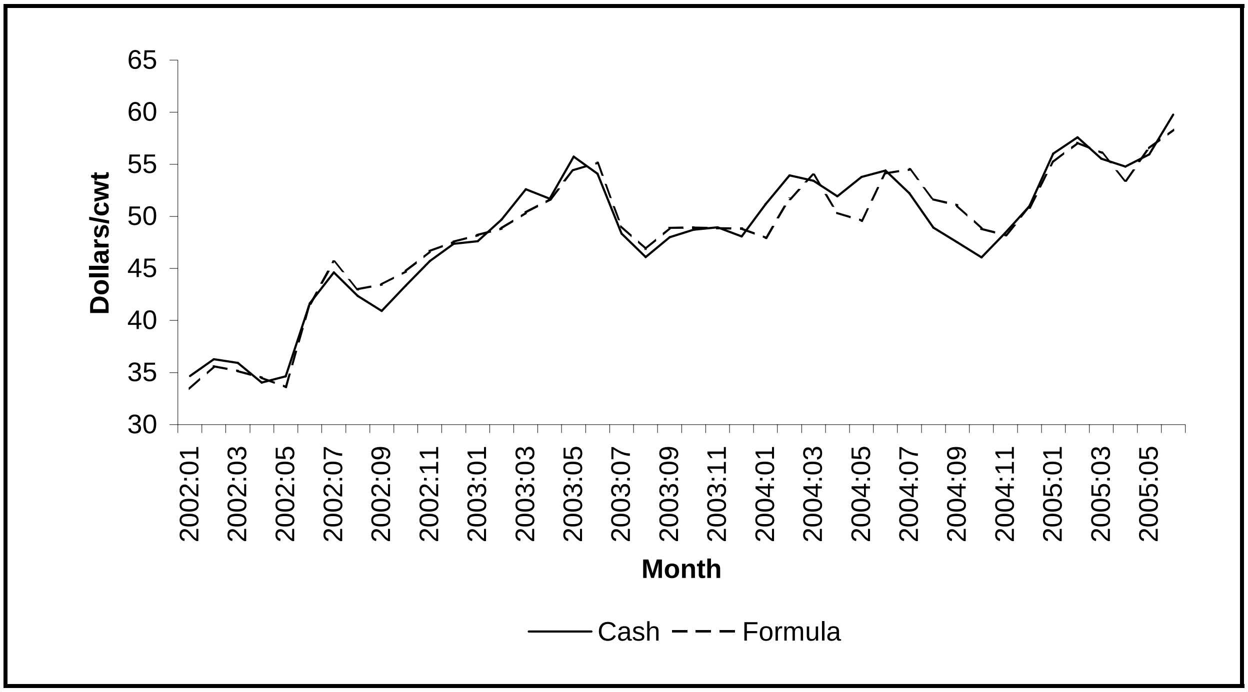
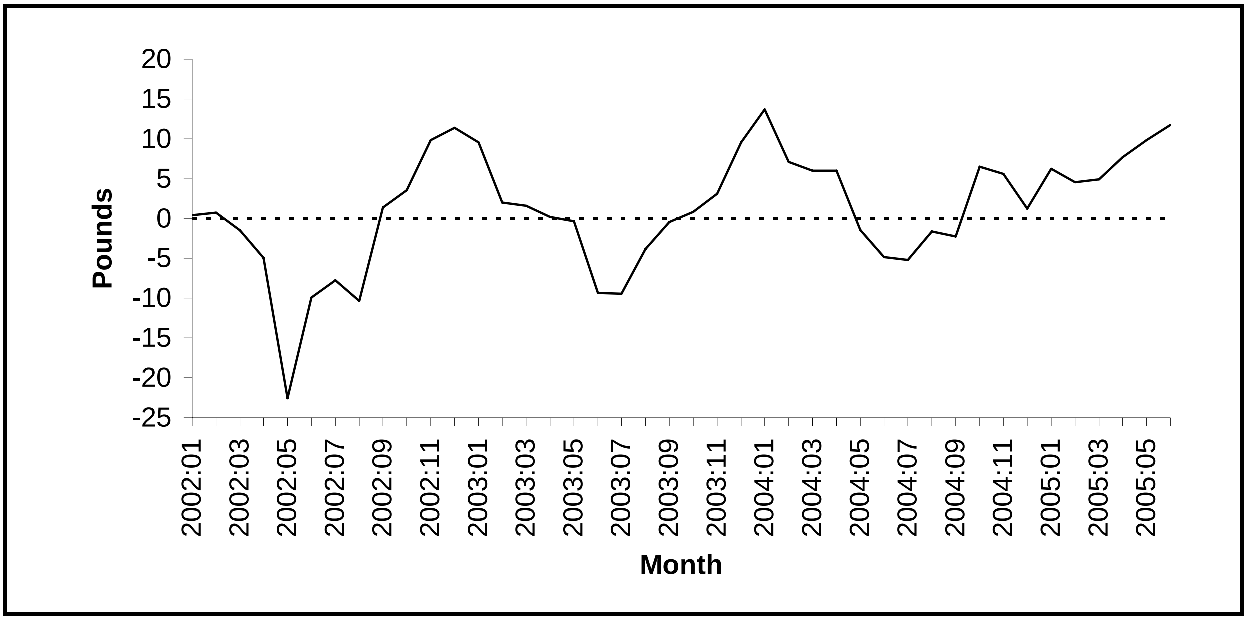


Table 2-4. Statistical Tests of the Equality of Means and Variances of Real Prices of Fed Lamb by Procurement Method, January 2002–June 2005

Statistics	Test	Price	Test Statistics For Formula Versus Cash Procurement
Mean	t-test	Real Prices	0.017
Variance	F-test	Real Prices	1.044
	Bartlett test	Real Prices	0.019
Mean	t-test	Real Normalized Prices	0.279
Variance	F-test	Real Normalized Prices	1.179
	Bartlett test	Real Normalized Prices	0.273

Note: The two sample t-test has 82 degrees of freedom (42 sample observations multiplied by 2 samples less 2 mean parameter estimates) and a critical value of 1.96 at the α = 0.05 level.

Figure 2-2. Difference between Formula and Cash Average Live Slaughter Weights of Fed Lamb, January 2002–June 2005



methods averaged 139.16 pounds, while those procured by cash methods averaged 137.97 pounds. The average liveweight variables possess unit roots and are cointegrated at the α = 0.05 level. The standard deviation of the differences is 7.32 pounds, which is 6.2 times the value of the mean difference (1.18 pounds). The differences between the two variables also trend upward (Figure 2-2). A linear regression of the differences onto a monthly trend variable indicates that the difference increased an average of 0.26 pounds per month.

Per-unit (hundredweight) prices of fed lambs are often a function of liveweight. Differences in liveweights could exist among lambs procured under various marketing arrangements throughout a month. Consequently, we normalized each real price series by average liveweight. Monthly formula prices were divided by monthly average liveweight of slaughter lambs procured through formula and forward contracting mechanisms. Monthly cash lamb prices were each divided by monthly average liveweight of slaughter lambs procured through negotiations and auctions. The mean values for normalized real formula-priced lambs and cash lambs were \$0.348/pound and \$0.351/pound, respectively. The standard deviation for each series was \$0.043 and \$0.047, respectively.

Table 2-4 presents the results of sample t- and F-tests on the difference in mean values and variances of the two weight-normalized slaughter lamb price series. Two-sample t-tests of the null hypothesis of no difference in mean values could not be rejected at the α = 0.05 level for each of the two series. Similarly, the F-tests and Bartlett tests both failed to reject the null hypothesis of no differences in the variances of the two prices series at the α = 0.05 level.

2.3 REDUCED FORM MODELS OF PRICE DIFFERENCES

This section examines the differences between prices of slaughter lamb procured through formula and cash methods.

2.3.1 Differences between Normalized Real Formula and Cash Slaughter Lamb Prices

Figure 2-3 illustrates the difference between normalized real formula and cash prices of fed slaughter lambs between January 2002 and June 2005. The price difference averaged –$0.003/cwt with a standard deviation of $0.023 over the sample period. This is consistent with the results in Section 2.2 that could not reject the null hypothesis of no difference in the means of the price series. However, the price difference series displays significant variability around an expected value, which is essentially zero. We investigate if this variability is systematic or purely the result of stochastic processes.

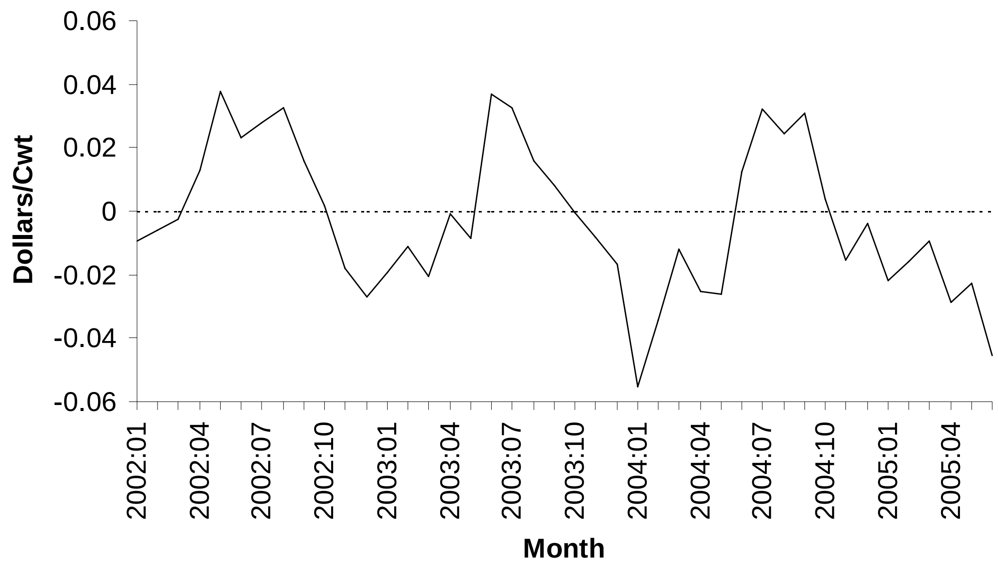
Formula/Cash-Price Reduced Form Model

We posit that factors such as seasonality, wholesale lamb prices, wholesale lamb price risk, sheep and lamb inventory, and number of lambs sold by procurement method affect differences between normalized formula and cash lamb prices. Therefore, the following reduced form model is specified as a means of quantifying potential systematic causes for variations in price differences between formula and cash slaughter lamb prices:

$$FCP = \psi_1 \left(S, FCRP, R, QI, FCN\right) + \mu_t \qquad (2.1)$$

where *FCP* is the normalized real formula slaughter lamb price less the normalized real cash slaughter lamb price; *S* represents a vector of quarterly seasonal binary variables; *FCRP* is the real formula carcass lamb price less the real spot

Figure 2-3. Difference between Real Normalized Formula and Cash Slaughter Lamb Prices, January 2002–June 2005



carcass lamb price ($/cwt); *R* is the standard deviation of the real spot carcass lamb price ($/cwt); *QI* is the January 1 inventory of sheep and lambs (thousand head); *FCN* is the number of lambs sold under formula arrangements less the number of lambs sold under cash terms (thousand head); and μ_t is a white noise disturbance term. Table 2-5 provides descriptive statistics of the variables.

Cash carcass prices are used as a proxy for negotiated carcass prices because the latter are not available. An increase in the difference between formula and cash carcass price (*FCRP*) is expected to increase the difference between normalized formula and cash slaughter lamb price. That is, one would expect that lamb packers would adjust live lamb formula price offers based on changes in their formula arrangements for lamb carcasses. Risk associated with the wholesale lamb carcass market on price of slaughter lambs is considered by including the standard deviation of cash carcass prices (*R*). Formula (and contract) procurement of slaughter livestock is often viewed as a risk-reducing strategy (Schroeder et al., 1991). Thus, if the standard deviation of carcass price increases, one would expect that the difference between formula and cash prices would increase as packers would likely move toward using formulas to procure slaughter lambs.

Table 2-5. Variable Definitions for the Price Differences Model, January 2002–June 2005

Symbol	Definition	Mean	Standard Deviation
FCP	Weight-normalized real formula slaughter lamb price minus the weight-normalized real cash slaughter lamb price, $/cwt	–0.003	0.023
S_2	Second quarter seasonal binary variable	0.286	0.457
S_3	Third quarter seasonal binary variable	0.214	0.415
S_4	Fourth quarter seasonal binary variable	0.214	0.415
FCRP	Real formula carcass lamb price minus the real cash carcass lamb price, $/cwt	–5.507	2.815
R	Standard deviation of real cash carcass price, $/cwt	2.867	1.929
QI	January 1 inventory of sheep and lambs, thousand head	6.256	0.162
FCN	Number of slaughter lambs sold through formula pricing less the number of slaughter lambs sold through cash, head	72,743.45	28,152.53

Sheep and lamb inventory levels (*QI*) represent the pool of available slaughter lambs. However, the expected marginal impact of inventory changes on the difference between formula and cash prices is ambiguous. In general, increases in inventories reduce the spot prices of slaughter livestock (Brester and Marsh, 2001; Marsh, 1994; Wohlgenant, 1989). Thus, holding procurement allocations constant, increases in inventories could increase the formula/cash price spread. However, the opposite could happen if increases in inventories alter the percentage of lambs procured under formula and cash pricing arrangements.

The difference between the number of lamb procured using formula pricing and the number procured using cash pricing (*FCN*) is expected to inversely affect the dependent variable in Eq. (2.1). As more lambs are procured under formula methods (i.e., *FCN* increases), we would expect higher cash lamb prices. Consequently, the difference between formula and cash prices should decline.

Empirical Results for the Formula/Cash-Price Reduced Form Model

Monthly data for the January 2002 to June 2005 period were used to estimate the reduced form model. Lamb and sheep inventories, lamb carcass and slaughter prices, and quantities of lambs obtained by procurement method were obtained from the American Sheep Industry Association (2003–2004) and McDonnell, 2005–2006). All data were deflated by the CPI (1982–84=100). We used quarterly, rather than monthly, seasonal binary variables to obtain a more parsimonious specification.

The model allows for dynamic adjustments because of biological factors and price expectations of market participants. The dynamics are modeled using an autoregressive distributed lag (ARDL) specification (Greene, 2003). The single equation ARDL model is conceptually represented as

$$FCP_t = \frac{B(L)}{A(L)} Z_t + \frac{\mu_t}{A(L)}, \quad t = 1,\ 2,\ \ldots,\ n\ , \tag{2.2}$$

where FCP_t is the difference between formula and cash lamb prices, and Z_t is a vector of the exogenous variables presented in Eq. (2.1). The error term μ_t is assumed to possess white noise properties and is also uncorrelated with Z_t. The ratio $B(L)/A(L)$ is a rational generating function with polynomial lag operators (Greene, 2003). Eq. (2.2) defines a rational distributed lag process where the price difference (FCP_t) is, conceptually, an infinite distributed lag of Z_t and μ_t. The distributed lags are characterized by polynomial weights. Multiplying Eq. (2.2) by $A(L)$ yields the empirical form:

$$A(L)FCP_t = B(L)Z_t + \mu_t \tag{2.3}$$

with the polynomial lag denominator as

$$A(L) = 1 - a_1 L - a_2 L^2 - \ldots - b_q L^q \tag{2.4}$$

and the polynomial lag numerator as

$$B(L) = b_0 + b_1 L + b_2 L^2 \ldots + b_r L^r\ . \tag{2.5}$$

Thus, $L^q FCP_t = FCP_{t-q}$ and $L^r Z_t = Z_{t-r}$ for the respective polynomial lag operators. For the lamb price difference model, q and r are initially set to a lag order of 2. This implies second order lags on the dependent and independent variables. Although the error term contains no lags in the above transformation, it is usually tested for autoregressive structures in empirical specifications. The ARDL(2,2) specification allows for complex roots and oscillations of the dependent variable.

An ARDL(2,2) version of Eq. (2.1) can be estimated using OLS if μ_t is white noise. If the estimated error term results in an AR(1) or AR(2) process, then nonlinear least squares is the appropriate estimator. Differences in procurement quantities (*FCN*) and procurement prices (*FCP*) could be jointly determined. However, a Hausman specification test failed to reject the null hypothesis of exogeneity of *FCN* at the α = 0.10 level. ADF unit root tests failed to reject the null hypothesis of nonstationarity at the α = 0.10 level for the dependent variable and most of the independent variables. However, the ADF test of the appropriate residuals in Eq. (2.1) indicated that the equation is conintegrated. Because of the large number of parameters generated by the ARDL(2,2) specification, we used a Wald coefficient restriction test to truncate lags on those coefficients that were not jointly statistically significant at the α = 0.10 level.

The coefficient estimates of Eq. (2.1) are presented in Table 2-6. The coefficients were estimated using OLS because the Breusch-Godfrey Lagrangean Multiplier (LM) test for serial correlation failed to reject the null hypothesis of no AR(1) or AR(2) process in the error term at the α = 0.10 level. The second quarter seasonality binary variable (S_2) was omitted because it was statistically insignificant. The AR(1) and AR(2) components of the lagged dependent variable were not statistically significant. The Wald coefficient restriction test indicated the contemporaneous, and one-period lags on the formula less cash carcass price variable (*FCRP*) were jointly significant at the α = 0.05 level. Also, the Wald test indicated that the contemporaneous, one-period, and two-period lags on the price risk variable (*R*) were jointly significant at the α = 0.05 level. Approximately 61% of the variation of the difference between formula and cash lamb prices is explained by variations in formula/cash carcass price differences (*FCRP*), price risk (*R*), sheep and lamb inventories (*QI*), differences between formula and cash lamb procurement numbers (*FCN*), and seasonality (*S*). The positive signs on the three coefficients of carcass price risk are consistent with *a priori* expectations. That is, an increase in output price risk increases the price difference between formula and cash prices.

Table 2-6. OLS Estimates of the Formula/Cash Slaughter Price Difference Reduced Form Model

Regressors	Dependent Variable: Formula Less Cash Slaughter Lamb Price (*FCP*)
Constant	–0.724 (–3.478)
Formula carcass less cash carcass price ($FCRP_t$)	–0.002 (–1.494)
Lagged formula carcass less cash carcass price ($FCRP_{t-1}$)	–0.002 (–1.651)
Standard deviation of cash carcass price (R_t)	0.001 (0.557)
Lagged standard deviation of cash carcass price (R_{t-1})	0.001 (0.634)
Lagged standard deviation of cash carcass price (R_{t-2})	0.004 (2.418)
Inventory of sheep and lambs (QI_t)	1.206 (2.754)
Lagged inventory of sheep and lambs (QI_{t-1})	–1.093 (–2.660)
Formula less cash lamb numbers (*FCN*)	–0.003 (–1.964)
Third quarter seasonal binary variable (S_3)	0.035 (4.967)
Fourth quarter seasonal binary variable (S_4)	0.021 (2.750)
Regression Statistics:	
Adjusted R^2	0.611
Standard error of the regression	0.015
Mean of the dependent variable	–0.003

Note: The model contains 30 degrees of freedom. The critical t-values at the α = 0.05 level is 2.042, and 1.697 at the α = 0.10 level.

2.3.2 Parameter Stability of the Reduced Form Price Differences Model

The above reduced form price difference model is based on a relatively small sample. Consequently, it is important to test the stability of the estimated coefficients. Time-series stability tests are commonly based on recursive residuals. This is particularly the case if one suspects the structure of an industry has changed during the sample period (Brown, Durbin, and Evans, 1975; Greene, 2003).

The cumulative sum of the residuals (or CUSUM) test is often used for determining the stability of estimated parameters. The CUSUM test statistic (W_t) is the ratio of scaled recursive residuals to the standard deviation of the scaled residuals. Under the null hypothesis of stable parameter estimates, W_t has a zero mean and a variance equal to the number of residuals being summed. The test is performed by plotting W_t against time within established 95% or 99% confidence bounds (Greene, 2003).

For the model estimated in Eq. (2.1), the test statistic W_t is bounded by the 95% confidence interval. Results indicated that W_t did not violate the confidence interval boundaries. Hence, the null hypothesis of stable parameter estimates cannot be rejected at the $\alpha = 0.05$ level.

The stability of the parameter estimates indicates that structural change has not occurred during the sample period. These results also indicate that the small price differences among lamb procurement methods noted above were consistent throughout the sample period.

2.4 TIME-SERIES MODELS OF SLAUGHTER LAMB PRICES

Given that the dependent variable in Eq. (2.1) is nearly centered on zero, an autoregressive-moving average model (ARMA) may adequately explain the variation in price differences. In this section, we estimate a time-series model to determine if a purely stochastic process is able to describe the data-generating process as well as the previously estimated economic model. If so, then the value of the economic model would be diminished. Although time-series models ignore economic causality, they may provide information regarding the underlying data-generating process (Greene, 2003).

2.4.1 Formula/Cash Price Differences

We specify a time-series model in which the explanatory variables consist of an r^{th} order lag on the dependent variable [AR(r)] and a q^{th} order lag on the moving average error term [MA(q)] with seasonality included. The r^{th} and q^{th} lag orders need not be equal. Consequently, an ARMA(r,q) model is also estimated to see if noneconomic behavior explains variation in the dependent variable.

The general specification is given by

$$A(L)Y_t = B(L)\mu_t \tag{2.7}$$

where Y_t represents the dependent variable (FCP_t) and μ_t is a white noise disturbance term. The polynomial lag operators *A(L)* and *B(L)* are defined in Eqs. (2.4) and (2.5). Stationarity of the equation requires that the characteristic roots (eigenvalues) of $A(L)$ lie outside the unit circle, and invertability of $B(L)$ requires that its roots (eigenvalues) lie outside the unit circle (Johnston and DiNardo, 1997). Thus, conceptually, an ARMA(q,r) process can be expressed as an infinite autoregressive or moving average error process.

For the normalized formula/cash lamb price difference (*FCP*), the order of the ARMA(q,r) was selected based on adjusted R-squared statistics, standard error of regression, and the Akaike Information Criterion (AIC). Seasonality is also included in the estimated time-series model. The empirical model was estimated as an ARMA(4,4) using nonlinear least squares. The results are reported in Table 2-7.

The adjusted R-square was 0.64, indicating a purely stochastic process explained the behavior of formula/cash lamb price differences about as well as the economic model. The eigenvalues of the AR(4) difference equation consisted of two pairs of conjugate complex roots for which the modulus of each is less than unity. These results imply a stationary (stable) AR process in Eq. (2.7). The MA process was invertible, and the Wald coefficient test indicated that the MA coefficients were jointly significantly different from zero at the α = 0.05 level.

Table 2-7. Parameter Estimates of the Formula/Cash Slaughter Price Difference Time-Series Model

Regressors	Dependent Variable: Formula Less Cash Slaughter Lamb Price (***FCP***)
Constant	–0.008
	(–0.831)
Lagged dependent variable (*t-1*)	0.225
	(0.943)
Lagged dependent variable (*t-2*)	0.169
	(1.171)
Lagged dependent variable (*t-3*)	0.521
	(4.113)
Lagged dependent variable (*t-4*)	–0.540
	(–3.094)
Lagged error term (*t-1*)	0.020
	(0.068)
Lagged error term (*t-2*)	–0.383
	(–2.719)
Lagged error term (*t-3*)	–0.856
	(–19.171)
Lagged error term (*t-4*)	0.296
	(1.299)
Second quarter seasonal binary variable (S_2)	0.003
	(0.263)
Third quarter seasonal binary variable (S_3)	0.024
	(1.481)
Fourth quarter seasonal binary variable (S_4)	–0.006
	(–0.387)
Regression Statistics:	
Adjusted R^2	0.643
Standard error of the regression	0.015
Mean of the dependent variable	–0.003
Akaike information criterion	–5.375

Note: The model contains 26 degrees of freedom. The critical t-values are 1.706 at the α = 0.10 level and 2.056 at the α = 0.05 level.

2.4.2 Summary of the Time-Series Model Results

The time-series model explained nearly as much of the variation in formula/cash prices as the economic model. Thus, it appears that the economic model likely suffers from missing quantifiable information. That is, although a purely stochastic ARMA model may be as useful for prediction as the economic model, it is not helpful for understanding policy analyses. The presence of AR and MA error terms generally imply that an economic model has been misspecified. Often, this misspecification is the result of the inability to properly measure all of the economic variables that underlie the data-generating process. However, when the ARMA(4,4) specification was added to the specification of Eq. (2.1), the parameter estimates on the MA error term structure became statistically insignificant, while the coefficients on the economic variables remained statistically different from zero. Hence, the economic model is a better tool for evaluating the effects of shocks to the lamb industry than a purely stochastic model.

2.5 THE IMPACT OF ALTERNATIVE MARKETING ARRANGEMENTS ON MARKET PRICES

In this section, we present a monthly lamb econometric model for determining the effect of AMAs on market prices based on MPR data. We estimate a monthly model to provide sufficient observations for the model because data on procurement volumes are only available since 2001. We develop a monthly demand and supply structural model for the retail, wholesale, slaughter, and feeder levels and then solve it for equilibrium prices. Because changes in procurement methods may also influence potential lamb processor market power, we develop a function that represents meat packer market power for live lamb purchases. Marginal impacts of lamb procurement methods are obtained by jointly estimating the monthly equilibrium price model and market power equation.

2.5.1 A Monthly Structural Lamb and Sheep Price Model

The equilibrium price model for retail, wholesale, slaughter (fed and cull), and feeder lambs is obtained from a structural model of lamb demand and supply functions within the lamb meat marketing chain. MPR data provide percentages of lamb procurement by lamb packers/processors based on the following categories: formula pricing, forward contracting, negotiation, auctions, packer ownership, and live lamb imports. In our model, we combined the formula-priced and forward-contracted lamb into a single category entitled "formula." We maintain the packer ownership and import categories and combine the negotiated and auctioned lamb procurement methods into a single category entitled "cash."[3]

Conceptually, these three approaches (formula, packer ownership, and cash) to lamb procurement by lamb packers could affect retail lamb demand through changes in meat quality. These procurement methods also represent cost shifters (albeit, perhaps differing costs) of the wholesale and slaughter domestic lamb derived supply functions. Following Tomek and Robinson (1990), procurement costs can also be shifters of domestic slaughter lamb derived demand. Each procurement method could have a different impact on domestic wholesale lamb carcass prices and on domestic slaughter lamb prices if they entail different cost or risk factors. This is likely given differences in shares of lamb obtained by each procurement method. From 2001 to 2004, the average proportions of live lambs obtained by procurement method for all U.S. lamb packers were 43.8% formula, 0.9% contracted, 11.7% negotiated, 38.0% auction, 4.7% packer owned, and 0.8% imported (American Sheep Industry Association, 2003–2004).

We develop a monthly structural model of inverse demand and supply functions to capture retail quality effects and the cost impacts of differing procurement methods. Rank identification of the structural model permits econometric estimation of lamb equilibrium prices and, subsequently, specific solutions can be obtained through the reduced form. The reduced form coefficients (multipliers) are then used to quantify the effects of marketing methods (AMA) costs on all market-level sectors resulting from potential limits on procurement methods.

---

[3] Negotiated and auction procurement methods have similarities and differences. The methods are similar in that they represent an "open market" approach to price discovery. However, auctions represent a public method of price determination, while negotiations are usually characterized by private treaty agreements. Preliminary research indicated that separating negotiated and auction procurement methods provided no additional information about the use and impacts of AMAs. Therefore, the two procurement methods were combined into a single category.

The monthly structural model specifies inverse demand and supply functions for the retail sector, the wholesale (boxed or cut-out) sector, the slaughter lamb sector, the ewe (cull) slaughter sector, and the feeder lamb sector. The specifications are based on the theory of consumer utility maximization and firm profit maximization whereby input demands and output supplies are derived from first-order conditions from profit-maximizing behavior by competitive firms (Brester and Marsh, 2001; Varian, 1992; Wohlgenant, 1989). Inverse behavioral functions are specified because supply quantities are assumed to be predetermined on a monthly basis. The model is represented by the following:

Retail Sector:

Inverse retail lamb demand:

$$p_r^d = m_1\left(q_r^d, p_r^b, p_r^y, p_r^k, Y, T_q\right) + \mu_1 \quad (2.8)$$

Inverse retail lamb supply:

$$p_r^s = m_2\left(q_r^s, p_{bx}, mc, s\right) + \mu_2 \quad (2.9)$$

Market-clearing quantity:

$$q_r^d = q_r^s = q_r \quad (2.10)$$

Market-clearing price:

$$p_r^d = p_r^s = p_r \quad (2.11)$$

Wholesale (Cut-Out) Sector:

Inverse wholesale lamb demand:

$$p_{bx}^d = m_3\left(q_l^d, p_r, q_s, mc, s\right) + \mu_3 \quad (2.12)$$

Inverse wholesale lamb supply:

$$p_{bx}^s = m_4\left(q_l^s, p_{sl}, cs, pf, po, pc, pi, mpr, s\right) + \mu_4 \quad (2.13)$$

Market-clearing quantity:

$$q_l^d = q_l^s = q_l \quad (2.14)$$

Market-clearing price:

$$p_{bx}^d = p_{bx}^s = p_{bx} \quad (2.15)$$

Slaughter Lamb Sector:

Inverse slaughter lamb demand:

$$p_{sl}^{d} = m_5 \left(q_{sl}^{d}, p_{bx}, p_{bp}, cs, pf, po, pc, pi, mpr, s \right) + \mu_5 \quad (2.16)$$

Inverse slaughter lamb supply:

$$p_{sl}^{s} = m_6 \left(q_{sl}^{s}, p_{fr}, p_n, s \right) + \mu_6 \quad (2.17)$$

Market-clearing quantity:

$$q_{sl}^{d} = q_{sl}^{s} = q_{sl} \quad (2.18)$$

Market-clearing price:

$$p_{sl}^{d} = p_{sl}^{s} = p_{sl} \quad (2.19)$$

Slaughter Ewe Sector:

Inverse slaughter ewe demand:

$$p_{ew}^{d} = m_7 \left(q_{ew}^{d}, p_{bp}, p_{em}, s \right) + \mu_7 \quad (2.20)$$

Inverse slaughter ewe supply:

$$p_{ew}^{s} = m_8 \left(q_{ew}^{s}, p_h, s \right) + \mu_8 \quad (2.21)$$

Market-clearing quantity:

$$q_{ew}^{d} = q_{ew}^{s} = q_{ew} \quad (2.22)$$

Market-clearing price:

$$p_{ew}^{d} = p_{ew}^{s} = p_{ew} \quad (2.23)$$

Feeder Lamb Sector:

Inverse feeder lamb demand:

$$p_{fr}^{d} = m_9 \left(q_{f}^{d}, p_{sl}, p_n, s \right) + \mu_9 \quad (2.24)$$

Inverse feeder lamb supply:

$$p_{fr}^{s} = m_{10} \left(q_{f}^{s}, p_h, s \right) + \mu_{10} \quad (2.25)$$

Market-clearing quantity:

$$q_{fr}^{d} = q_{fr}^{s} = q_{fr} \quad (2.26)$$

Market-clearing price:

$$p_{fr}^{d} = p_{fr}^{s} = p_{fr} \tag{2.27}$$

Table 2-8 presents variable definitions. Disturbance terms (μ_1 – μ_{10}) are assumed to exhibit white noise properties within equations but contemporaneous correlations across equations. Eqs. (2.8) and (2.9) represent inverse lamb meat demand and supply functions at the retail level. Retail demand by consumers (the price of retail lamb meat $\left(p_r^d\right)$) is a function of per capita retail quantity demanded of lamb $\left(q_r^d\right)$, which includes imported and domestic lamb, the retail prices of meat substitutes including beef $\left(p_r^b\right)$, poultry $\left(p_r^y\right)$, and pork $\left(p_r^k\right)$, per capita consumer expenditures $\left(Y\right)$, and consumer lamb quality preferences $\left(T_q\right)$. Retail supply price $\left(p_r^s\right)$ is a function of per capita retail lamb quantities supplied $\left(q_r^s\right)$, boxed lamb price $\left(p_{bx}\right)$, and retail food marketing costs $\left(mc\right)$. Eqs. (2.10) and (2.11) represent retail market-clearing quantities and prices.

Eq. (2.12) specifies wholesale demand (by retailers) price $\left(p_{bx}^d\right)$ as a function of wholesale quantity demanded of domestic and imported lamb and mutton $\left(q_l^d\right)$, the retail price of lamb (p_r), the wholesale quantity of meat substitutes (beef, pork, and chicken, (q_s), food marketing costs (mc), and seasonality (s). Eq. (2.13) specifies wholesale supply price $\left(p_{bx}^s\right)$ as a function of wholesale quantity supplied of domestic and imported lamb $\left(q_l^s\right)$, price of slaughter lamb (p_{sl}), lamb processing cost (cs), lamb procurement costs of formula arrangements (pf), lamb procurement costs of packer ownership (po), lamb procurement costs of cash transactions (pc), lamb procurement costs of imports (pi), MPR requirements (mpr), and seasonality (s). Eqs. (2.14) and (2.15) represent market-clearing conditions.

Because data related to procurement costs associated with each AMA are not available, volume shares of each marketing alternative are used as proxies. The variable (pf) includes formula and contract volumes, (po) consists of packer ownership volumes, (pc) represents cash (negotiated and auction market volumes), and (pi) represents live import volumes. MPR was generally implemented in April 2001, but actual lamb MPR reported data did not begin until December 2001. Thus, for lamb, the variable (mpr) is a binary variable

Table 2-8. Variable Definitions for the Monthly Lamb Procurement Model, August 2001–December 2004

Symbol	Definition	Mean	Standard Deviation
p_r	Real retail price of domestic lamb, cents per pound	254.51	16.48
p_r^b	Real retail beef price, cents per pound	372.38	36.80
p_r^y	Real retail poultry price, cents per pound	106.43	3.30
p_r^k	Real retail pork price, cents per pound	272.28	8.99
Y	Real per capita consumption expenditures, dollars	14,212	373.68
p_{bx}	Real lamb carcass cut-out value, dollars per cwt	110.91	13.55
p_{em}	Real mutton carcass cut-out value, dollars per cwt	NA	NA
p_{sl}	Real price of domestic slaughter lambs, dollars per cwt	44.64	8.34
p_{ew}	Real price of ewes, dollars per cwt	24.41	3.40
p_{fr}	Real price of feeder lambs, dollars per cwt	48.51	9.14
p_{bp}	Real lamb pelt and drop credit (offal) value, dollars per head	71.16	7.74
p_n	Real price of #2 yellow corn, Central U.S., dollars per bushel	1.23	0.14
p_h	Real price of hay (grass and alfalfa), dollars per ton	39.87	2.79
cs	Real lamb processing and packaging costs, dollars per cwt	16.05	1.13
mc	Index of food marketing costs (1987=100)	NA	NA
q_r	Per capita consumption of lamb, retail weight, pounds	0.30	0.02
q_l	Quantity of domestic lamb and mutton production and imports, carcass weight, million pounds	29.82	4.81
q_{sl}	Quantity of yearling lamb slaughter, live weight, million pounds	30.96	3.93
q_{ew}	Quantity of sheep slaughter, live weight, million pounds	1.83	0.31
q_f	Quantity of feeder lambs, thousand head	4,277.75	172.59
q_s	Quantity of wholesale beef, pork, and chicken production, billion pounds	6.73	0.99
T_q	Retail lamb quality, monthly average yield grade, 1–5	2.68	0.10
CPI	Consumer price index (1982–84=100)	1.83	0.04
pf	Packer formula (formula plus contract) procurement of slaughter lambs, percent	43.20	8.06

(continued)

Table 2-8. Variable Definitions for the Monthly Lamb Procurement Model, August 2001–December 2004 (continued)

Symbol	Definition	Mean	Standard Deviation
po	Packer ownership of slaughter lambs, percent	4.67	0.70
pc	Packer cash (negotiated and auction) procurement of slaughter lambs, percent	51.30	8.24
pi	Packer procurement of imported slaughter lambs, percent	0.81	1.09
mpr	Mandatory price reporting (December 2001–December 2004 = 1; 0 otherwise)	0.62	0.49
t_f	Technological genetics changes, average live lamb slaughter weight, pounds	136.08	4.46
m_k	Estimated oligopsony power	0.00005	0.003
s_i	Quarterly seasonal dummies (i = 2, 3, 4; quarter 1 omitted)	NA	NA

NA = Not applicable.

that accounts for the impact of the legislation on derived supply behavior caused by potential increased market transparency.

Eqs. (2.16) and (2.17) present inverse derived demand and supply equations for the slaughter lamb sector. Slaughter lamb demand (by meat processors) price $\left(p_{sl}^{d}\right)$ is a function of the quantity demanded of slaughter lambs $\left(q_{sl}^{d}\right)$, the output price of boxed lamb (p_{bx}), the joint product value of lamb pelts and drop credits (p_{bp}), lamb processing costs (*cs*), lamb procurement costs (*pf, po, pc, pi*), MPR (*mpr*), and seasonality (*s*). Slaughter lamb supply (by feedlots) price $\left(p_{sl}^{s}\right)$ is a function of quantity supplied of fed slaughter lambs $\left(q_{sl}^{s}\right)$, the input price of feeder lambs (p_{fr}), the input price of corn (p_n), and seasonality (*s*). Eqs. (2.18) and (2.19) provide market-clearing identities.

Note that lamb procurement costs and mandatory price variables are included on the right-hand side of Eqs. (2.13) and (2.16). Changes in procurement costs and market price transparency are expected to shift derived wholesale supplies of boxed lamb and derived processor demand for slaughter lamb. Processors adjust to cost changes by altering sale prices of boxed lamb and purchase prices of live lamb.

Eqs. (2.20) and (2.21) represent inverse slaughter ewe derived demand by processors and inverse derived supply of slaughter ewes by lamb producers. Slaughter ewe derived demand price $\left(p_{ew}^{d}\right)$ is a function of the quantity demanded of slaughter ewes $\left(q_{ew}^{d}\right)$, the joint product value of lamb pelts and drop credit (p_{bp}), the boxed price of mutton (p_{em}), and seasonality (s). Slaughter ewe derived supply price $\left(p_{ew}^{s}\right)$ is a function of the quantity supplied of slaughter ewes $\left(q_{ew}^{s}\right)$, the price of hay (p_h), and seasonality (s). Eqs. (2.22) and (2.23) provide market-clearing identities.

Eqs. (2.24) and (2.25) present inverse derived feeder lamb demand and primary feeder lamb supply equations. Feeder lamb demand (by feedlots) price $\left(p_{fr}^{d}\right)$ is a function of the quantity of feeder lambs demanded $\left(q_{fr}^{d}\right)$, the output price of slaughter lambs (p_{sl}), the input price of corn (p_n), and seasonality (s). Primary inverse feeder lamb supply price $\left(p_{fr}^{s}\right)$ is a function of the quantity supplied of feeder lambs $\left(q_{fr}^{s}\right)$, the input cost of hay (p_h), and seasonality (s). Eqs. (2.26) and (2.27) represent market-clearing identities.

2.5.2 A Monthly Equilibrium Price Model

The empirical model to be estimated uses equilibrium prices for each market level based on market-clearing assumptions for quantities and prices. Thus, Eqs. (2.8) through (2.27) can be reduced to the following five-equation model:

Price of retail lamb:

$$p_r = m_{11}\left(q_r, p_r^b, p_r^y, p_r^k, Y, T_q, p_{bx}, mc, s\right) + \epsilon_1 \tag{2.28}$$

Price of boxed lamb:

$$p_{bx} = m_{12}\left(q_l, p_r, q_s, mc, p_{sl}, cs, pc, po, pm, pi, mpr, s\right) + \epsilon_2 \tag{2.29}$$

Price of slaughter lambs:

$$p_{sl} = m_{13}\left(q_{sl}, p_{bx}, p_{bp}, cs, pf, po, pc, pi, mpr, p_{fr}, p_n, s\right) + \epsilon_3 \tag{2.30}$$

Price of slaughter ewes:

$$p_{ew} = m_{14}\left(q_{ew}, p_{bp}, p_{em}, p_h, s\right) + \epsilon_4 \tag{2.31}$$

Price of feeder lambs:

$$p_{fr} = m_{15}\left(q_{fr}, p_{sl}, p_n, p_h, s\right) + \epsilon_5 \tag{2.32}$$

Eqs. (2.28) through (2.32) express equilibrium prices for each market level in terms of equilibrium quantities and all other pertinent demand and supply shifters. A sixth equation is included in the model to identify changes in potential lamb packer market power (m_k) as a result of changes in lamb procurement methods as follows:

$$m_k = m_{16}\left(pf, po, pc, pi\right) + \epsilon_6 . \tag{2.33}$$

The model of equilibrium prices consists of a triangular coefficient matrix of the dependent variables because of its recursive structure. For example, retail lamb price, boxed lamb price, and slaughter lamb price are regressors in Eqs. (2.29), (2.30), and (2.32), respectively. Disturbances terms ($\epsilon_1 - \epsilon_6$) are assumed to have a nondiagonal covariance matrix because of potential common specification errors and common stochastic factors (e.g., weather) within the vertical market structure (Johnston and DiNardo, 1997). Market rigidities, biological lags, and price expectations dictate that dynamics be included in the estimation through the use of distributed lags.

Eq. (2.33) is specified such that marginal changes in procurement methods can be related to marginal changes in market power. That is, a policy that limits a specific lamb procurement method might not only increase procurement costs, but it may also ameliorate market power effects. For example, suppose that lamb processors are limited in the percentage of fed lambs that they are allowed to procure through formula and packer ownership methods. Although market cost inefficiencies are likely to be introduced, the action could reduce oligopsony purchasing power.

Several methods exist to estimate the degree of oligopsony market power (Appelbaum, 1982; Muth and Wohlgenant, 1999; Crespi, Gao, and Peterson, 2005; Schroeter, 1988; Stiegert, Azzam, and Brorsen, 1993). However, data limitations in the lamb processing industry prevent the direct application of these approaches. Therefore, the following “market power” equation is specified:

$$LK_t = \psi\left(LC_t, TN_t, s_2, s_3, s_4\right) + \mu_t \tag{2.34}$$

where *LK* is the four-firm lamb packer concentration ratio (percent); *LC* represents unit lamb processing and packaging costs (dollar/cwt); *TN* represents technological change in the lamb processing industry (trend); s_2, s_3, and s_4 represent seasonal binary variables for the second, third, and fourth quarters of each calendar year; and μ_t is a random error term with white noise properties. From 2001 to 2004, the four-firm lamb packer concentration ratio averaged about 65%. Assuming the variable LK_t includes a measure of market power and that Eq. (2.34) is properly specified (i.e., unit costs and technology are expected to affect concentration), the estimated residuals (i.e., the difference between the actual and predicted values of LK_t) could plausibly represent an estimate of market power. Of course, it is likely that the residuals of Eq. (2.34) contain other factors beyond those associated with market power. However, the estimated residuals would represent the largest market power effects possible.

2.5.3 Data Development and Estimation Procedures for the Monthly Reduced Form Price Model

The sample period for the estimation of the reduced form model consists of 40 monthly observations from August 2001 to December 2004 (voluntary price reporting began in August 2001, even though MPR for lamb did not begin until December 2001). Lamb price, quantity, and processing cost data were obtained from the American Sheep Industry Association (McDonnell, 2005–2006). Prices and quantities of meat substitutes, food marketing costs, corn price, and hay price data were obtained from the USDA (*Red Meats Yearbook*; *Livestock, Dairy, and Poultry Situation and Outlook* reports; *Agricultural Outlook*; *Feed Yearbook*; *Agricultural Statistics*). Food marketing costs were not reported on a monthly basis. Therefore, lamb processing costs were used as a proxy. Boxed mutton price was also not reported on a monthly basis, so the boxed price of lamb was used as a proxy. Lamb packer concentration ratios are only reported on an annual basis (USDA GIPSA). A linear interpolation of the annual observations are used to generate monthly concentration values. All price, expenditures, and processing cost data were deflated by the CPI (CPI, 1982–84=100). CPI data were obtained from the *Economic Report of the President* (various issues).

The market power equation, Eq. (2.34), is estimated in double log form using OLS and monthly data from August 2001 to December 2004. The length of the data series is consistent with that used for the monthly price equilibrium model. The OLS results are as follows:

$$\ln LK_t = 4.238 - 0.023 \ln LC_t - 0.0001TN + 0.002s_3$$
$$(188.475) \quad (-2.761) \quad (-0.561) \quad (1.267) \qquad (2.35)$$
$$\bar{R}^2 = 0.135 \quad S.E. = 0.004 \quad \bar{Y} = 4.175$$

The largest adjusted R^2 and lowest standard error of the estimate were obtained by omitting the second and fourth quarter seasonal binary variables. Other than the constant term, only the lamb processing cost variable is significantly different from zero. The sign indicates that lower unit costs are associated with increases in market concentration. This may reflect advantages gained from scale economies. Nonetheless, the parameter estimate is not economically significant. In addition, note that the equation does not fit the data particularly well. Thus, the residuals of Eq. (2.35) likely contain information beyond that attributable to market power effects. That is, the residuals should represent the largest possible market power effects.

The residuals of Eq. (2.35) are approximately normally distributed (using a Jacque-Bera test statistic) with a mean of –0.0005 and a standard deviation of 0.003. These residuals are used as the dependent variable in Eq. (2.33) of the monthly price model as a proxy for m_k. Because this proxy likely contains information in addition to the effects of market power, the estimated parameters of Eq. (2.33) should be considered an upper bound of the market power effects resulting from changes in procurement methods.

ADF unit root tests indicated the variables of the price equilibrium model (Eqs. [2.28] through [2.33]) were nonstationary. However, ADF tests of the OLS residuals indicated that the equations were cointegrated at the $\alpha = 0.05$ significance level. Thus, the model was estimated with all variables in data levels. The natural logarithm of each variable was used for estimation purposes. Therefore, estimated coefficients are interpreted as elasticities. Livestock and meat quantities are assumed to be predetermined on a monthly basis. Wu-Hausman tests of the exogeneity were performed using the model's exogenous variables as instruments. The null hypothesis of no simultaneous equation bias was rejected at the $\alpha = 0.05$ level. Thus, Eqs. (2.28) through (2.33) were estimated by three stage least squares (3SLS). First-stage instruments included all of the model's exogenous variables. The third-stage generalized least squares (GLS) weighted covariance matrix was not iterated because little efficiency gains occur in small samples (Greene, 2003). The volume shares for the four lamb procurement methods sum to 1.0. Therefore, the smallest lamb procurement variable, live imports (*pi*), was deleted from the empirical specification. For the sample period, domestic lamb processors imported an average of 0.8% of live lambs per year. However, since 2003, U.S. lamb processors have not imported live lambs.

2.5.4 Empirical Results for the Monthly Equilibrium Price Model

Tables 2-9, 2-10, and 2-11 present the 3SLS results for the monthly equilibrium price model. In each equation, distributed lags on the regressors were included to reflect dynamic adjustments. Lagged values of variables were not retained in the model if they were found to be statistically insignificant at the α = 0.10 level in initial regressions. Likewise, contemporaneous variables were not retained in the model if they were not significantly different from zero provided that the one-period lag on the variable was statistically significant. Because of overparameterization of the model, quarterly rather than monthly seasonal binary variables were used.

Most of the estimated coefficients (40 of 49) are significantly different from zero at the α = 0.10 level and possess theoretically correct signs. In the retail lamb price equation (2.28), substitute retail beef and pork prices are positively related to lamb price as expected (Table 2-9). Increases in lamb quality also positively affect lamb price. For example, a 1% decrease in yield grade (which represents an increase in quality) increases retail lamb price by 0.42% (the sum of the contemporaneous and lagged quality coefficients –0.914 and 0.492).

In the boxed lamb price equation (Eq. [2.29]), a 1% increase in food marketing costs (*mc*) decreases the boxed lamb price by 0.19%, which reflects a reduction in wholesale derived demand (Table 2-9). Furthermore, a 1% increase in lagged slaughter lamb price ($P_{sl,t-1}$) increases the boxed lamb price by 0.61%. This input cost change decreases derived wholesale supply. In addition, the impacts of formula and cash procurement are both statistically different from zero. The null hypothesis that these two coefficients were not significantly different from each other could not be rejected at the α = 0.01 level.

Table 2-9. 3SLS (Double Log) Estimates of Retail Lamb Prices and Lamb Cut-Out Values

Regressors	Dependent Variables	
	Retail Lamb Price (p_r)	**Lamb Cut Out Price (p_{bx})**
Constant	–0.768 (–0.128)	5.751 (5.716)
Per capita lamb consumption (q_r)	–0.165 (–2.205)	
Retail price of beef (p_r^b)	0.366 (1.961)	
Retail price of poultry (p_r^b)	–1.162 (–4.045)	
Retail price of pork (p_r^b)	1.187 (2.583)	
Per capita consumer expenditures (Y)	–0.047 (–0.066)	
Retail lamb quality (T_q)	–0.914 (–3.361)	
Lagged retail lamb quality ($T_{q\ t-1}$)	(0.492) (1.970)	
Quantity of lamb production (q_l)		–0.182 (–4.728)
Food marketing costs (mc)		–0.186 (–2.625)
Lagged price of slaughter lambs ($p_{sl\ t-1}$)		0.614 (7.794)
Quantity of lamb substitutes (q_s)		–0.029 (–0.681)
Retail price of lamb (p_r)		–0.314 (–3.768)
Formula lamb procurement (pf)		–0.265 (–2.178)
Packer ownership (po)		–0.011 (–0.884)
Cash lamb procurement (pc)		–0.217 (–1.558)
Mandatory price reporting (mpr)		–0.026 (–0.923)
Regression Statistics:		
Adjusted R^2	0.512	0.914
Standard error of the regression	0.046	0.037
Log mean of the dependent variable	5.534	4.705

Note: The model contains MT-K degrees of freedom. M is the number of equations (6), T is the adjusted number of observations (40 after allowing for t–1 lagged terms), and K is the number of estimated parameters (49). Thus, for 191 degrees of freedom, the critical t-value at the α = 0.10 level is 1.658.

In the slaughter lamb price equation (Eq. [2.30]), boxed lamb price and pelt/drop credit values positively affect derived slaughter demand (0.359 and 0.537, respectively, Table 2-10).

Table 2-10. 3SLS (Double Log) Estimates of Slaughter Lamb Prices and Slaughter Ewe Prices

	Dependent Variables	
Regressors	**Fed Lamb Price (p_{sl})**	**Slaughter Ewe Price (p_{ew})**
Constant	–2.543 (–2.459)	5.871 (5.887)
Quantity of lamb production (q_l)	–0.147 (–3.010)	
Formula lamb procurement (*pf*)	0.254 (2.077)	
Packer ownership (*po*)	–0.023 (–1.618)	
Cash lamb procurement (*pc*)	0.268 (2.000)	
Mandatory price reporting (*mpr*)	0.129 (5.316)	
Lamb cut-out value (p_{bx})	0.359 (2.431)	0.148 (0.495)
Price of lamb by-products (p_{bp})	0.537 (3.913)	0.133 (0.446)
Lamb processing costs (*cs*)	–0.001 (–0.211)	–0.534 (–2.891)
Lagged price of feeder lambs ($p_{fr\ t-1}$)	0.198 (2.289)	
Lagged price of corn ($p_{n\ t-1}$)	0.171 (2.416)	
Seasonal binary variable (s_3)	–0.029 (–2.538)	
Quantity of ewe production (q_{ew})		–0.592 (–5.641)
Lagged price of hay ($p_{h\ t-1}$)		–0.604 (–3.037)
Regression Statistics:		
Adjusted R^2	0.967	0.428
Standard error of the regression	0.036	0.092
Log mean of the dependent variable	3.790	3.132

Note: The model contains MT-K degrees of freedom. M is the number of equations (6), T is the adjusted number of observations (40 after allowing for t–1 lagged terms), and K is the number of estimated parameters (49). Thus, for 191 degrees of freedom, the critical t-value at the α = 0.10 level is 1.658.

Lagged feeder lamb price and lagged corn price positively affect slaughter lamb price. That is, increases in input costs reduce derived slaughter supply. Specifically, a 1% increase in the lagged feeder lamb price increases slaughter price by 0.20%.

Likewise, a 1% increase in the lagged corn price increases the slaughter lamb price by 0.17%. In addition, the impacts of formula and cash procurement are both statistically different from zero. The null hypothesis that these two coefficients were not significantly different from each other could not be rejected at the α = 0.01 level.

In the slaughter ewe price equation (Eq. [2.31]), a 1% increase in the lagged hay price decreases the ewe price by 0.60% (Table 2-10). That is, higher animal maintenance cost encourages cull ewe slaughter (herd reductions).

In the feeder lamb price equation (Eq. [2.32]), corn price represents a proxy for finishing costs of gain and is a significant shifter of derived demand. A 1% increase in corn price reduces feeder price by 0.12% (Table 2-11). Lamb slaughter price directly influences feeder lamb price. The empirical results indicate that a 1% increase in slaughter lamb price increases feeder lamb price by 0.84%.

2.5.5 Effects of Procurement Methods on Equilibrium Prices

The effects of procurement methods are generally significant in each of the equilibrium price equations. Thus, lamb procurement costs are shifters of derived wholesale supply and slaughter demand. For example, in the boxed lamb price equation, a 10% increase in formula lamb procurement (*pf*) reduces boxed lamb price by 2.65% (Table 2-9). In the slaughter lamb equation, a 10% increase in formula lamb procurement increases slaughter lamb price by 2.54%. These impacts are consistent with the theory that packer/processor formula and contract procurement methods reduce transaction, risk, and logistics costs. If sufficient competition exists within the industry, these cost savings would be distributed among the vertical sectors depending on relative primary demand and supply elasticities and are manifest in a narrowing of the farm-to-wholesale marketing margin (Brester and Marsh, 2001; Tomek and Robinson, 1990).

The effect of lamb procurement through packer ownership (*po*) was not statistically significant in the boxed lamb price equation. However, packer ownership was statistically significant in the slaughter lamb demand price equation. The negative sign suggests that increases in packer ownership of

Table 2-11. 3SLS (Double Log) Estimates of Feeder Lamb Prices and Lamb Packer Market Power

Regressors	Dependent Variables	
	Feeder Lamb Price (p_{fr})	Lamb Market Power (m_k)
Constant	9.350 (1.991)	–0.077 (–1.846)
Lagged price of hay ($p_{h\ t-1}$)	–0.417 (–4.111)	
Price of slaughter lambs (p_{sl})	0.844 (9.108)	
Price of corn (p_n)	–0.123 (–1.710)	
Quantity of feeder lambs (q_{fr})	–1.142 (–2.452)	
Lamb genetics technology (T_f)	0.493 (2.158)	
Formula lamb procurement (*pf*)		0.009 (1.788)
Packer ownership (*po*)		0.002 (3.566)
Cash lamb procurement (*pc*)		0.010 (1.762)
Lagged market power ($m_{k,t-1}$)		0.723 (8.841)
Regression Statistics:		
Adjusted R^2	0.949	0.807
Standard error of the regression	0.045	0.002
Log mean of the dependent variable	3.872	–0.0005

Note: The model contains MT-K degrees of freedom. M is the number of equations (6), T is the adjusted number of observations (40 after allowing for t–1 lagged terms), and K is the number of estimated parameters (49). Thus, for 191 degrees of freedom, the critical t-value at the α = 0.10 level is 1.658.

lambs reduce slaughter lamb price. However, the magnitude of the coefficient is only –0.023, which suggests that the market power effect is economically small. Given that packer ownership of lambs represented only 4.7% of total procurement volume, the result is not surprising.

The effect of lamb procurement through cash market transactions (*pc*) is statistically significant in the boxed lamb price equation and indicates that a 10% increase in lamb procurement using cash transactions reduces boxed lamb price by 2.17%. A 10% increase in lamb procurement using cash transactions increases slaughter lamb price by 2.68%. Essentially, this procurement method results in a narrowing of the farm-to-wholesale marketing margin. Note that a marginal increase in formula procurement reduces the lamb farm-to-wholesale marketing margin. Likewise, a marginal increase in cash procurement also reduces the lamb farm-to-wholesale margin. The two effects are similar, and both methods have similar procurement volumes (43% for formula and 51% for cash procurement).

2.5.6 Effects of Procurement Methods on Potential Market Power

The estimated market power equation (Eq. [2.33]) included a Koyck distributed lag. The modulus of the function's real root is less than unity, which indicates that the difference equation is stable. Each procurement method variable is statistically significant and jointly significant at the $\alpha = 0.01$ level using a Wald coefficient restriction test. The model explains about 81% of the variation in the dependent variable (Table 2-11).

Results indicate that increases in formula procurement (*pf*) and increases in packer ownership (*po*) increase lamb processors' market power. In all cases, this should be interpreted as potential effects rather than actual effects. We are unable to estimate whether market power is actually exercised in this market. However, we are estimating the potential changes in market power given changes in AMAs should such market power actually exist. Nonetheless, the short-run economic effects are quite small (i.e., a 10% increase in *pf* and *po* increases lamb processors' oligopsony power by 0.10% and 0.02%, respectively). Although contrary to *a priori* expectations, increases in cash procurement methods (*pc*) are positively correlated with market power. Specifically, a 10% increase in *pc* increases market power by 0.10%. This counterintuitive result may be caused by the sample period considered. During the period in which MPR data were gathered, the lamb industry was dominated by a few large packers. Furthermore, overall industry production is quite small. Hence, regardless of procurement method, it is possible that packers were able to exert some market power regardless of procurement method. However, the economic effect of this buying power in all cases was quite small.

2.6 SUMMARY OF THE EXTENT OF USE AND PRICE EFFECTS OF ALTERNATIVE MARKETING ARRANGEMENTS

According to MPR data, lamb packers procure fed lambs primarily through formula price arrangements (42.2%) and auctions (39.4%). Negotiated sales account for 12% of fed lamb procurement, and packer ownership represents 4.9%. Contracted procurement represents only 0.8% of lamb procurement, while imports represent only 0.7%.

This compares favorably with information obtained from packer surveys. Table 7-15 in Volume 2 shows that packers reported obtaining 40.1% of their fed lambs through auctions. Also, packers report obtaining 32.1% from dealers/brokers, and 22.5% from direct trade. The combination of these two (54.6%) is almost identical to the 54.2% obtained from formula and negotiated methods reported in the MPR. In addition, the survey data indicate that packers had procured no lambs through packer ownership or forward contracts, and only 5.3% through marketing agreements.

The small procurement shares for contracts necessitated the aggregation of formula and contract procurement into a single category termed “formula.” Because negotiated and auction prices are generally considered to both represent spot prices, they were aggregated into a single category termed “cash.”

Over the sample period, formula procurement trended downward, while auction procurement trended upward (each about 0.26 percentage points per month).

The means and standard deviations of formula and cash fed lamb prices using MPR data were similar during the sample period. The price series were highly correlated with an estimated correlation coefficient of 0.970. A reduced form model of the difference between normalized formula and cash fed lamb prices indicated that lamb inventories, lamb carcass price risk, and seasonality were the primary determinants of variations in the difference. Changes in lamb inventories had the largest effects on price differences. As inventories increase, the difference between formula/cash prices also increased. The second most important factor was changes in carcass price risk, which was directly related to liveweight price differences between formula and cash prices. In addition, the estimated parameters were found to be stable throughout the sample period indicating that structural change was not occurring. Finally, ARMA time-series models explained a similar amount of the differences between formula and cash prices as did the economic model.

The results of the price equilibrium and market power equations indicate that changes in procurement methods for lamb impose costs on the lamb marketing system by reducing efficiencies but may also provide some benefits by altering potential market power effects. For example, if formula procurement is curtailed, lamb acquisition costs rise. However, some of this increase in costs may be offset by a reduction in oligopsony power. Ultimately, a combination of these effects yields net changes in lamb prices, quantities, and producer surplus.

The implementation of MPR in 2001 was intended to increase pricing efficiency through improved market price transparency (Perry et al., 2005). In addition, its inclusion as a binary variable in the equilibrium price model allows for estimates of the effect of lamb procurement methods net of USDA price reporting regulations. The estimated coefficient for the binary variables was not statistically significant in the boxed lamb price equation. However, it was statistically significant, albeit economically small, in the slaughter lamb equation. The binary variable indicates the MPR increased slaughter lamb price by only 0.129%. Given that lamb markets are relatively thin, the primary impact of MPR may have been to reduce price risk rather than influence price levels (Marsh and McDonnell, 2005).

The AMA method of lamb procurement was found to have a statistically significant, although economically small, effect on lamb prices. For example,

- In the boxed lamb price equation, a 10% increase in the share of formula lamb procurement (*pf*) reduces boxed lamb price by 2.65% probably because of reductions in price risk. A 10% increase in cash procurement (*pc*) also reduces boxed lamb price (2.17%). However, the impact of packer ownership had no statistically significant effect on boxed lamb prices.
- In the slaughter lamb equation, a 10% increase in formula lamb procurement increases the slaughter lamb price by 2.54% probably because of risk reductions. A 10% increase in cash procurement increases slaughter

prices by 2.68%. A 10% increase in packer ownership reduces slaughter lamb prices by 0.23%.

Approximately 60% of the difference between formula and cash lamb prices is explained by variations in formula/carcass price differences, carcass price risk, sheep and lamb inventories, differences between formula and cash lamb procurement numbers, and seasonality. An important result consistent with *a priori* expectations is that an increase in output price risk increases the price difference between formula and cash prices.

3 Alternative Marketing Arrangements and Procurement Costs

Participants in the lamb packer industry interviews indicated that AMAs help packers secure a steady supply of fed lambs for slaughter and coordinate both fed lamb and lamb meat logistics. Although packer ownership of fed lambs is relatively small, such ownership is often used to fill gaps in fed lamb supplies. Also, packers noted that formula arrangements are relatively low-cost methods for acquiring fed lambs. In addition, AMAs reduce the amount of lamb meat that must be frozen, which reduces its value relative to fresh meat, by helping match fed lamb slaughter with lamb meat sales.

Section 2.5 used a monthly reduced form price model to estimate the marginal impacts of changes in AMAs on boxed lamb prices. Results indicated that the use of formula pricing arrangements reduced boxed lamb price because of cost savings. Examples of cost savings include factors such as reductions in logistics and procurement costs, risk, and improved capacity utilization. The following section focuses on a single element of these potential cost savings—reductions in fed lamb procurement costs.

Data limitations do not allow for the direct estimation of a cost function for the lamb packing industry. Consequently, we used MPR data from January 2002 to June 2005 to estimate a farm–processor marketing margin model to examine the impacts of various lamb procurement methods on costs in the lamb packing industry. Three procurement methods are considered: formula, cash, and packer ownership.

3.1 PROCUREMENT COST MODEL

If adequate firm-level data were available, a traditional cost function based on the duality of cost and production functions could be estimated. Applying a cost minimization objective function to such data could yield estimates of optimal input factor demands and total costs (Greene, 2003; Nerlove, 1963). First principles would be used to derive total costs as a function of relative input prices, production volumes, and output prices.

Because data limitations preclude the estimation of a dual cost function, we estimate a farm–wholesale lamb price marketing margin model. The marketing margin represents all costs required to convert fed slaughter lamb into boxed or wholesale lamb. Therefore, the margin represents processing costs, procurement costs, profit, and allowances for risk. Because a procurement cost variable is not directly available, we constructed a proxy by subtracting slaughter costs from the farm–wholesale lamb marketing margin. The difference represents an upper bound on procurement costs. To calculate this proxy, we first add lamb pelt and drop credit values to lamb carcass value to obtain a total wholesale value of lamb. Then, we subtract slaughter lamb value from total wholesale value to obtain our proxy for procurement costs. This proxy is then specified as a function of lamb production, procurement methods, processing costs, and seasonality. This specification is intended to approximate the econometric estimation of a cost function in that production volume and marketing inputs are used to explain marketing margins between farm-level and wholesale-level lamb prices.

The lamb procurement cost model is specified as follows:

$$C = c\left(ql, pf, po, pc, vpc, s\right) + \mu \qquad (3.1)$$

where *C* represents lamb procurement costs in dollars per head, *ql* is lamb slaughter production (liveweight, million pounds), *pf* is the percentage of lambs procured by packers using formulas (and contracts), *po* is the percentage of lambs procured by packers through packer ownership, *pc* is the percentage of lambs procured by packers through cash (negotiations and auctions), *vpc* is variable lamb processing costs (dollars/head), *s* is a vector of quarterly seasonal binary variables, and μ is a random error term (see Table 2-8 for a list of variable definitions). We assume that lamb slaughter production is exogenous on a monthly basis.[1]

Eq. (3.1) is expected to contain market rigidities. Hence, the model is further specified with autoregressive distributed lags (ARDL) to capture noninstantaneous adjustments to exogenous market factors. The dynamic equation is expressed as follows:

$$A(L)C_t = B(L)X_t + \epsilon_t, \qquad t = 1, 2, \ldots, n \tag{3.2}$$

where C_t is the proxy for lamb procurement costs, X_t is a vector of exogenous factors as specified in Eq. (3.1), and ϵ_t is a white noise disturbance term. Although initially assumed to be white noise, Greene (2003) notes that the estimated error term may be autoregressive. The ratio $B(L)/A(L)$ is the rational generating function with a polynomial numerator and denominator as defined in Eqs. (2.4) and (2.5).

Data used for constructing the dependent variable were obtained from the American Sheep Industry Association (2003–2004) and McDonnell (2005–2006). Slaughter costs were only available for January 2002 ($7.50/head) and June 2005 ($9.00/head). Therefore, missing values were obtained through linear interpolation. This proxy for the unobservable dependent margin implies that the parameter estimates of Eq. (3.1) represent upper bounds. Any errors associated with the calculation of C are manifest in the error term associated with the estimated equation such that our parameter estimates are unbiased. All observations of the dependent variable C were deflated by the CPI (1982 – 84 = 100). The processing cost variable (*vpc*) includes variable costs of processing lamb carcasses. This variable is also deflated by the CPI. Its specification represents a vertical marketing cost (margin) factor. A change in processing (or marketing) costs is expected to affect derived demand for live lambs by lamb packers. The ADF unit root test indicated the existence of unit roots for the variables C, *pf*, *po*, and *pc*. Each variable was integrated of order one (I(1)), and the equation was cointegrated at the $\alpha = 0.05$ level.

[1] As in the previous section, we have excluded the percentage of lambs procured through imports from the model to avoid matrix singularity in the regression.

3.2 EMPIRICAL RESULTS

Eq. (3.1) is estimated using nonlinear least squares to accommodate the joint combination of lagged dependent variables and autoregressive errors. The final empirical model included second-order distributed lags on procurement methods and processing costs, contemporaneous lamb production, and a first-order lag on the dependent variable. The final dynamic model was selected based on the values of adjusted R-squared, standard error of regression, and the AIC. The regression results are presented in Eq. (3.3) with values in parentheses representing t-ratios:

$$
\begin{aligned}
C_t = &-39.395 + 0.760pf_t - 1.146pf_{t-1} + 0.328pf_{t-2} + 0.710po_t - 0.0986po_{t-1} + 0.500po_{t-2} \\
&(-1.837) \quad (3.158) \quad (-2.917) \quad (0.972) \quad (2.957) \quad (-2.850) \quad (1.944) \\
&+ 0.576pc_t - 1.080pc_{t-1} + 0.463pc_{t-2} + 0.089vpc_t + 2.885vpc_{t-1} - 0.301vpc_{t-2} \\
&(2.367) \quad (-2.894) \quad (1.483) \quad (0.093) \quad (2.743) \quad (-0.522) \\
&+ 0.043ql_t + 0.451s2 - 0.551s3 + 0.258s4 + 0.685C_{t-1} - 0.444\mu_{t-1} \\
&(0.841) \quad (1.171) \quad (-1.592) \quad (0.726) \quad (5.009) \quad (-2.125)
\end{aligned}
\tag{3.3}
$$

$$\bar{R}^2 = 0.838 \qquad S.E. = 0.771 \qquad \bar{Y} = 5.352 \qquad AIC = 2.624$$

The modulus of the difference equation term (0.685) and the inverted autoregressive unit roots (–0.444) are less than unity. Thus, the regression mean and the AR(1) process are stationary. The CUSUM test indicated that the estimated coefficients are stable at the α = 0.05 level.

The critical t-value statistic for the coefficient estimates at the α = 0.05 level (21 degrees of freedom) is 2.080. However, because of potential explanatory power of joint lagged exogenous variables, the Wald coefficient restriction test was applied. The test rejected the null hypothesis that the second-order lags of Eq. (3.3) were not significantly different from zero at the α = 0.05 level. The coefficient on a one-period lag on the dependent variable was significantly different from zero at the α = 0.05 level; however, a two-period lag was not. Therefore, a second order lag on the dependent variable was omitted in the final specification equation. The dynamics of Eq. (3.3) can be expressed in terms of its long-run solution because the equation is stationary. Thus, the intercept and sum of the slope coefficients for each variable are divided by 1 minus the coefficient of the difference equation (1 – 0.685). The long run equation reduces to

$$
\begin{aligned}
C_t = & -125.063 - 0.184pf_t + 0.711po_t - 0.130pc_t + 8.486vpc_t + 0.135ql_t \\
& \qquad\quad (1.435) \qquad (0.673) \qquad (-1.275) \qquad (25.682) \qquad (0.761) \\
& + 1.432s2 - 1.749s3 + 0.819s4,
\end{aligned} \tag{3.4}
$$

where the dependent and independent variables represent long-run (mean) values and the coefficients are equilibrium multipliers. The equilibrium elasticities are reported in parentheses.

Of particular interest is the relative effect of packer procurement methods on lamb procurement costs. Increases in formula lamb procurement reduce procurement costs. The same result also occurs for increases in cash procurement methods. For example, a 1% increase in formula procurement decreases lamb procurement costs by 1.44%, while a 1% increase in cash procurement decreases procurement costs by 1.28%. The Wald coefficient restriction test was used to test the equality of the summed slope coefficients in Eq. (3.3) for these two procurement methods. The test indicated that the coefficients for formula and cash purchase methods were not statistically different from each other at the α = 0.05 level.

Packer ownership was directly related to lamb procurement costs. For example, a 1% increase in procurement through packer ownership increased procurement costs by 0.67%. The Wald coefficient restriction test indicated that there was a significant difference between lamb procurement by packer ownership versus formula, and there was a significant difference between packer ownership and cash procurement methods.

The results of Eqs. (3.3) and (3.4) indicate differing impacts of packer procurement methods on lamb procurement costs. Increases in formula and cash procurement methods decrease procurement costs. However, increases in packer ownership increase procurement costs. The implications are that increased formula procurement reduces transactions and logistics costs and contributes to lamb marketing efficiencies (i.e., lower procurement costs). Increases in cash procurement also reduce procurement costs perhaps because these methods increase the price of slaughter lambs, which reduces the marketing margin used as a proxy for procurement costs. However, increases in packer ownership procurement increase procurement costs probably because of the added costs and risks associated with owning live lambs.

The lamb processing cost variable has a positive effect on procurement costs, which is consistent with theoretical predictions. That is, an increase in processing costs causes reductions in derived demand for slaughter lambs and derived supply of wholesale lamb. The long-run elasticity is quite large, which is to be expected given the high correlation between processing costs and the packer slaughter cost variables (a correlation coefficient of –0.92) that were used to construct the dependent variable.

3.3 SUMMARY OF THE EFFECTS OF ALTERNATIVE MARKETING ARRANGEMENTS ON PROCUREMENT COST

Data limitations prevented the direct estimation of an aggregate cost function for the lamb processing sector. However, we estimated a monthly procurement cost model using MPR data and information provided by the American Sheep Industry Association (2003–2004) and McDonnell (2005–2006). The econometric results indicate that increases in formula and cash procurement methods reduce lamb procurement costs, while increases in packer ownership increase procurement costs. Perhaps this is why only a small percentage of fed lambs are procured through packer ownership. The effects of formula and cash procurement methods on procurement costs were similar and not statistically different from one another.

4 Quality Differences Associated with Alternative Marketing Arrangements

AMAs between lamb packers and fed lamb producers may influence retail lamb meat quality. For example, the use of formulas, contracts, and packer ownership may be driven by a desire to procure higher quality fed lambs (Boland, Bosse, and Brester, forthcoming). The desire for higher quality fed lambs is the result of increasing consumer demand for higher quality retail lamb meat.

4.1 LAMB QUALITY

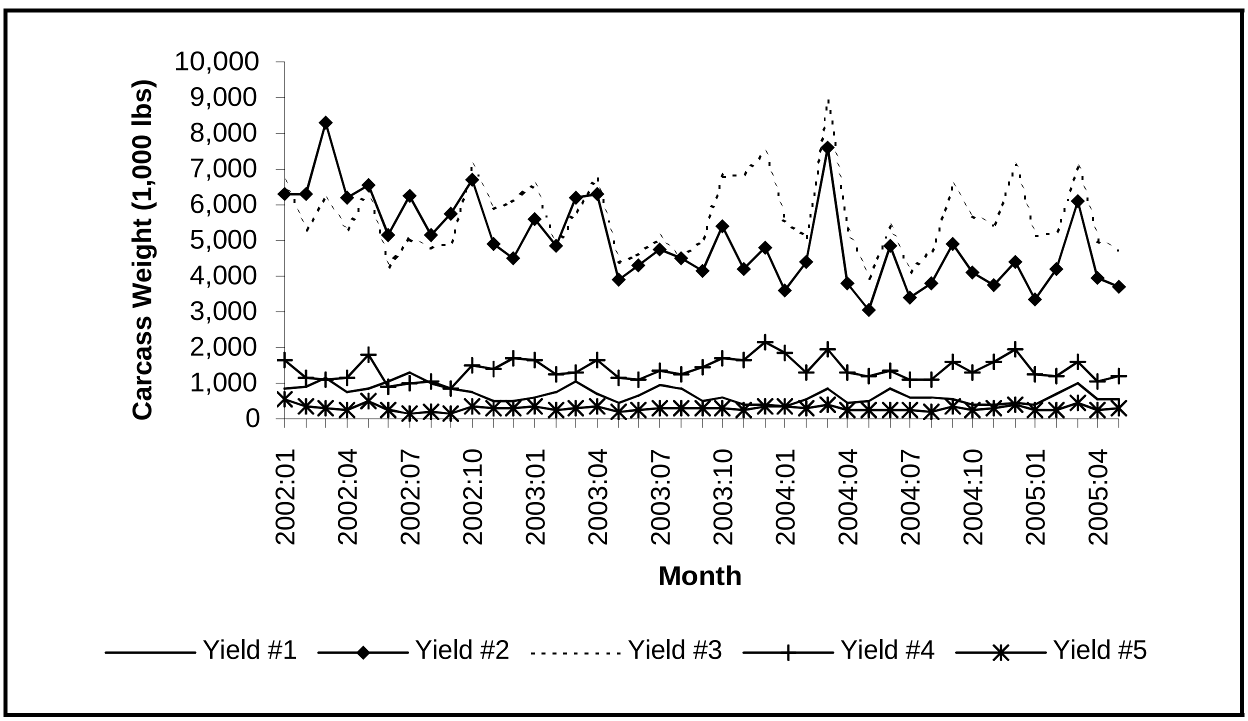
MPR data provided by the American Sheep Industry Association (2003–2004) and McDonnell (2005–2006) include yield grade information for fed slaughter lambs. MPR data indicate that all fed lambs receive yield grades. However, mature sheep (rams and ewes) are not graded. Yield grade scores are integer values ranging from 1 to 5.[1] Yield grades represent relative amounts of boneless trimmed lamb meat obtained from a lamb carcass. Thus, yield grade provides some information about lamb quality. In general, lower yield grade numbers indicate better lamb quality. For example, the Mountain States Lamb Cooperative uses a quality grid based on yield grade. Yield Grade 5 and Yield Grade 4 receive $0.30/lb and $0.08/lb discounts, while Yield Grade 2 and Yield Grade 3 receive

[1] In addition to yield grades, fed lamb carcasses are generally graded for quality (i.e., Prime, Choice, and Select). However, MPR data on these quality grade variables were not consistently reported.

$0.08/lb premiums (Boland, Bosse, and Brester, forthcoming). However, Yield Grade 1 receives neither a premium nor a discount. Hence, Yield Grade 1 appears to have lower quality with respect to Yield Grades 2 and 3, but higher quality relative to Yield Grades 4 and 5. Therefore, lower yield grade numbers are associated with higher lamb quality for Yield Grades 2 through 5. However, the use of yield grade as a proxy for lamb quality may bias our results upward, because Yield Grade 1 is not superior to Yield Grades 2 and 3 (although it is of superior quality compared with Yield Grades 4 and 5). However, the data indicate that Yield Grade 1 lambs represented only about 5% of total lamb slaughter in 2004. Hence, the upward bias inherent in our procedure is likely small.

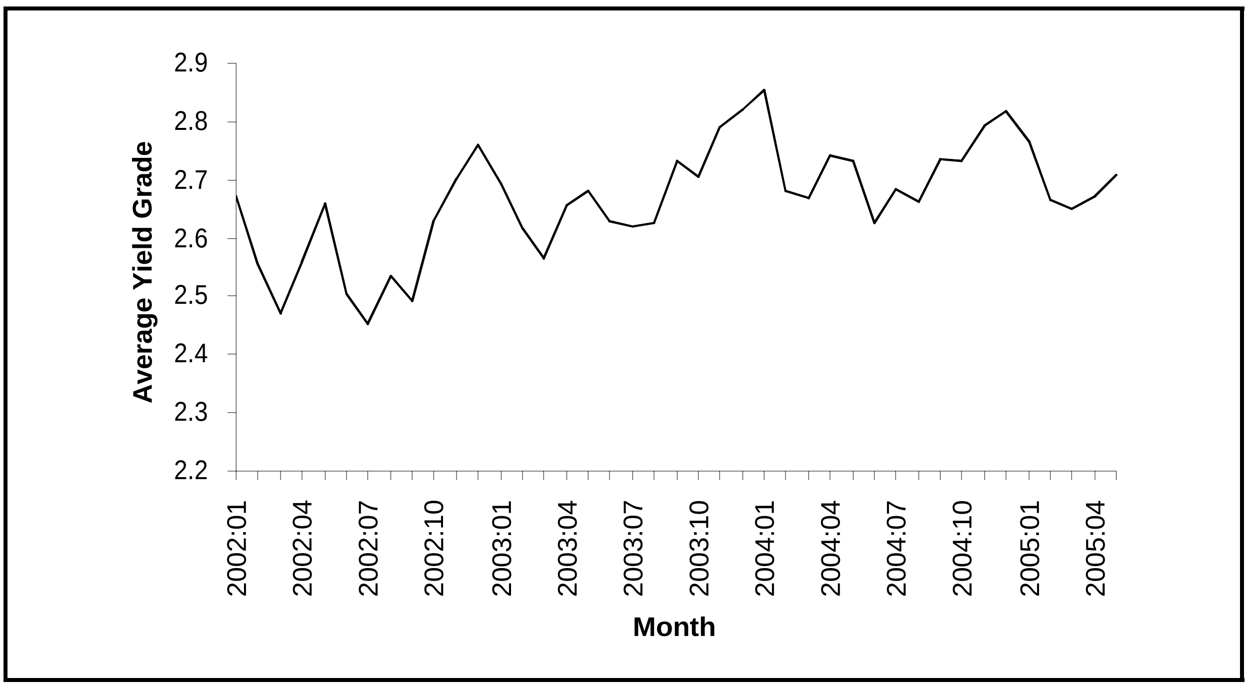
MPR data also report federally inspected carcass production (total weight) for each yield grade category. Thus, carcass weights and yield grade data can be combined to measure the quantity of lamb produced by yield grade. Figure 4-1 presents the carcass lamb production by yield grades for the 2002:1 to 2005:05 period. Yield Grades 2 and 3 dominate (82%) carcass lamb production.

Figure 4-1. Lamb Carcass Production by Yield Grade, January 2002–May 2005



We use average yield grade as an indicator of slaughter lamb quality and quantify the relationship between this variable, other exogenous factors, and procurement method. The yield grade dependent variable is calculated as a weighted average of monthly carcass quantities sold under each yield grade. Figure 4-2 presents the average yield grade (*YG*) over the 2002:1 to 2005:05 period. Average yield grade increased over the period, which corresponds to a decrease in quality. A linear regression of *YG* onto a time trend indicated that yield grade increased about 0.004 (or 0.20%) per month. The coefficient of variation for *YG* was relatively small (about 3.56%). The Jarque-Bera statistic failed to reject the null hypothesis of a normal distribution for *YG*. The ADF unit root test failed to reject the null hypothesis of a unit root in the average yield data at the α = 0.05 level. The results of these tests have implications for the modeling approach described in the next section.

Figure 4-2. Average Yield Grade of Lamb Carcasses, January 2002–May 2005



4.2 MODEL DEVELOPMENT

Average yield grade is expected to be influenced by several factors including feedlot profitability, technology, inventory levels, wholesale demand, and procurement methods. We specify this relationship as

$$YG_t = \zeta_1 \left(PL / PN, Tech, INV, WD, pf, po, pc, s_2, s_3, s_4 \right) + \mu_t . \quad (4.1)$$

Table 4-1 presents the variable definitions and descriptive statistics. Average yield grade (*YG*) is hypothesized to be a function of the slaughter lamb/corn price ratio (*PL/PN*), technology (*Tech*), lamb inventories (*INV*), wholesale demand for lamb (*WD*); formula (*pf*), packer ownership (*po*), cash (*pc*) procurement methods, and seasonality (*s*). The disturbance term μ_t is assumed to possess white noise properties.[2]

Table 4-1. Variable Definitions for the Slaughter Lamb Quality Model

Symbol	Definition	Mean	Standard Deviation
YG	Weighted average yield grade of slaughter lamb	2.67	0.10
PL/PN	Price of slaughter lamb divided by the price of corn	39.72	0.42
Tech	Technological change (lagged average live weight of lamb), pounds	135.34	6.74
INV	Monthly inventory of sheep and lambs, million head	6.26	0.16
WD	Real price of boxed lamb	116.18	12.95
pc	Lamb procurement by formula and contract methods, percent	41.83	6.81
po	Lamb procurement by packer ownership, percent	4.97	2.45
Pc	Lamb procurement by auctions and negotiations, percent	52.47	7.10
S_2	Binary variable for the second quarter	0.27	0.45
S_3	Binary variable for the third quarter	0.22	0.42
S_4	Binary variable for the fourth quarter	0.22	0.42

The price ratio (*PL/PN*) represents the expected profitability of lamb feedlots. *A priori*, an increase in this ratio (an increase in expected profitability) could result in increased average

[2] As in the model presented in Section 2, we have excluded the percentage of lambs procured through imports from the model to avoid matrix singularity in the regression.

liveweight of slaughter lamb and, thus, increase yield grade score (lower quality). Technology (*Tech*) captures improved genetics that could reduce yield grade score (increase quality). Because a specific measure of technological change is not available, a one-period lag on average liveweight of lamb is used as a proxy.

Lamb inventories (*INV*) represent the availability of slaughter lambs. As inventories increase, efficiency gains may occur throughout the feeding–processing sector. Hence, one might expect that larger inventories may be associated with lower yield grades (higher quality). Wholesale lamb demand (*WD*), as measured by the boxed lamb price, is a function of retail consumer demand. As wholesale demand increases, slaughter lamb producers are likely to reduce the length of feeding programs to take advantage of higher lamb prices. Hence, yield grades are likely to decline (an increase in lamb quality) because younger lambs tend to have lower yield grade numbers (higher yields). Average yield grades may also be influenced by seasonal factors. Thus, seasonality is represented by quarterly binary variables (s_2, s_3, s_4).

The lamb procurement variables *pf*, *po*, and *pc* represent the percentage of lambs procured by formula, packer ownership, and cash methods. Procurement methods may affect lamb quality. For example, formula and packer ownership procurement methods may increase lamb quality because both methods allow for better feeding and selection opportunities. We test whether each procurement method significantly influences average yield grade. In addition, if the procurement variables are significantly different from zero, we test whether the coefficients (marginal impacts) differ between the three procurement methods.

4.3 LAMB QUALITY EMPIRICAL RESULTS

The sample period for the quality model consists of monthly data from 2002:01 to 2005:05. All MPR data were obtained from the American Sheep Industry Association (2003–2004) and McDonnell (2005–2006). The boxed lamb price (*WD*) was deflated by the CPI (1982–84=100).

Based on ADF tests, all variables were nonstationary and integrated of order one [I(1)] at the α = 0.05 level. The ADF test of the OLS residuals of Eq. (4.1) rejected the null hypothesis of unit roots; therefore, the equation was cointegrated. Thus, Eq. (4.1) was estimated with the data in level form with distributed lags included to account for expectations and rigidities in lamb quality adjustments. Lags on the independent variables, however, were not statistically significant based on the Wald coefficient restriction test. Also, the Koyck term was not significantly different from zero at the α = 0.10 level and, thus, was omitted.

The Breusch-Godfrey LM test indicated the existence of serial correlation of orders one and two [AR(1) and AR(2)] at the α = 0.05 level for the OLS estimates of Eq. (4.1). Thus, Eq. (4.1) was estimated using nonlinear least squares. The final regression results of the lamb quality equation (estimated in double logs) are presented in Eq. (4.2) with t-ratios in parentheses:

$$
\begin{aligned}
\ln YG_t = {} & \underset{(5.771)}{6.660} + \underset{(0.821)}{0.024}\ln PL_t / PN_t - \underset{(-2.954)}{0.319}\ln Tech_t - \underset{(-5.738)}{1.350}\ln INV_t - \underset{(-0.491)}{0.031}\ln WD_t \\
& - \underset{(-2.298)}{0.157}\ln pf_t - \underset{(-0.851)}{0.009}\ln po_t - \underset{(-2.224)}{0.251}\ln pc_t - \underset{(-0.104)}{0.001}s2 + \underset{(0.278)}{0.003}s3 + \underset{(4.319)}{0.039}s4 \\
& - \underset{(-1.928)}{0.295}\mu_{t-1} - \underset{(-3.512)}{0.493}\mu_{t-2}
\end{aligned}
\tag{4.2}
$$

$$\bar{R}^2 = 0.813 \qquad S.E. = 0.016 \qquad \overline{YG}\ (\log mean) = 0.981$$

The critical t-values at the α = 0.05 level and α = 0.10 level are 2.056 and 1.706, respectively, with 26 degrees of freedom.

The inverted autoregressive roots were conjugate complex ($-0.15 \pm 0.69i$) with the modulus equal to 0.706. Thus, the stochastic error structure displayed a stable oscillating pattern (Figure 4-2). Excluding the autoregressive error structure, the CUSUM test of Eq. (4.2) indicated that the estimated coefficients were stable at the α = 0.05 level.

All variables except the intercept, two seasonal dummies, slaughter lamb/corn price ratio (*PL/PN*), boxed lamb price (*WD*), and the packer ownership procurement variable (*po*) were statistically different from zero at the α = 0.05 level.

An increase in technology, as measured by lagged lamb average liveweight, increases lamb quality (i.e., the negative sign indicates a reduction in yield grade score, which is an increase in quality). For example, a 1% increase in technology improves lamb yield grade by 0.32%. McDonnell (2005–2006) has suggested that improved breeding stock genetics occurred throughout the late 1990s. The regression results also indicate that larger lamb inventories are associated with improved lamb quality, perhaps because of improved cost efficiencies. A 1% increase in lamb inventories causes a 1.35% improvement in lamb quality in the short run. The long-run effect is identical because the Koyck term (lagged dependent variable) in Eq. (4.2) was not statistically different from zero.

Formula procurement methods are associated with improved lamb quality. This is consistent with *a priori* expectations that such methods are employed to improve end-use quality. The elasticity estimate indicates that a 1% increase in formula procurement increases quality by 0.157%. Although the negative coefficient on packer ownership indicates that increases in this procurement method may increase quality, its statistical insignificance may be an artifact of the small share of lamb procured through this method.

The effect of cash procurement methods on lamb quality was also statistically significant. Although the absolute values appear to be different, the Wald coefficient test indicated that no significant difference exists (at the $\alpha = 0.05$ level) between the coefficient estimates of formula and cash procurement methods. This is contrary to the presumption that the quality of lambs procured through cash methods is necessarily poorer than the quality of lambs procured through formula methods.

In addition, the largest percentage of lambs continue to be procured through cash methods (52%, on average, based on MPR data), and previous regression results indicate that only small differences exist between prices of slaughter lambs procured through cash versus formula methods. Recall that MPR data only contain yield grade data that we use as a proxy for quality. However, anecdotal evidence suggests that lamb quality based on quality grades has increased over the sample period. There is a general inverse relationship between quality grade and yield grade. Therefore, we suspect that the positive influence of these two procurement methods on lamb quality reflects a general increase in lamb quality over the sample period.

4.4 SUMMARY OF THE EFFECTS OF ALTERNATIVE MARKETING ARRANGEMENTS ON LAMB QUALITY

We estimated a monthly model to determine if AMAs influence lamb quality. Yield grade was used as a proxy for lamb quality because of a lack of quality grade data. As yield grade score increases, lamb quality declines and retail cutability diminishes. Technological change has likely increased lamb quality over time. Formula procurement methods also increase lamb quality (lower yield grade scores). In addition, the statistical results indicate that lamb quality also increased because of cash market procurement. These results are consistent with anecdotal evidence that the overall quality of U.S. fed lamb has improved in recent years. The most important point is that there does not appear to be any statistically significant difference in the quality of lambs procured through formula and cash procurement methods.

5 Risk Shifting Associated with Alternative Marketing Arrangements

A variety of risks exist in the lamb/lamb meat marketing sector. The survey results reported in Volume 2 indicate that lamb producers use a variety of marketing methods to obviate price risk, market access risk, quality risks, logistical concerns, and price variability. Packers also indicated that they face a variety of risks including price risk, input supply risk, and risk of not meeting downstream retail orders. This section examines the impact of AMAs on the relative amounts of price risk incurred by lamb packers and lamb producers.

5.1 PRICE RISK SHIFTING

AMAs may influence the relative amounts of price risk incurred by lamb producers and lamb packers/processors. For example, cash markets (auctions and negotiations) result in a producer facing all price risk associated with fed lambs. Conversely, a price contract between a lamb packer/processor and a fed lamb producer specifies a transactions price and, thus, reduces the price risk faced by a producer. Formula pricing arrangements also reduce, but do not eliminate, a lamb producer's price risk. Shin and Vukina (2006) suggest that pairwise tests of the variability of prices received under various AMAs provide a measure of risk shifting among vertical sectors of the lamb industry. For different AMA combinations (i, j), the null and alternative hypotheses are given as

$$
\begin{aligned}
&H_0 : VAR(price\ \ of\ \ AMAi) = VAR(price\ \ of\ \ AMAj), \quad i \neq j \\
&H_1 : VAR(price\ \ of\ \ AMAi) \neq VAR(price\ \ of\ \ AMAj), \quad i \neq j
\end{aligned} \tag{5.1}
$$

Several tests can be used to test the null hypotheses. Most tests are fashioned as F-distributions or chi-squared distributions under the assumption of independent, normal price samples. Our pairwise test considers the variance of formula prices and cash prices.

5.2 MODELING STRATEGY

The empirical evaluation of risk shifting considers formula and contract lamb purchases as a single category. Formula prices refer to pricing strategies that use a base price and a formula that adjusts this price for quality and other factors. Forward contracts for lambs may stipulate a fixed price, a fixed quantity, a formula for establishing price, or some combination of the three factors. Negotiations and auctions represent cash market methods of procuring lambs. Negotiated prices involve packer bids on slaughter-ready pens of lambs at feedlots. Such negotiations are essentially private treaty sales. Auction markets involve open, public bidding on slaughter-ready lambs. Lambs acquired through packer ownership averaged only 4.67% of total lamb procurement. In addition, data are not available on packing companies' internal pricing of these lambs. Therefore, these lamb purchases are excluded from the analysis.

The empirical approach involves calculating the variance of nominal and real formula and cash procurement prices. A pairwise test of the equality of these variances is conducted using the F-test and Bartlett's test.

5.3 DATA

Monthly price data for formula and cash lamb procurement were obtained from MPR data (American Sheep Industry Association, 2003–2004; McDonnell, 2005–2006). Observations were available for the 2002:01 to 2005:06 period. Table 5-1 presents the descriptive statistics for the price series in both nominal and real terms (1982–84=100).

Table 5-1. Descriptive Statistics of Nominal and Real (1982–84=100) Slaughter Lamb Prices by Procurement Method Using MPR Data, January 2002–June 2005, Dollars per Cwt

Statistics	Procurement Method: Cash Price		Procurement Method: Formula Price	
	Nominal	Real	Nominal	Real
Mean	90.06	48.41	90.11	48.44
Standard Deviation	14.06	6.60	13.81	6.46
Jarque-Bera	2.08	3.31	3.55	6.30
Probability	0.35	0.19	0.17	0.04

Notes: The Jarque-Bera statistic is a test for the normality of each price series. The associate probability statistic indicates the failure to reject the null hypothesis of a normal distribution for each price series at the $\alpha=0.05$ level.

Cursory observation of the descriptive statistics is consistent with *a priori* expectations. That is, cash prices are expected to display a larger variation than formula prices. This pattern occurs for both nominal lamb prices (standard deviations of 14.06 and 13.81) and real lamb prices (standard deviations of 6.60 and 6.46).

5.4 EMPIRICAL RESULTS

Table 5-2 presents pairwise test results of the equality of the lamb price variances for both nominal and real prices. Two tests are performed. If the price series are statistically independent, a standard F-test is used on untransformed data, while the Bartlett test (chi-square distribution) uses the natural logarithm of the variances.

Table 5-2. Tests for the Equality of Variances between Formula and Cash Slaughter Lamb Prices Using MPR Data, January 2002–June 2005

Test	Degrees of Freedom	Formula Versus Cash Prices: Nominal	Formula Versus Cash Prices: Real
F-test	41,41	1.034	1.044
P value		0.908	0.891
Bartlett	1	0.013	0.019
P value		0.908	0.891

Notes: The P value for the null hypothesis of equal variances of the pairwise lamb price series is presented below each test statistic.

In all cases, the tests fail to reject the null hypotheses of equal variances at the α = 0.05 level. Thus, based on MPR data, it appears that statistically significant risk shifting from lamb producers to lamb packers/processors has not occurred as a result of AMAs.

5.5 SUMMARY OF ALTERNATIVE MARKETING ARRANGEMENTS AND RISK SHIFTING

AMAs have the potential to shift market price risk between fed lamb producers and lamb processors. The variance of prices for each AMA provides one measure of price risk by market participants. Using MPR data, we evaluated the null hypotheses that nominal and real formula and cash price series have equal variances. In each case, we were unable to reject the null hypothesis. Based on MPR data, statistically significant risk shifting from lamb producers to lamb packers/processors has not occurred as a result of AMAs.

It is important to note that lamb producers and packers use AMAs for reasons other than price risk management. For example, Table 6-22 in Volume 2 shows that the most important factor for using AMAs is that producers can sell lambs at higher prices. This was followed by securing a buyer for lambs and then by price risk reduction. Boland, Bosse, and Brester (forthcoming) also note the importance of market access for producers, but also a desire by processors to acquire slaughter lambs in an environment characterized by declining lamb numbers.

6 Measurement of the Economic Effects of Restricting Alternative Marketing Arrangements

In this section, we estimate short-run and long-run changes in equilibrium prices and quantities of live lamb and lamb meat that would result from changes in current lamb procurement methods. We develop an equilibrium displacement model that incorporates estimated procurement costs, accounts for interrelationships along the lamb marketing chain, and considers potential changes in product quality at the retail level. In addition, we estimate cumulative changes in consumer surplus at the retail level and producer surplus at each level of the lamb marketing chain to determine the economic effects of changes in procurement methods on consumers, producers, and importers of lamb and lamb meat. Finally, we incorporate the potential for lamb processing market power, if it exists, and estimate the effects of changes in that power resulting from changes in livestock procurement methods.

6.1 MODEL DEVELOPMENT

This section describes the modeling strategy for estimating the economic effects of changes in procurement methods on consumers, producers, and importers of lamb and lamb meat. An equilibrium displacement model is presented and used as the primary approach to estimating changes in economic effects. Later sections describe the parameterization of the model and simulation results.

6.1.1 Modeling Strategy

We develop an equilibrium displacement model assuming that limits on current procurement methods will impose additional marketing costs on suppliers. Conceptually, such costs shift relevant supply functions upward and to the left in each affected sector. A reduction in supply at the retail level causes a reduction in quantity demanded at that level. Concurrently, this change causes reductions in derived demand at each upstream level in the marketing chain. In a competitive market, the impacts and distribution of added marketing costs on prices and quantities at each market level are determined by the size of cost impacts and relative supply and demand elasticities at each level.

Figure 6-1 illustrates the relevant market linkages for a simplified case in which the lamb industry marketing chain is separated into a retail and farm sector. To simplify the illustration, fixed input proportions between the farm input (feeder lamb) and marketing services are assumed. Retail demand (D_r) and farm (feeder) supply (S_f) are considered the "primary" relations, while the demand for feeder lambs (D_f) and the retail supply of lamb (S_r) are considered "derived" relations (Tomek and Robinson, 1990). The intersection of demand and supply at each level determines relative market-clearing prices (P_r) and (P_f) and market-clearing quantity (Q_0). In this case, the farm-level market-clearing quantity is represented graphically on a retail weight equivalent basis. The difference in equilibrium prices ($P_r – P_f$) represents the farm–retail price spread or marketing margin.

If changes in AMAs increased costs only at the retail level, retail supply would shift from S_r to S_r' and the farm-level derived demand for feeder lambs would decline to D_f' (Figure 6-1). Retail price would increase to P_r' and farm price would decline to P_f'. Marketing cost increases would be reflected by a larger marketing margin ($P_r' – P_f'$), and a new equilibrium quantity would be established at Q_1. If retail demand were relatively inelastic, consumer expenditures would increase, but farm revenues and producer surplus would decline along with farm price and quantity.

Figure 6-1. Effects on the Lamb Sector of Imposing Additional Procurement Costs on the Retail Level

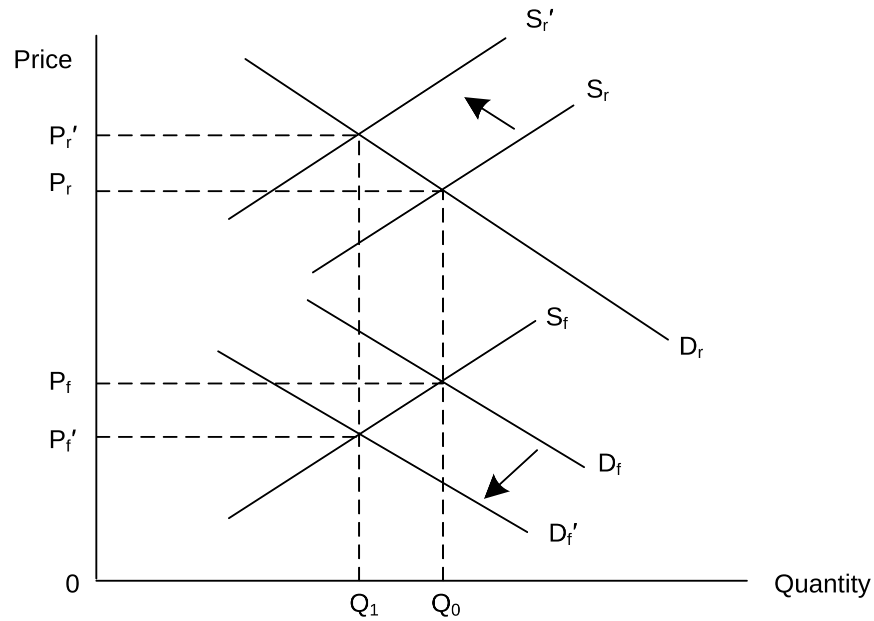


Figure 6-2 extends this simplified case by illustrating a situation in which procurement costs increase at both the retail and farm levels. The initial equilibrium occurs at P_r, P_f, and Q_0. Increased procurement costs associated with AMAs are reflected in reductions in both derived retail supply (S_r'') and primary farm supply (S_f''). The derived demand for lambs declines to D_f''. The new equilibrium prices are at P_r'' and P_f'', and the new equilibrium quantity is Q_2. Whether P_f'' is higher or lower than P_f depends on relative supply and demand shifts and elasticities at each level. However, Q_2 is unambiguously less than Q_0. That is, the quantity of lambs traded decreases because of increased procurement costs.

In Figure 6-2, the new equilibrium farm price P_f'' is higher than the original farm price of P_f. Nonetheless, the higher farm price does not mean that producers are better off because of associated declines in farm output. Producer surplus effects can be measured by the change that results from moving from the original equilibrium (P_f, Q_o) to the new equilibrium (P_f'', Q_2). In Figure 6-3, shaded area *A* represents farm-level producer surplus at the original equilibrium price and

Figure 6-2. Effects on the Lamb Sector of Imposing Additional Procurement Costs on the Retail and Farm Levels

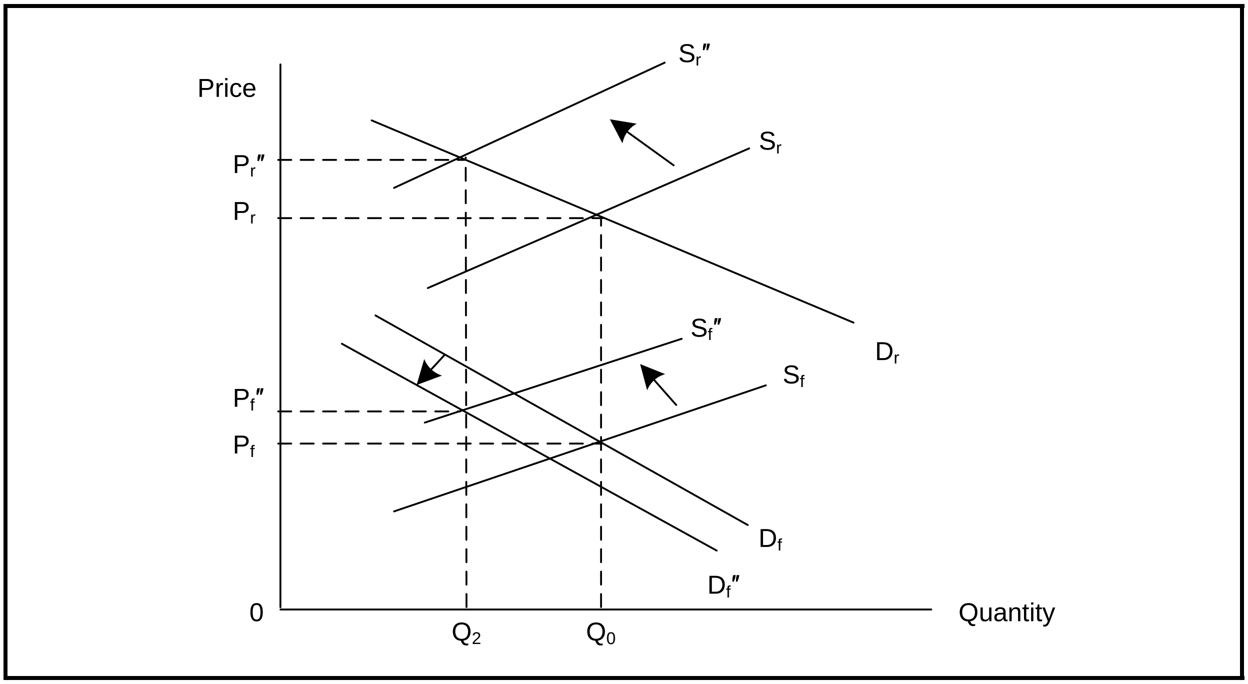
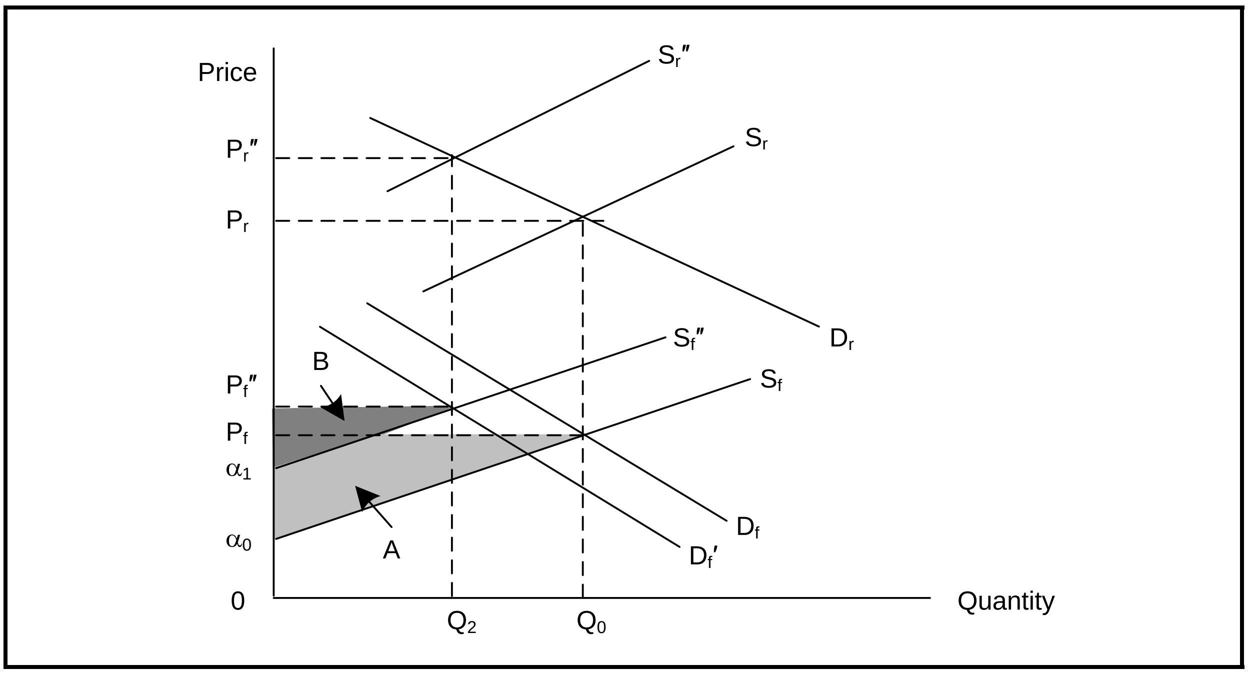


Figure 6-3. Changes in Farm-Level Producer Surplus Resulting From Imposing Additional Procurement Costs on the Retail and Farm Levels



quantity, and shaded area *B* represents farm-level producer surplus as a result of increased procurement costs that affect the retail and farm levels. Assuming linear supply and demand functions, elasticity estimates and equilibrium prices and quantities can be used to calculate the sizes of the shaded areas. Absent a consumer demand increase, the change in producer surplus illustrated in Figure 6-3 must be negative and is expressed as

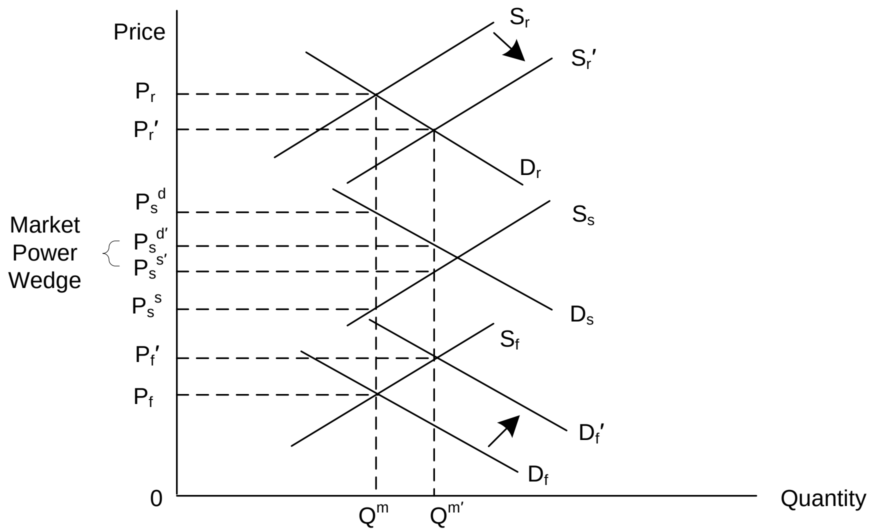
$$\Delta PS = B - A = \left[1/2\left(P_f^{"} - \alpha_1\right)Q_2\right] - \left[1/2\left(P_f - \alpha_0\right)Q_0\right], \quad (6.1)$$

where ΔPS represents the change in producer surplus.

Figure 6-4 illustrates the case in which a third market (slaughter lambs) has been added between the farm and retail levels. Lamb processors have a derived demand for slaughter lambs (D_s). Lamb feedlots provide a derived supply (S_s) of slaughter lambs. In addition, suppose that lamb processors are hypothetically able to use market power to drive a wedge between the slaughter lamb demand price (P_S^d) and the slaughter lamb supply price (P_S^s) at equilibrium quantity Q^m. This results in an equilibrium retail price of (P_r) and an equilibrium farm price of (P_f). A restriction on formula, contracted, or packer ownership marketing arrangements could reduce the potential market power of processors. In this case, the wedge between (P_S^d) and (P_S^s) would narrow, say to ($P_S^{d\prime}$) and ($P_S^{s\prime}$). Quantity equilibrium would be established at $Q^{m\prime}$. This requires an increase in the retail derived supply function to $S_r^{\prime}$ and an increase in the farm-level derived demand function to $D_f^{\prime}$. The size of these shifts depends on the relative sizes of the absolute value of the primary retail-level own-price elasticity of demand and the primary farm-level own-price elasticity of supply (Tomek and Robinson, 1990).

Figures 6-1 through 6-4 illustrate only the “cost side” effects of changes in procurement methods on retail- and farm-level prices and quantities. However, Section 4 reports that changes in procurement methods may also be detrimental to product quality. If so, consumer demand for domestically produced lamb products would decline and be represented by a downward shift in the primary demand curve.

Figure 6-4. Effects of Potential Market Power and Changes in Market Power on Equilibrium Quantities and Prices in the Retail, Slaughter, and Farm Levels



6.1.2 An Equilibrium Displacement Model of the Lamb Industry

An equilibrium displacement model is a linear approximation to a set of underlying and unknown demand and supply functions. The model's accuracy depends on the degree of nonlinearity of the true demand and supply functions and the magnitude of deviations from equilibrium being considered. If these deviations are relatively small, then a linear approximation of the true demand and supply functions should be relatively accurate (Brester, Marsh, and Atwood, 2004; Brester and Wohlgenant, 1997; Wohlgenant, 1993). Although *total* producer surplus measurements obtained from linear supply functions may or may not reflect actual values, *changes* in producer surplus caused by shifts in linear supply or demand functions should approximate actual changes provided that such shifts are relatively small.

A general structural model of supply and demand relationships in the lamb industry provides the framework for an equilibrium displacement model. The lamb industry is modeled as a series of primary and derived demand and supply relations and associated equilibria within the farm-retail marketing chain. The model incorporates variable input proportions among live lamb, lamb meat, and marketing service inputs by allowing production quantities to vary across market levels (Tomek and

Robinson, 1990; Wohlgenant, 1993). The use of variable input proportions accounts for input substitution in response to changing output and input prices (Wohlgenant, 1989).

We model the lamb marketing chain as four distinct sectors: retail (consumer), wholesale (processor), slaughter (lamb feeding), and farm (feeder lamb). In addition, lamb imports at the retail and wholesale levels are included in the model. Although we are unable to test for the existence of oligopsony markdown behavior in the slaughter lamb market because of data limitations, we assume the most general case—that lamb packers may exert oligopsony power in the purchase of slaughter lambs.

In general terms, the structural supply and demand model is given by the following (error terms have been omitted):

Retail Lamb Sector:

Domestic retail lamb primary demand:

$$Q_L^{drd} = f_1\left(P_L^{dr}, P_L^{ir}, \boldsymbol{Z}_L^{dr}\right) \tag{6.2}$$

Domestic retail lamb derived supply:

$$Q_L^{drs} = f_2\left(P_L^{dr}, Q_L^{dws}, \boldsymbol{W}_L^{dr}\right) \tag{6.3}$$

Imported retail lamb primary demand:

$$Q_L^{ird} = f_3\left(P_L^{ir}, P_L^{dr}, \boldsymbol{Z}_L^{ir}\right) \tag{6.4}$$

Imported retail lamb derived supply:

$$Q_L^{irs} = f_4\left(P_L^{ir}, Q_L^{iws}, \boldsymbol{W}_L^{ir}\right) \tag{6.5}$$

Wholesale Lamb Sector:

Domestic wholesale lamb derived demand:

$$Q_L^{dwd} = f_5\left(P_L^{dw}, Q_L^{drd}, \boldsymbol{Z}_L^{dw}\right) \tag{6.6}$$

Domestic wholesale lamb derived supply:

$$Q_L^{dws} = f_6\left(P_L^{dw}, Q_L^{dss}, \boldsymbol{W}_L^{dw}\right) \tag{6.7}$$

Imported wholesale lamb derived demand:

$$Q_L^{idw} = f_7\left(P_L^{iw}, Q_L^{ird}, \boldsymbol{Z}_L^{iw}\right) \tag{6.8}$$

Imported wholesale lamb derived supply:

$$Q_L^{iws} = f_8\left(P_L^{iw}, \mathbf{W}_L^{iw}\right) \tag{6.9}$$

<u>*Slaughter Lamb Sector:*</u>

Domestic slaughter lamb derived demand:

$$Q_L^{dsd} = f_9\left(P_L^{dsd}, Q_L^{dwd}, \mathbf{Z}_L^{ds}\right) \tag{6.10}$$

Domestic slaughter lamb derived supply:

$$Q_L^{dsd} = f_{10}\left(P_L^{dss}, Q_L^{dfs}, \mathbf{W}_L^{ds}\right) \tag{6.11}$$

Potential market power price wedge:

$$p_L^{dsd} = f_{11}\left(P_L^{dss}, \theta\right) \tag{6.12}$$

<u>*Feeder Lamb Sector:*</u>

Domestic feeder lamb derived demand:

$$Q_L^{dfd} = f_{12}\left(P_L^{fd}, Q_L^{dsd}, \mathbf{Z}_L^{df}\right) \tag{6.13}$$

Domestic feeder lamb primary supply:

$$Q_L^{dfs} = f_{13}\left(P_L^{df}, \mathbf{W}_L^{df}\right) \tag{6.14}$$

Variable definitions are presented in Table 6-1. The four lamb market sectors are linked by downstream quantity (weight) variables among the demand equations and upstream quantity (weight) variables among the supply equations (Wohlgenant, 1993). Each $\mathbf{Z}_L^{ij}$ and $\mathbf{W}_L^{ij}$ (i = domestic [*d*] or imported [*i*] lamb and j = market levels [*r*—retail, *w*—wholesale, *s*—slaughter, *f*—farm]) represent vectors of demand and supply shifters. These shifters are defined in Section 6.2.4. that describes the structural model and empirical results.

The equilibrium displacement model was developed by assuming market-clearing quantities (e.g., $Q_L^{drd} = Q_L^{drs} = Q_L^{dr}$). Eqs. (6.2) through (6.14) were then totally differentiated, and log differentials were used to express the relations in elasticity

Table 6-1. Variable Definitions for the Equilibrium Displacement and Structural Models

Symbol	Definition	Mean	Standard Deviation
Q_L^{dr}	Quantity (per capita) of domestic retail lamb, pounds	1.51	0.51
Q_L^{ir}	Quantity (per capita) of imported retail lamb, pounds	0.02	0.02
Q_L^{dw}	Quantity of wholesale domestic lamb, billion pounds	0.34	0.09
Q_L^{iw}	Quantity of wholesale imported lamb, billion pounds	0.07	0.05
Q_L^{ds}	Quantity of domestic slaughter lamb, million pounds	687.08	185.09
Q_L^{df}	Quantity of domestic feeder lambs, million head	7.69	2.45
P_L^{dr}	Real price of domestic retail lamb, cents per pound	285.55	27.99
P_L^{ir}	Real price of imported retail lamb, cents per pound	262.97	31.63
P_L^{dw}	Real price of domestic wholesale lamb, cents per pound	126.15	30.93
P_L^{iw}	Real price of imported wholesale lamb, cents per pound	103.57	23.18
P_L^{dsd}	Real demand price of domestic slaughter lamb, dollars per cwt		
P_L^{dss}	Real supply price of domestic slaughter lamb, dollars per cwt	62.03	17.45
P_L^{df}	Real price of domestic feeder lamb, dollars per cwt	66.25	18.37
$\boldsymbol{Z}_L^{ij}$	Demand shifters for the *i*th market (import/domestic) at the *j*th market level	—[a]	—[a]
$\boldsymbol{W}_L^{ij}$	Supply shifters for the *i*th market at the *j*th market level	—[a]	—[a]
$\boldsymbol{\Theta}$	Lamb processor potential market power wedge	—[a]	—[a]
z_L^{dr}	Change in consumer demand for domestic lamb caused by changes in procurement method	—[a]	—[a]
w_L^{dr}	Changes in costs of supplying domestic retail lamb caused by changes in procurement method	—[a]	—[a]
w_L^{dw}	Changes in costs of supplying domestic wholesale lamb caused by changes in procurement method	—[a]	—[a]
w_L^{ds}	Changes in costs of supplying domestic slaughter lamb caused by changes in procurement method	—[a]	—[a]
w_L^{df}	Changes in costs of supplying domestic feeder lamb caused by changes in procurement method	—[a]	—[a]
ρ	$P_L^{dsd} \ / \ P_L^{dss}$	—[a]	—[a]
Q_{be}	Quantity of domestic breeding ewes, million head	7.68	2.75
Q_w^{dw}	Quantity of domestic wholesale wool (graded and scoured), million pounds	91.16	34.37
Q_w^{iw}	Quantity of imported wholesale wool (graded and scoured), million pounds	72.46	30.23

(continued)

Table 6-1. Variable Definitions for the Equilibrium Displacement and Structural Models (continued)

Symbol	Definition	Mean	Standard Deviation
P_L^{de}	Real price of domestic slaughter ewes, dollars per cwt	28.02	6.270
P_L^{dw}	Real price of domestic wholesale wool, cleaned and scoured, cents per pound	73.16	37.700
P_{ct}	Real price of upland cotton, cents per pound	63.50	29.370
P_w	Real domestic wool price, shorn, cents per pound		
P_{sw}	Real domestic wool support price, cents per pound	117.42	61.890
P_w^{iw}	Real import wholesale wool price, cents per pound	283.96	136.060
P_b^r	Real price of retail beef, cents per pound	227.38	41.660
P_k^r	Real price of retail pork, cents per pound	175.53	31.710
P_y^r	Real price of retail poultry, cents per pound	78.91	20.350
P_b^w	Real price of wholesale beef, cents per pound	100.43	29.730
P_k^w	Real price of wholesale pork, cents per pound	59.40	24.420
P_y^w	Real price of wholesale poultry, cents per pound	52.07	17.840
Y	Real per capita personal consumption expenditures, thousand dollars	11.06	1.900
Y_x	Real personal consumption expenditures, billion dollars	2,737.14	744.620
M_c	Index of food marketing costs (1987=100)	313.35	24.000
L_c	Index of food labor costs (1987=100)	324.89	18.170
P_{bp}	Real price of lamb by-products, no. 1 pelt, dollars per pelt	7.18	3.260
E_x	Real U.S./(average Australia and New Zealand exchange rate)	1.11	0.930
E_x^a	Real U.S./Australian exchange rate	1.15	0.930
K	Lamb meat packer four-firm concentration ratio	60.50	9.460
P_n	Real price of no. 2 yellow corn, dollars per bushel	2.66	1.350
P_{hy}	Real price of all hay, dollars per ton	68.33	16.310
R_f	Lamb slaughter price-corn price ratio	26.48	8.130
T	Trend (1970–2003)	16.50	9.960
MD	Binary variable for meat price freeze, 1970–1972=1.0	0.09	0.290
ID	Binary variable for lamb import duty, 1985–1990=1.0	0.18	0.390
WD	Binary variable for loss of wool price support, 1996–2001=1.0	0.82	0.039

[a] Variables without means and standard deviations are inputs to the model and thus do not have data values.

form. This results in the following equilibrium displacement model that was used to approximate changes from initial equilibrium in the U.S. lamb industry:

$$EQ_L^{dr} = \eta_d^{dr} EP_L^{dr} + \eta_d^{ir} EP_L^{ir} + Ez_L^{dr} \tag{6.15}$$

$$EQ_L^{dr} = \epsilon_d^{dr} \; EP_L^{dr} + \tau_d^{wr} EQ_L^{dw} + Ew_L^{dr} \tag{6.16}$$

$$EQ_L^{ir} = \eta^{ir} EP_L^{ir} + \tau_i^{wr} EQ_i^{wr} + EQ_L^{ir} \tag{6.17}$$

$$EQ_L^{ir} = \epsilon^{ir} \; EP_L^{ir} + \tau_i^{wr} EQ_i^{wr} \tag{6.18}$$

$$EQ_L^{dw} = \eta_d^{dw} EP_L^{dw} + \tau_d^{rw} EQ_L^{dr} \tag{6.19}$$

$$EQ_L^{dw} = \epsilon_d^{dw} \; EP_L^{dw} + \tau_d^{sw} EQ_L^{ds} + Ew_L^{dw} \tag{6.20}$$

$$EQ_L^{iw} = \eta_i^{iw} EP_L^{iw} + \tau_i^{rw} EQ_L^{ir} \tag{6.21}$$

$$EQ_L^{iw} = \epsilon^{iw} \; EP_L^{iw} \tag{6.22}$$

$$EQ_L^{ds} = \eta^{ds} EP_L^{ds} + \tau_d^{ws} EQ_L^{dw} \tag{6.23}$$

$$EQ_L^{ds} = \epsilon^{ds} \; EP_L^{ds} + \tau_d^{fs} EQ_L^{df} + Ew_L^{ds} \tag{6.24}$$

$$EP_L^{dsd} = \left(1 / \rho\right) EP_L^{dss} + \left(1 / \rho\right) E\theta \tag{6.25}$$

$$EQ_L^{df} = \eta^{df} EP_L^{df} + \tau_d^{sf} EQ_L^{ds} \tag{6.26}$$

$$EQ_L^{df} = \epsilon^{df} \; EP_L^{df} + Ew_L^{df} \tag{6.27}$$

The term E represents a relative change operator (e.g., $EQ_L^{dr} = dQ_L^{dr} / Q_L^{dr} = d\ln Q_L^{dr}$). Table 6-2 provides definitions for all parameters. In addition, each z_L^{ij} and w_L^{ij} represent single elements of the demand $\left(\boldsymbol{Z}_L^{ij}\right)$ and supply $\left(\boldsymbol{W}_L^{ij}\right)$ shifters. Specifically, these elements represent percentage cost or quality changes from initial equilibria caused by changes in procurement methods. That is, z_L^{dr} represents potential quality shifters for consumer demand for domestic lamb resulting from changes in lamb and meat procurement practices. Similarly, w_L^{ij} represents cost shifters for the primary and derived lamb supply functions, which may result from changes in procurement practices. All other elements of $\boldsymbol{Z}_L^{ij}$ and $\boldsymbol{W}_L^{ij}$ are assumed to remain constant as a result of changes in procurement practices.

Table 6-2. Parameter Definitions, Short-Run and Long-Run Elasticity Estimates Used in the Equilibrium Displacement Model, and Standard Deviations

Parameter	Definition	Estimate[a] Short Run	Estimate[a] Long Run	Standard Deviations[a]
η_d^{dr}	Own-price elasticity of primary demand for retail domestic lamb	–0.523	–1.108	0.160
η_d^{ir}	Cross-price elasticity of demand for retail domestic lamb with respect to the price of retail imported lamb	0.293	0.621	0.117
η_i^{ir}	Own-price elasticity of primary demand for retail imported lamb	–0.407	–0.631	0.262
η_i^{dr}	Cross-price elasticity of demand for retail imported lamb with respect to the price of retail domestic lamb	0.775	1.202	0.330
η_d^{dw}	Own-price elasticity of derived demand for wholesale domestic lamb	–0.350	–1.032	0.064
η_i^{iw}	Own-price elasticity of derived demand for wholesale imported lamb	–0.228	–0.407	0.121
η^{ds}	Own-price elasticity of derived demand for domestic slaughter lamb	–0.333	–0.865	0.043
η^{df}	Own-price elasticity of derived demand for domestic feeder lamb	–0.112	–0.285	0.048
ϵ^{dr}	Own-price elasticity of derived domestic retail lamb supply	0.151	3.963	0.070
ϵ^{ir}	Own-price elasticity of derived imported retail lamb supply	10.000	10.000	NA
ϵ^{dw}	Own-price elasticity of derived domestic wholesale lamb supply	0.158	3.854	0.069
ϵ^{iw}	Own-price elasticity of derived imported wholesale lamb supply	10.000	10.000	NA
ϵ^{ds}	Own-price elasticity of derived domestic slaughter lamb supply	0.118	2.950	0.052
ϵ^{df}	Own-price elasticity of primary domestic feeder lamb supply	0.086	2.261	0.048

[a] Short-run standard deviations for each elasticity are obtained from the structural model that is presented later in the report. Long-run standard deviations are not needed for the analysis.

The equilibrium displacement model was implemented by placing all of the endogenous variables in Eqs. (6.15) through (6.27) onto the left-hand side of each equation:

$$EQ_L^{dr} - \eta_d^{dr} EP_L^{dr} - \eta_d^{ir} EP_L^{ir} = Ez_L^{dr} \tag{6.28}$$

$$EQ_L^{dr} - \epsilon^{dr} EP_L^{dr} - \tau_d^{wr} EQ_L^{dw} = Ew_L^{dr} \tag{6.29}$$

$$EQ_L^{ir} - \eta_i^{ir} EP_L^{ir} - \eta_i^{dr} EP_L^{dr} = 0 \tag{6.30}$$

$$EQ_L^{ir} - \epsilon^{ir} EP_L^{ir} - \tau_i^{wr} EQ_L^{iw} = 0 \tag{6.31}$$

$$EQ_L^{dw} - \eta_d^{dw} EP_L^{dw} - \tau_d^{rw} EQ_L^{dr} = 0 \tag{6.32}$$

$$EQ_L^{dw} - \epsilon^{dw} EP_L^{dw} - \tau_d^{sw} EQ_L^{ds} = Ew_L^{dw} \tag{6.33}$$

$$EQ_L^{iw} - \eta_i^{iw} EP_L^{iw} - \tau_i^{rw} EQ_L^{ir} = 0 \tag{6.34}$$

$$EQ_L^{iw} - \epsilon^{iw} EP_L^{iw} = 0 \tag{6.35}$$

$$EQ_L^{ds} - \eta^{ds} EP_L^{dsd} - \tau_d^{ws} EQ_L^{dw} = 0 \tag{6.36}$$

$$EQ_L^{ds} - \epsilon^{ds} EP_L^{dss} - \tau_d^{fs} EQ_L^{df} = Ew_L^{ds} \tag{6.37}$$

$$\rho EP_L^{dsd} - EP_L^{dss} = E\theta \tag{6.38}$$

$$EQ_L^{df} - \eta^{df} EP_L^{df} - \tau_d^{sf} EQ_L^{ds} = 0 \tag{6.39}$$

$$EQ_L^{df} - \epsilon^{df} EP_L^{df} = Ew_L^{df} \tag{6.40}$$

For any given set of elasticity estimates, Eqs. (6.28) through (6.40) can be used to determine the relative changes in endogenous quantities and prices for any given exogenous changes in costs and/or consumer demand. In matrix notation, Eqs. (6.28) through (6.40) can be written as

$$\boldsymbol{A \bullet Y = B \bullet X}, \tag{6.41}$$

where **A** is a 13x13 nonsingular matrix of elasticities; **Y** is a 13x1 vector of changes in the endogenous price and quantity variables; **B** is a 13x6 matrix of parameters associated with the exogenous variables; and **X** is a 6x1 vector of percentage changes in the exogenous cost, demand, and potential market power shift variables. Relative changes in the endogenous variables (**Y**) caused by relative changes in marketing (procurement) costs and benefits (**X**) are calculated by solving Eq. (6.41) as

$$Y = A^{-1} \bullet B \bullet X \qquad (6.42)$$

6.2 ESTIMATING DEMAND AND SUPPLY ELASTICITIES IN THE LAMB INDUSTRY

Solutions for **Y** in Eq. (6.42) require elasticity estimates for elements of the matrix **A**. The extant literature reports few demand and supply elasticity estimates for the lamb industry. Thus, most of these estimates are obtained by direct estimation.

We estimate a system of structural equations so that resulting elasticity estimates are consistent with respect to sample period and model specification, data generation, methodology, and evaluation procedures. However, it should be noted that several problems occur in estimating lamb demand and supply elasticity coefficients compared with estimating structural elasticities in the beef, pork, and poultry sectors:

- Reported time-series lamb industry data are not as consistent compared with data reported for the other meat sectors, particularly with respect to retail and boxed meat prices, by-product prices, and marketing margins (American Sheep Industry Association, 2003–2004; Babula, 1996).
- Relatively few lamb studies exist for making valid comparisons of elasticity estimates (Babula, 1997). This also makes it difficult to obtain demand and supply elasticity estimates from other external sources.
- Of the lamb studies that exist, the variability of model (structural and time-series) specifications, sample periods, and estimation methods limits validation of our model elasticities with those of other research.

Nonetheless, some elasticity estimates have been reported for certain lamb sectors (e.g., breeding stock, lamb slaughter, imports, and retail demand) and serve as a general benchmark for evaluating our demand and supply parameter estimates (Babula, 1996; Babula, 1997; Capps, Byrne, and Williams, 1995; International Trade Commission, 1999; Van Tassell and Whipple, 1994; Vere, Griffith, and Jones, 2000; Whipple and Menkhaus, 1990; Whipple and Menkhaus, 1989). We discuss comparisons between these published estimates and our estimated elasticities in Section 6.5.

6.2.1 Structural Model Required for Econometric Estimates

To effectively evaluate the economic effects of marketing arrangements in the lamb sector, vertical relationships among demand and supply sectors in the lamb-meat marketing channel should be estimated jointly (Brester, Marsh, and Atwood, 2004; Gardner, 1975; Marsh, 2003; Tomek and Robinson, 1990; Wohlgenant, 1989). In addition, the domestic and import wool and meat sectors should be included (Babula, 1996, 1997; Gardner, 1982; Malecky, 1975). For our structural analysis, the market levels of the lamb industry considered are

1. breeding stock (ewes) and lamb crop production, noted as the feeder lamb level;
2. feedlot production for slaughter, noted as the slaughter lamb level;
3. cull production for slaughter, noted as the slaughter ewe level;
4. carcass production, noted as the wholesale level;
5. retail meat cut production, noted as the retail level;
6. lamb meat imports, specific to the wholesale level;
7. wool production at the wholesale level (wool converted to a scoured basis); and
8. wool imports at the wholesale level (scoured basis for further processing).

The implied demand and supply relationships are characterized by variables unique to each level and also by variables specific to other vertical sectors. For example, meat packer demand for slaughter lambs depends on lamb slaughter price, carcass price at the wholesale level, and marketing costs between packers and retailers.

The advantages of specifying multimarket levels in an econometric model rest with properties of the parameter estimates and comprehensiveness of the comparative statics. A system of demand and supply equations allows parameter estimates to account for vertical information and stochastic error processes that improve the consistency and asymptotic efficiency of parameter estimates (Greene, 2003). For example, parameter estimates of a single-demand equation at the feeder lamb level ignore endogenous, exogenous, and error term information implicit in a demand system that includes upstream slaughter, wholesale, and retail levels (Marsh, 2003; Wohlgenant, 1989).

In a systems model, the comparative statics are contingent on total elasticities. These elasticities measure direct and indirect changes in equilibrium prices and quantities at all market levels from arbitrary shocks (Marsh, 2003; Wohlgenant, 1989). Lamb buyers and sellers at these levels have vested interests in public and private policy changes, which can be evaluated using comparative statics. Examples include lamb quality changes that may shift consumer preferences and demand or restrictions on contracting arrangements that could affect lamb finisher and meat packer transaction and plant utilization costs. The result could be a shift in the feedlot supply of, and the packer demand for, slaughter lambs. Moreover, relative primary demand and supply elasticities, the nature of marketing margins, and the source of market shock(s) determine the distribution of price, quantity, and producer and consumer surplus changes between the marketing levels (Brester, Marsh, and Atwood, 2004; Gardner, 1975; Tomek and Robinson, 1990).

6.2.2 Previous Research on Lamb Industry Elasticities

Research involving demand, supply, and price determination in the sheep and lamb industry is relatively scarce compared with that of other meats (Babula, 1996). This may be the result of the lamb industry’s relatively small share of U.S. per capita meat consumption. For example, 2003 retail per capita consumption of all red meats (beef, veal, pork, and lamb) was 118 pounds, and consumption of all red meat and poultry was 218 pounds (USDA, ERS, 2004b). Per capita lamb consumption was 1.1 pounds in 2003, or one-half of 1% of total meat consumption. In 1970, lamb consumption represented about 2% of total meat consumption.

Lamb’s small market share, however, does not negate its importance to specific consumers and producers of the product. In 2003, U.S. consumers spent about $1.7 billion on retail lamb products, and feeder lamb producers generated about $312.3 million of lambs. The U.S. lamb industry generally produces high-valued cuts for the domestic market and targets cultural and ethnic populations concentrated in the Northeast and

Western states (Jones, 2004b). Lower valued cuts are rendered or sold as pet food. The U.S. exports only small amounts of lamb products. However, most cull ewes and rams are exported to Mexico. The United States imports significant quantities of lamb carcasses and fresh and frozen lamb cuts from Australia and New Zealand. In 2003, lamb imports constituted about 53% of U.S. lamb and mutton consumption (USDA/ERS, 2004a).

Domestic lamb production and marketing are primarily concentrated in Texas, California, Wyoming, South Dakota, and Colorado (USDA/NASS, 2004a). U.S. sheep and lamb production has declined precipitously over the past several decades. Total sheep and lamb inventory has declined from 21.8 million head in 1970 to 6.32 million head in 2003. Concurrently, lamb and sheep slaughter has declined from 10.55 million head to 2.98 million head. Many reasons account for these declines including a long-term decline in the demand for lamb and wool, predator losses, labor costs, termination of wool incentive payments, environmental restrictions, and reduced access to federal grazing lands (Jones, 2004b; U.S. International Trade Commission, 1999).

In light of these problems, research in the lamb industry has focused on supply issues (Purcell, Reeves, and Preston, 1991; Van Tassell and Whipple, 1994; Whipple and Menkhaus, 1989), demand issues (Purcell, 1998; Williams and Capps, 1991; Whipple and Menkhaus, 1989), marketing margin and packer concentration issues (Brester and Musick, 1995; Capps, Byrne, and Williams, 1995; Menkhaus, Whipple, and Ward, 1989), and lamb import issues (Babula, 1996, 1997; U.S. International Trade Commission, 1999). Other research involves econometric modeling of the Australian and New Zealand sheep and lamb industries, including wool markets (Reynolds and Gardiner, 1980; Richie, 1979; Vere, Griffith, and Jones, 2000).

The above studies generally provide information regarding the structure of demand and supply in the lamb industry. A few studies report elasticity estimates. Much of this previous research relates to comparative statics and impact multipliers associated with marketing, risk management, and policy decisions. Also, previous studies evaluated the effects of lamb packer concentration, market price transmissions, and demand and supply variables on lamb marketing margins.

Research on the supply side of the lamb industry has addressed issues related to sheep breeding stock and lamb marketing through the use of structural and time-series models. Van Tassell and Whipple (1994) analyzed the cyclical nature of the U.S. sheep industry in terms of farm prices and sheep breeding inventories using harmonic regressions and both monthly and annual data from 1924 to 1993. GLS methods were used, and results indicated long-term 8- to 13-year cycles for prices and quantities. The Akaike Information Criteria (AIC) was used to detect a 1968 to 1972 structural change, perhaps as a result of the Mideast oil embargo, inflationary pressures, and the U.S. meat price freeze. Whipple and Menkhaus (1989) estimated annual dynamic supply functions for breeding stock, wool production, and lamb slaughter using least squares regression and simulation techniques for the 1924 to 1983 period. Empirical results based on capital formation theory emphasized the importance of output and input prices (including labor cost) on production responses. Estimated long-run supply elasticities (10 years) for breeding stock, lamb slaughter, and wool were elastic (3.05, 2.83, and 1.38, respectively). Vere, Griffith, and Jones (2000) estimated an integrated econometric model of the Australian beef, pork, and lamb industries using quarterly data from 1970 to 1996. Their purpose was to measure the effects of cyclical variations, external events, and policies on the economic activities of the livestock sectors. Structural demand, supply, and price relationships were estimated as partial adjustment processes using simultaneous equations estimators. Estimated supply elasticities for breeding stock ranged from 0.06 to 0.09 in the short run and from 2.52 to 3.34 in the long run. Estimated short-run and long-run lamb marketings (slaughter) supply elasticities were 0.25 and 2.73, respectively. The authors' estimate of the long-run retail elasticity of demand for lamb was –1.54, which was consistent with elastic retail demands for beef (–1.38) and pork (–1.59).

Whipple and Menkhaus (1989), Williams and Capps (1991), Babula (1997), and the International Trade Commission (1999) reported various results from lamb demand research. Estimates of retail primary demand were used to measure consumer responses to marketing and demand diversification programs intended to assist the lamb industry (Jones, 2004a). Estimates of retail demand elasticities varied: Whipple and Menkhaus (1989) reported a retail lamb demand elasticity of –3.96 based on inverting a retail price flexibility estimated by the Yule-Walker approach (1950 to 1987 annual data); Williams and Capps (1991) reported a price elasticity of –0.62 for lamb demand; and Babula's (1997) investigation of the effects of a U.S. countervailing duty on lamb imports estimated the retail demand elasticity as –0.78 using a 3SLS estimator. The U.S. International Trade Commission's investigative report on the U.S. import duty for lamb in 1999 (later rescinded by the World Trade Organization [WTO]) considered a spectrum of retail demand elasticities (–0.75 to –1.25) as relevant for impact analysis.

Analysis of demand and supply behavior in the U.S. lamb industry must consider lamb imports. Imports of high-value lamb carcasses and fresh and frozen lamb meat cuts from Australia and New Zealand have increased, even as overall U.S. lamb consumption has declined (Jones, 2004b). Imports as a share of per capita U.S. lamb consumption have substantially increased from about 6% in 1975 to about 46% in 2003. During the 1985 to 1990 period, the U.S. Department of Commerce imposed a countervailing duty on imports of New Zealand lamb meat. The U.S. government determined that New Zealand lamb industry subsidies were at least partially responsible for increasing import market shares. Babula (1997) econometrically investigated the effects of this countervailing duty on U.S. lamb supply, demand, and price at the meat packing-wholesale level using monthly data from January 1981 to May 1994. Results indicated the countervailing duty increased the wholesale lamb price by 10% and reduced domestic quantity demanded for lamb by 3.5%. The 3SLS estimates of import demand elasticities ranged from –0.08 to –1.14, and cross elasticities (the effect of U.S. lamb price on the demand for lamb imports) ranged from –1.69 to 2.20 (the sign of the former does not meet *a priori* expectations for consumption substitutes). The price elasticity of supply for lamb at the wholesale level was elastic (3.0).

6.2.3 Conceptual Lamb Model for Estimation of Elasticities

This current research requires information on primary and derived demand and supply structures and related price elasticities. Thus, an econometric model of vertical demand and supply relationships in the farm-to-retail marketing system is required. The wool and lamb import markets are necessarily included (Babula, 1997; Gardner, 1982). According to Gardner (1975) and Tomek and Robinson (1990), integrating marketing-chain relationships improves the estimation accuracy of upstream and downstream demand and supply responses. For example, the derived demand elasticity for livestock at the farm level is jointly a function of primary demand, marketing margins, factors specific to other market levels, net imports, and factors specific to the farm level such as feed costs (Marsh, 2003; Wohlgenant, 1989).

A crucial aspect of our econometric model is the estimation of primary demand and primary supply because shifts in these functions affect derived demand and supply functions. Moreover, the effects of initial conditions or shocks in the marketing sector also depend on primary-level elasticities. For example, increased costs incurred by meat packers shift derived slaughter demand and wholesale and retail supply functions. Subsequently, the distribution of these cost changes on prices and quantities at the retail and farm levels is conditional on elasticities of retail demand and farm supply (Brester, Marsh, and Atwood, 2004; Lusk and Anderson, 2004).

The microeconomic theory underlying the behavioral relations of primary consumer demand for lamb and primary producer supply of lamb is derived from first-order conditions of constrained utility maximization and firm profit maximization, respectively (Varian, 1992). Moreover, the derived (input) demands and output supplies in the marketing chain are a function of first-order conditions of firm profit maximization. This optimization principle can be demonstrated by considering a lamb feeding firm that purchases 60- to 80-pound feeder lambs and grain finishes them to 120 to 140 pounds of slaughter weight for sale to meat packers. The firm's unconstrained profit function would be

$$\pi = P_L Q_L - P_f Q_f - \sum_{i=1}^{p} r_i q \ , \qquad (6.43)$$

where π is the feeding firm's profit; P_L is the price of slaughter lambs; Q_L is liveweight quantity of slaughter lambs sold; P_f is price of feeder lambs; Q_f is liveweight quantity of feeder lambs purchased; and r_i and q_i are prices and quantities of other inputs such as feed, labor, medical, and other supplies in the finishing operation. Following Varian (1992), the finisher's supply function for slaughter lambs is based on solving the first-order condition of profit maximization:

$$\frac{\partial \pi \left(P_L, P_f, r_i\right)}{\partial P_L} = Q_L \left(P_L, P_f, r_i\right). \tag{6.44}$$

Eq. (6.44) indicates the supply function of lambs depends on the output price of lambs (P_L), input price of feeder lambs (P_f), and other input costs (r_i).

Similarly, the demand function for feeder lambs is based on solving first-order conditions of profit maximization:

$$\frac{-\partial \pi \left(P_L, P_f, r_i\right)}{\partial P_f} = Q_f \left(P_f, P_L, r_i\right), \tag{6.45}$$

which indicates the input demand function for feeder lambs depends on the input price of lambs, slaughter price of lambs, and other input costs. Since π is a convex function, the second-order derivatives of the left-hand sides of Eqs. (6.44) and (6.45) assure a nonnegative slope of output supply and a nonpositive slope of input demand.

The optimization principle holds for any profit-maximizing (or cost-minimizing) firm operating in competitive marketing channels. Thus, aggregating the relevant micro-level functions of feeder lamb producers, fed lamb producers, lamb packers and processors, and meat retailers yields the appropriate primary and derived market-level functions. The input price vector, r_i, in Eq. (6.43) could also include marketing costs, a relevant proxy for the effects of marketing margins in vertically related agricultural demand and supply functions (Tomek and Robinson, 1990).

6.2.4 Model Specification

Our complete, vertical structural lamb model is an improvement over more limited specifications of previous studies. For purposes of estimating elasticities, we assume that the lamb market is competitive. Hence, individual sellers face infinitely elastic demands and individual buyers face infinitely elastic supplies. This assumption may be questioned because of increased meat packing and retail grocery concentration since the 1980s. However, studies have indicated meat and livestock price distortions from potential market power in these markets are relatively minor (Azzam and Anderson, 1996; Azzam and

Schroeter, 1991; Brester and Marsh, 2001; Marsh and Brester, 2004; Morrison-Paul, 2001).

The structural specifications of the lamb model are as follows:

Domestic Retail Lamb Sector:

Domestic retail lamb demand:

$$Q_L^{drd} = h_1\left(P_L^{drd}, P_L^{ird}, P_B^r, P_K^r, P_Y^r, Y\right) \tag{6.46}$$

Domestic retail lamb supply:

$$Q_L^{drs} = h_2\left(P_L^{drs}, P_L^w, L_c\right) \tag{6.47}$$

Market-clearing quantity:

$$Q_L^{drd} = Q_L^{drs} = Q_L^{dr} \tag{6.48}$$

Market-clearing price:

$$P_L^{drd} = P_L^{drs} = P_L^{dr} \tag{6.49}$$

Imported Retail Lamb Sector:

Imported retail lamb demand:

$$Q_L^{ird} = h_3\left(P_L^{ird}, P_L^{dr}, P_B^r, P_K^r, P_Y^r, Y\right) \tag{6.50}$$

Imported retail lamb supply:

$$Q_L^{irs} = h_4\left(P_L^{irs}, Q_L^{iw}, L_c\right) \tag{6.51}$$

Market-clearing quantity:

$$Q_L^{ird} = Q_L^{irs} = Q_L^{ir} \tag{6.52}$$

Market-clearing price:

$$P_L^{ird} = P_L^{irs} = P_L^{ir} \tag{6.53}$$

Domestic Wholesale Lamb Sector:

Domestic wholesale lamb demand:

$$Q_L^{dwd} = h_5\left(P_L^{dwd}, P_L^{dr}, P_B^w, P_K^w, P_Y^w, M_c\right) \tag{6.54}$$

Domestic wholesale lamb supply:

$$Q_L^{dws} = h_6\left(P_L^{dws}, P_L^{ds}, P_{bp}, L_c\right) \tag{6.55}$$

Market-clearing quantity:

$$Q_L^{dwd} = Q_L^{dws} = Q_L^{dw} \tag{6.56}$$

Market-clearing price:

$$P_L^{dwd} = P_L^{dws} = P_L^{dw} \tag{6.57}$$

Imported Wholesale Lamb Sector:

Imported wholesale lamb demand:

$$Q_L^{iwd} = h_7\left(P_L^{iwd}, P_L^{dw}, E_x, P_K^w, P_Y^w\right) \tag{6.58}$$

Imported wholesale lamb supply:

$$Q_L^{iws} = h_8\left(P_L^{iws}, C_L^i, E_x, Q_{az}\right) \tag{6.59}$$

Market-clearing quantity:

$$Q_L^{iwd} = Q_L^{iws} = Q_L^{iw} \tag{6.60}$$

Market-clearing price:

$$P_L^{iwd} = P_L^{iws} = P_L^{iw} \tag{6.61}$$

Domestic Slaughter Lamb Sector:

Domestic slaughter lamb demand:

$$Q_L^{dsd} = h_9\left(P_L^{dsd}, P_L^{dw}, M_c P_{bp}, K\right) \tag{6.62}$$

Domestic slaughter lamb supply:

$$Q_L^{dss} = h_{10}\left(P_L^{dss}, P_L^f, P_n, P_w\right) \tag{6.63}$$

Market-clearing quantity:

$$Q_L^{dsd} = Q_L^{dss} = Q_L^{ds} \tag{6.64}$$

Market-clearing price:

$$P_L^{dsd} = P_L^{dss} = P_L^{ds} \tag{6.65}$$

Domestic Slaughter Ewe (Cull) Sector:

Domestic slaughter ewe demand:

$$Q_L^{ded} = h_{11}\left(P_L^{ded}, P_L^{dw}, M_c P_{bp}, K\right) \tag{6.66}$$

Domestic slaughter ewe supply:

$$Q_L^{des} = h_{12}\left(P_L^{des}, P_{hy}, P_w, Q_{be}\right) \tag{6.67}$$

Market-clearing quantity:

$$Q_L^{ded} = Q_L^{des} = Q_L^{de} \tag{6.68}$$

Market-clearing price:

$$P_L^{ded} = P_L^{des} = P_L^{de} \tag{6.69}$$

<u>Domestic Feeder Lamb Sector:</u>

Domestic feeder lamb demand:

$$Q_L^{dfd} = h_{13}\left(P_L^{dfd}, R^f\right) \tag{6.70}$$

Domestic lamb crop:

$$Q_L^{dfs} = h_{14}\left(Q_{be}, T\right) \tag{6.71}$$

Domestic breeding ewe supply:

$$Q_L^{des} = h_{15}\left(P_L^{df}, P_{hy}, P_w, P_{sw}, P_L^{de}\right) \tag{6.72}$$

Market-clearing quantity:

$$Q_L^{dfd} = Q_L^{dfs} = Q_L^{df} \tag{6.73}$$

Market-clearing price:

$$P_L^{dfd} = P_L^{dfs} = P_L^{df} \tag{6.74}$$

<u>Domestic Wholesale Wool Sector:</u>

Domestic wholesale wool demand:

$$Q_w^{dwd} = h_{16}\left(P_w^{dwd}, P_w^{iwd}, P_{ct}, Y_x\right) \tag{6.75}$$

Domestic wholesale wool supply:

$$Q_w^{dws} = h_{17}\left(P_w^{dws}, P_{ws}, Q_L^{df}, D_{Lw}\right) \tag{6.76}$$

Market-clearing quantity:

$$Q_w^{dwd} = Q_w^{dws} = Q_w^{dw} \tag{6.77}$$

Market-clearing price:

$$P_w^{dwd} = P_w^{dws} = P_w^{dw} \tag{6.78}$$

Imported Wholesale Wool Sector:

Imported wholesale wool demand:

$$Q_w^{iwd} = h_{18}\left(P_w^{iwd}, P_w^{dw}, P_{ct}, Y_x, E_x^a\right) \tag{6.79}$$

Imported wholesale wool supply:

$$Q_w^{iws} = h_{19}\left(P_w^{iws}, C_w^i, E_x^a, Q_{az}\right) \tag{6.80}$$

Market-clearing quantity:

$$Q_w^{iwd} = Q_w^{iws} = Q_w^{iw} \tag{6.81}$$

Market-clearing price:

$$P_w^{iwd} = P_w^{iws} = P_w^{iw} \tag{6.82}$$

Table 6-1 provides variable definitions for the lamb model. The demand and supply equations are expressed with quantities as dependent variables. For all market-level sectors, prices and quantities are assumed to be in equilibrium within annual time periods.

Eqs. (6.46) and (6.47) represent domestic primary retail demand and derived retail supply of lamb, respectively. Retail demand is a function of domestic retail lamb price $\left(P_L^{dr}\right)$; import retail lamb price $\left(P_L^{ir}\right)$; retail prices of beef, pork, and poultry $\left(P_B^r, P_K^r, P_Y^r\right)$; and per capita personal consumption expenditures (Y). Retail supply is a function of domestic retail lamb price $\left(P_L^{dr}\right)$, wholesale lamb price $\left(P_L^{dw}\right)$, and food labor costs (L_c). Eqs. (6.50) and (6.51) represent import retail demand and import retail supply of lamb, respectively. Import demand is a function of retail import lamb price $\left(P_L^{ir}\right)$, domestic retail lamb price $\left(P_L^{dr}\right)$, and other neoclassical arguments given in Eq. (6.46). Import supply is a function of import retail price $\left(P_L^{ir}\right)$, the wholesale import supply of lamb $\left(Q_L^{iw}\right)$, and food labor costs (L_c). The variable $\left(Q_L^{iw}\right)$ serves as the base for import retail supply and consists of imported wholesale lamb carcasses and lamb cuts (fresh and frozen) that are further processed into retail cuts.

Domestic wholesale demand and supply of lamb are given by Eqs. (6.54) and (6.55). Wholesale demand is a function of wholesale lamb price $\left(P_L^{dw}\right)$, retail lamb price $\left(P_L^{dr}\right)$, wholesale prices of competitive meats $\left(P_B^w, P_K^w, P_Y^w\right)$, and food marketing costs (M_c). Wholesale lamb supply is a function of wholesale lamb price $\left(P_L^{dw}\right)$, input price of slaughter lamb $\left(P_L^{ds}\right)$, lamb by-product value (pelt price, P_{bp}), and food labor cost (L_c).

Wholesale lamb import demand and import supply are represented by Eqs. (6.58) and (6.59). Lamb import demand is a function of wholesale lamb import price $\left(P_L^{iw}\right)$; the price of wholesale lamb $\left(P_L^{dw}\right)$; the U.S./(average of Australian and New Zealand) exchange rate (E_x); and the wholesale prices of beef, pork, and poultry $\left(P_B^w, P_K^w, P_Y^w\right)$. Wholesale lamb import supply depends on lamb import price $\left(P_L^{iw}\right)$, Australian and New Zealand export costs $\left(C_L^i\right)$, the U.S./(average Australian and New Zealand) exchange rate (E_x), and quantity of lamb and sheep production in Australia and New Zealand (Q_{az}).

Domestic lamb slaughter demand and supply are given in Eqs. (6.62) and (6.63). Slaughter (meat packer) demand is a function of slaughter lamb price $\left(P_L^{ds}\right)$, wholesale price of lamb $\left(P_L^{dw}\right)$, food marketing costs (M_c), lamb by-product value (pelt price, P_{bp}), and lamb meat packer concentration (K). Slaughter supply (by lamb feeders) is a function of slaughter lamb price $\left(P_L^{ds}\right)$, input price of feeder lambs $\left(P_L^{df}\right)$, the price of feed corn (P_n), and the price of shorn wool (P_w).

The demand and supply for cull sheep (ewes and rams) is provided by Eqs. (6.66) and (6.67). Packer demand depends on ewe slaughter price $\left(P_L^{de}\right)$, wholesale price of lamb $\left(P_L^{dw}\right)$, food marketing costs (M_c), lamb by-product value (pelt price, P_{bp}), and lamb packer concentration (K). Cull sheep supply is a function of ewe slaughter price $\left(P_L^{de}\right)$, the price of hay (P_{hy}), the price of shorn wool (P_w), and breeding stock inventory (Q_{be}). Age distributions of the breeding stock constrain the supply of cull sheep (Whipple and Menkhaus, 1989).

Domestic demand for feeder lambs (by lamb feeders) and supply of feeder lambs (by lamb producers) are expressed in Eqs. (6.70) and (6.71). The derived demand for feeder lambs represents the major input demanded by lamb finishers. Eq. (6.70) specifies feeder lamb demand as a function of feeder lamb price $\left(P_L^{df}\right)$ and the lamb price-corn price ratio (R^f), which is a proxy for feedlot profitability (Marsh, 1999). The supply of feeder lambs (Eq. 6.71) is expressed as a function of sheep breeding inventories (Q_{be}) and a trend factor (T) to account for changes in technology/productivity of lamb production. Eq. (6.72) represents breeding sheep inventories, which provide the basis for feeder lamb production (Whipple and Menkhaus, 1989). Breeding inventory (or supply of breeding stock) depends on the output price of feeder lambs $\left(P_L^{df}\right)$, price of hay (P_{hy}), the price of shorn wool (P_w), the wool support price (P_{sw}), and the slaughter price of ewes $\left(P_L^{de}\right)$. Breeding inventories are specified to recursively enter Eq. (6.71). Therefore, the economic variables that determine breeding inventories also affect the production of feeder lambs.

Eqs. (6.75) through (6.82) represent the wool sector. Wool has been a critical joint product of the lamb and sheep industry. Producers received wool support (direct) payments under the National Wool Act of 1954 until 1995. The Wool Act was subsequently suspended between 1996 and 2001 (Jones, 2004b). The Farm Security and Rural Investment Act of 2002 reinstated wool price supports through marketing assistance loans and loan deficiency payments for the 2002 to 2007 lamb crops. Before the termination of the 1954 Wool Act, wool revenues accounted for about 20% to 25% of total revenues in the lamb and sheep industry. Since the Act's termination, wool's revenue share has fallen to about 10% (Jones, 2004b).

USDA data indicate that from 1990 to 2003, about 57% of wool consumed in the United States was imported, primarily from Australia, New Zealand, Canada, South Africa, and South America (USDA/NASS, 2004a). The imports consist of graded, clean content wool usable for further processing to produce apparel and carpets.

Domestic wool demand and supply are represented by Eqs. (6.75) and (6.76), respectively. Domestic wool demand depends on domestic wool price $\left(P_L^{dw}\right)$, import wool price $\left(P_L^{iw}\right)$, the price of cotton (P_{ct}), and personal consumption expenditures (Y_x). Domestic wool supply depends on domestic wool market price $\left(P_L^{dw}\right)$, wool support price (P_{sw}), and the potential for wool production, for which the production of lambs serves as a proxy, $\left(Q_L^{df}\right)$, and a wool binary variable (D_{Lw}) to account for the 1996 to 2001 period during which wool price supports were halted.

Wholesale import demand and supply of wool are represented by Eqs. (6.79) and (6.80). Import demand (Eq. [6.79]) is a function of wool import price $\left(P_L^{iw}\right)$, domestic wool price $\left(P_L^{dw}\right)$, price of cotton (P_{ct}), personal consumption expenditures (Y_x), and the United States/Australian exchange rate $\left(E_x^a\right)$. Wool import supply (Eq. [6.80]) is a function of wool import price $\left(P_L^{iw}\right)$, cost of producing wool for export by Australia and New Zealand $\left(C_w^i\right)$, United States/Australian exchange rate $\left(E_x^a\right)$, and quantity of sheep and lambs produced in Australia and New Zealand (Q_{az}).

U.S. trade in live sheep and lambs is very small (Jones, 2004b). Thus, live lamb imports are not considered in the model.

6.2.5 Other Model Considerations

The structural model includes a variety of economic factors, such as feed prices, prices of competitive meats (including lamb imports), personal consumption expenditures, lamb packer concentration, input prices, food marketing costs, and exchange rates. The sample period includes several decades during which other factors may also be of potential significance. Three specific events are the structural change in meat demand and the meat price freeze of the early 1970s (Knutson, Penn, and Boehm, 1990; Van Tassel and Whipple, 1994), the 1993 suspension of the 1954 Wool Act (Public Law 103-130) resulting in no wool price supports from 1996 to 2001 (Jones, 2004b), and U.S. countervailing duties on New Zealand lamb imports from 1985 to 1990 (Babula, 1997). As noted in Table 6-1, these events are accounted for with binary variables labeled *MD*, *WD*, and *ID*, respectively. The meat binary variable (*MD*) is included in all demand equations. The import duty binary variable (*ID*) is included in wholesale and retail lamb demand equations, and the wool binary variable (*WD*) is included in the wool supply equation. In addition, the model should account for dynamic effects such as consumer demand and technology/productivity changes (Brester and Marsh, 2001). Trend variables (*T*) are used to account for these changes.

6.2.6 Model Dynamics

Conceptually, the lamb and wool model represents a set of economically integrated demand and supply relations in the farm–retail marketing chain. The static form of the model can be represented in general matrix notion as

$$\beta Y_t + \Gamma Z_t = \mu_t , \tag{6.83}$$

where Y_t is a Gx1 vector of endogenous variables, Z_t is a Kx1 vector of exogenous variables, μ_t is a Gx1 vector of disturbance terms, β is a GxG matrix of coefficients for the Y_t vector, and Γ is a GxK matrix of coefficients for the Z_t vector. The model assumes zero off-diagonal terms for the β matrix, rank identification of the Γ matrix, and a nondiagonal covariance matrix for μ_t, or contemporaneously correlated errors (Johnston and DiNardo, 1997). The μ_t's within each equation are assumed to be normally distributed with zero mean and constant variance; however, their time-series properties may be autoregressive (Greene, 2003).

Assuming cointegrated relationships allows the model to be estimated in data-level form by a system's GLS estimator, or Seemingly Unrelated Regressions (SUR). The estimator yields consistent and asymptotically efficient coefficient distributions (Greene, 2003). However, if β is characterized by nonzero off-diagonals (i.e., joint dependency), then 3SLS estimates are appropriate.

The presence of biological lags, technical production constraints, and buyer and seller expectations likely generate dynamics in livestock and meat supply and demand behavior (Brester and Marsh, 1983; Marsh, 2003; Rucker, Burt, and LaFrance, 1984; Tomek and Robinson, 1990; Whipple and Menkhaus, 1989). Thus, Eq. (6.83) is modified to account for partial adjustment processes in the behavioral relations through autoregressive distributed lags (ARDL) or ARMAX (ARDL with autocorrelated errors) (Greene, 2003; Marsh, 2003). In this context, the model can be rewritten as

$$\beta(L)Y_t + \Gamma(L)Z_t = \mu_t , \tag{6.84}$$

where $\beta(L)$ and $\Gamma(L)$ are polynomial lag operators that impose finite lag structures on the endogenous (Y_t) and exogenous (Z_t) vectors. The lag operators are given as

$$\beta(L) = 1 - \beta_1 L - \beta_2 L^2 - \beta_3 L^3 \dots \beta_p L^p \tag{6.85}$$

and

$$\Gamma(L) = \Gamma_0 + \Gamma_1 L + \Gamma_2 L^2 + \Gamma_3 L^3 \dots \Gamma_q L^q . \tag{6.86}$$

Thus, the polynomial form $\beta(L)Y_t$ of Eq. (6.85) gives $L^pY_t = Y_{t-p}$, and the polynomial form $\Gamma(L)Z_t$ of Eq. (6.86) gives $L^qZ_t = Z_{t-q}$. Solving for the Y_t vector of Eq. (6.84) gives

$$Y_t = \frac{\Gamma(L)}{\beta(L)} Z_\tau + \frac{1}{\beta(L)} \mu_\tau , \qquad (6.87)$$

which conceptually gives Y_T as an infinite distributed lag function of Z_t and μ_t (Greene, 2003). The implied set of polynomial coefficient weights for Z_t are formed by the rational generating function, $\Gamma(L)/\beta(L)$. The infinite moving average (MA) error structure for μ_t is restricted by the polynomial weights of $\beta(L)$. The rational generating function allows for short-run flexibility in the distributed lag patterns of the exogenous variables. However, the long-run behavior of each Z variable is conditioned by $\beta(L)$ (Greene, 2003).

Pragmatically, the empirical lags on the dependent variables (p in Eq. [6.85]) and the independent variables (q in Eq. [6.86]) for livestock and meat are usually of order 1 or 2 (Marsh, 2003). Van Tassell and Whipple (1994) found cyclical lengths in breeding sheep inventories and lamb prices (1924 to 1993 annual data) that averaged between 8 and 13 years. However, they indicated that cycle lengths have shortened in recent years. Thus, for the supply side of the lamb market, p is initially specified in the polynomial denominator as order 2 (permitting complex roots or cycling), and q is initially specified as order 1 in the polynomial numerator. For the demand side of the market, p and q of the polynomials are initially set at lag order 1, which implies geometric distributed lags.

The number of parameters for empirical estimation is relatively large using these initial specifications of lag orders. To achieve a more parsimonious set of parameters and improve estimation efficiency, higher order lags are truncated if they are found to be statistically insignificant. However, for any given variable, if contemporaneous and lag values are all found to be insignificant, the parameter value with the largest t-statistic is retained in the model to maintain theoretical consistency.

6.3 DATA CONSIDERATIONS

The sample period consists of annual data for the years 1970 to 2003. As noted by Capps, Byrne, and Williams (1995), the dearth of published work in the lamb industry can be attributed, in part, to data deficiencies. For the current study, market-level price and quantity data specific to live lamb, lamb meat, wool production, wool and pelt prices, food marketing and labor costs, meat prices, corn and hay prices, and trade data were obtained from various USDA sources. They include the *Agricultural Statistics*; *Livestock, Dairy and Poultry Situation and Outlook* reports; *Red Meats Yearbook*; *Dairy, Livestock, and Poultry: U.S. Trade and Prospects*; and the American Sheep Industry Association. Other data were obtained from the *Economic Report of the President*, international financial statistics of the International Monetary Fund (various issues), and USDA, GIPSA (2002).

Complete data series were available for most of the variables identified in the model. However, a few variables lacked a consistent data series; therefore, missing observations were imputed. These variables included retail lamb and lamb import prices, wholesale lamb import price, lamb pelt price, and wholesale lamb cut-out-value.

The retail lamb price series was the most problematic because it contained several missing observations. The USDA's ERS published average (retail cut) price data for the years 1970 to 1980 and the American Sheep Industry Association (2003–2004) provided average (retail cut) price data for the years 1987 to 1996 and 2001 to 2003. Missing observations for the years 1981 to 1986 and 1997 to 2000 were imputed using least squares regression. Following Capps, Byrne, and Williams (1995), available data on retail lamb prices were initially regressed onto a constant term, lamb carcass price, trend, and trend squared. However, the trend variables were deleted from the model because they were found to be statistically insignificant. The retail lamb import price series was constructed by adding the domestic wholesale-retail basis (retail price less wholesale price) for lamb to the wholesale import price of lamb.

The wholesale price of imported lamb was calculated by dividing the U.S. import value of lamb, mutton, and goat meat (fresh and frozen) by import quantities (carcasses and primals on a carcass equivalent basis) (*USDA Dairy, Livestock, and Poultry: U.S. Trade and Prospects*). This import price measure is quite aggregate but was included because the American Sheep Industry Association could provide only cost, insurance, and freight (c.i.f.) price data for Australia and New Zealand lamb carcasses and primals from 1998 to the present. The correlation between calculated import prices and American Sheep Industry Association's c.i.f. data for the years 1998 to 2003 was relatively high.

Data for lamb pelt prices (a proxy for lamb by-product values) was reported for the years 1976 to 2003 (American Sheep Industry Association). The use of econometrically backcasted pelt prices for the 1970 to 1975 period resulted in poor empirical results. Consequently, the shorn wool market price was used as a proxy for pelt price in the appropriate regression equations.

Prices of lamb carcasses (East Coast) are used as measures of domestic wholesale prices in the model. Lamb cut-out values may be a better measure for this series. However, cut-out values have only been reported since 2001. All price and value variables were deflated by the CPI (CPI, 1982–84=100) obtained from the *Economic Report of the President*.

6.4 STATISTICAL AND ESTIMATION PROCEDURE CONSIDERATIONS

A series of diagnostic tests were conducted to ensure appropriate statistical properties of the data. For example, unit root and cointegration tests were used to examine the time-series properties and stationarity of the data. If the data are found to be nonstationary and not cointegrated, then subsequent regression results could yield spurious results and misleading inferences. ADF unit root tests indicated unit roots (or nonstationarity) in many of the lamb model variables. Unit roots may cause spurious regression results (i.e., unreliable asymptotic t-values and inconsistent parameter estimators) if the equations to be estimated are not cointegrated (Johnston and DiNardo, 1997). However, ADF tests of OLS residuals of each lamb equation rejected the null hypothesis of unit roots at the $\alpha = 0.05$ level. Thus, the model was estimated in data-level form (but with all variables in natural logarithms).

Wu-Hausman tests were conducted to identify potential joint endogeneity in the right-hand-side variables (Johnston and DiNardo, 1997). The rational lag structure of Eq. (6.83) resulted in insignificant coefficients for several contemporaneous prices, leaving only lag orders of t–1 as statistically significant (particularly in the supply equations). Thus, Wu-Hausman tests were conducted only in the equations with significant slope coefficients on current period (t) prices (primarily the demand functions). Results for those equations failed to reject the null hypothesis of no simultaneous equations bias at the α = 0.05 level.

Based on the lamb model assumptions and statistical tests, the Eviews 5.1 SUR estimator with iterative nonlinear GLS solutions was used because of the potential for a nondiagonal covariance matrix and AR errors (Quantitative Micro Software, 2004). Because the model is specified with equilibrium quantities as dependent variables, the demand and supply equations are estimated in separate blocks to reduce demand and supply identification problems.

In applied agricultural economics research, demand and supply equations are often econometrically estimated using a combination of inverse and ordinary demand and supply functions to aid in identifying supply and demand functions (Eales and Unnevehr, 1993; Eales, 1996; Marsh, 2003; Babula, 1997). However, the equilibrium displacement model for lamb is specified such that estimates of elasticities (rather than flexibilities) of demand and supply are required. Theoretically, the inverses of price flexibilities obtained from inverse demand and/or supply functions provide lower-bound estimates for elasticities. Empirically, these inverses often generate unreasonably large elasticity estimates. We investigated this issue by estimating the demand functions of our model as price-dependent relations. This approach yielded several inconsistencies among estimates across the model. Therefore, we ameliorated the identification issues by estimating ordinary demand functions and ordinary supply functions in separate regression blocks.

Finally, the entire rational distributed lag model was also estimated using quarterly data. However, a lack of consistently reported quarterly data required the use of a variety of proxies to complete each series. Consequently, empirical results of the quarterly model were determined to be inferior to the results of the annual model for the purposes of this study.

6.5 EMPIRICAL RESULTS

Table 6-2 presents SUR estimates for lamb market-level demand and supply elasticities, and Table 6-3 presents the SUR estimates of the lamb market-level transmission elasticities. The empirical results support the rational lag hypotheses because each equation contains a significant parameter estimate of the lagged dependent variable for first-order difference equations or geometric distributed lags (Pindyck and Rubinfeld, 1998). However, the sheep breeding or stock adjustment equation (of supply) was estimated as a second-order difference equation with two real roots resulting in dampened polynomial lags (Griliches, 1967). Based on Durbin h tests, the demand and supply equations did not require AR error corrections in the GLS estimator.

Table 6-3. Parameter Definitions, Quantity Transmission Elasticity Estimates, and Variances

Parameter	Definition	Estimate[a]	Standard Deviation[a]
τ_d^{rw}	Percentage change in domestic wholesale lamb quantity given a 1% change in domestic retail lamb quantity	0.839	0.066
τ_i^{rw}	Percentage change in imported wholesale lamb quantity given a 1% change in imported retail lamb quantity	1.027	0.024
τ_d^{ws}	Percentage change in domestic slaughter lamb quantity given a 1% change in domestic wholesale lamb quantity	0.999	0.008
τ_d^{sf}	Percentage change in domestic feeder lamb quantity given a 1% change in domestic slaughter lamb quantity	1.075	0.060
τ_d^{wr}	Percentage change in domestic retail lamb quantity given a 1% change in domestic wholesale lamb quantity	0.843	0.069
τ_i^{wr}	Percentage change in imported retail lamb quantity given a 1% change in imported wholesale lamb quantity	0.892	0.021
τ_d^{ws}	Percentage change in domestic wholesale lamb quantity given a 1% change in domestic slaughter lamb quantity	1.008	0.008
τ_d^{fs}	Percentage change in domestic slaughter lamb quantity given a 1% change in domestic feeder lamb quantity	0.783	0.042

[a] These estimates are obtained from the structural model that is presented later in the report.

The SUR blocks indicated contemporaneously correlated errors, with zero-order correlations running as high as 0.89 within the demand block and as high as 0.95 within the supply block. The systems estimator also provided the standard errors and covariances of the parameter estimates required for the equilibrium displacement model (Brester, Marsh, and Atwood, 2004). The adjusted R^2's and standard errors of regression are presented but should be interpreted with caution because of the GLS error covariance transformations of the product moment matrices (Greene, 2003).

Estimating fully specified supply and demand models is necessary to obtain consistent estimates of the elasticities needed to implement the equilibrium displacement model. In general, the following discussion of the estimated elasticities focuses on those that are used in the equilibrium displacement model.

6.5.1 Domestic Demand

SUR estimators provide consistent elasticity estimates for use in the equilibrium displacement model. All of the estimates of interest (own-price and cross-price elasticities) are significantly different from zero at the α = 0.05 level.[1] The price elasticities follow two patterns that are consistent with stable difference equations and marketing margin behavior (Griliches, 1967; Tomek and Robinson, 1990). First, the short-run elasticities are considerably smaller than the long-run elasticities. This suggests that consumers and intermediate purchasers are influenced by habit formations and institutional rigidities (Pollack, 1970). These expectations are manifest in partial adjustment processes as evidenced by significant and less-than-unity coefficient estimates on lagged dependent variables. Second, the absolute value of demand elasticity coefficients decrease from the retail level to the farm level. This is consistent with relative price spreads and primary and derived demand theory (Gardner, 1975; Tomek and Robinson, 1990; Wohlgenant, 1989).

Table 6-2 summarizes the demand elasticity estimates obtained from the SUR estimates presented in Tables 6-4 through 6-7. The long-run elasticities are calculated by dividing the short-run elasticities by 1.0, minus the estimated coefficients of the

[1] Some of the parameter estimates (elasticities) in the demand block were not statistically different from zero at the α = 0.05 level. The meat demand binary variable (MD) was omitted from several demand equations, and the import duty binary variable (ID) was omitted from the wholesale lamb demand equation.

Table 6-4. SUR (Double Log) Estimates of Domestic and Imported Retail Lamb Demand

Regressors	Dependent Variables: Domestic Retail Lamb Demand $\left(Q_L^{dr}\right)$	Dependent Variables: Imported Retail Lamb Demand $\left(Q_L^{ir}\right)$
Constant	5.109 (2.038)	–24.485 (–3.765)
Domestic retail lamb price $\left(P_L^{dr}\right)$	–0.523 (–3.277)	0.775 (2.352)
Imported retail lamb price $\left(P_L^{ir}\right)$	0.293 (2.516)	
Retail beef price $\left(P_b^{r}\right)$	–0.041 (–0.352)	0.576 (1.490)
Retail pork price $\left(P_K^{r}\right)$	–0.201 (–1.489)	0.309 (0.773)
Retail poultry price $\left(P_Y^{r}\right)$	0.350 (2.033)	0.600 (1.200)
Per capita expenditures (*Y*)	–0.567 (–1.390)	1.667 (1.861)
Meat binary variable (*MD*)	0.254 (4.707)	1.524 (7.852)
Import binary variable (*ID*)	0.054 (2.324)	
Lagged domestic retail lamb demand $\left(Q_{Lt-1}^{dr}\right)$	0.528 (6.913)	
Lagged imported retail lamb price $\left(P_{Lt-1}^{ir}\right)$		–0.407 (–1.549)
Lagged imported retail lamb demand $\left(Q_{Lt-1}^{ir}\right)$		0.355 (4.209)
Trend (*T*)	0.003 (0.307)	0.043 (1.826)
Regression Statistics:		
Adjusted R^2	0.958	0.911
Standard error of the regression	0.051	0.176
Log mean of the dependent variable	0.351	–3.970

Table 6-5. SUR (Double Log) Estimates of Domestic and Import Wholesale Lamb Demand

	Dependent Variables	
Regressors	**Domestic Wholesale Lamb Demand $\left(Q_L^{dw}\right)$**	**Imported Wholesale Lamb Demand $\left(Q_L^{iw}\right)$**
Constant	2.040 (2.056)	–10.508 (–4.347)
Domestic wholesale lamb price $\left(P_L^{dw}\right)$	–0.350 (–5.478)	
Domestic retail lamb price $\left(P_L^{dr}\right)$	0.039 (0.480)	
Wholesale beef price $\left(P_B^{w}\right)$	–0.020 (–0.425)	0.513 (1.742)
Wholesale pork price $\left(P_K^{w}\right)$	–0.010 (–0.213)	0.110 (0.655)
Wholesale poultry price $\left(P_Y^{w}\right)$	–0.049 (–0.892)	0.726 (2.056)
Food marketing costs (M_c)	–0.068 (–0.410)	
Trend (T)	–0.017 (–5.269)	0.089 (4.877)
Lagged domestic wholesale lamb demand $\left(Q_{Lt-1}^{dw}\right)$	0.661 (10.474)	
Lagged imported wholesale lamb price $\left(P_{Lt-1}^{iw}\right)$		–0.228 (–1.888)
Lagged domestic wholesale lamb price $\left(P_{Lt-1}^{dw}\right)$		0.555 (2.462)
Exchange rate (E_x)		–0.074 (–0.435)
Meat binary variable (MD)		1.568 (7.667)
Lagged imported wholesale lamb demand $\left(Q_{Lt-1}^{iw}\right)$		0.440 (5.734)
<u>*Regression Statistics:*</u>		
Adjusted R^2	0.973	0.901
Standard error of the regression	0.040	0.202
Log mean of the dependent variable	–1.132	–2.951

Table 6-6. SUR (Double Log) Estimates of Domestic Slaughter Lamb and Ewe Demand

Regressors	Dependent Variables	
	Domestic Slaughter Lamb Demand $\left(Q_L^{ds}\right)$	**Domestic Ewe Demand** $\left(Q_L^{de}\right)$
Constant	5.513 (4.233)	11.324 (3.280)
Domestic slaughter lamb price $\left(P_L^{ds}\right)$	–0.333 (–7.670)	
Lagged domestic wholesale lamb price $\left(P_{Lt-1}^{dw}\right)$	–0.011 (–0.196)	
Food marketing costs (M_c)	–0.217 (–1.456)	–1.109 (–2.254)
Lamb by product price (P_{bp})	0.036 (2.961)	0.092 (1.720)
Lamb packer concentration (K)	–0.062 (–1.668)	–0.085 (–0.517)
Trend (T)	–0.016 (–5.436)	–0.033 (–4.678)
Lagged domestic slaughter lamb demand $\left(P_{Lt-1}^{ds}\right)$	0.615 (9.529)	
Slaughter ewe price $\left(P_L^{de}\right)$		–0.245 (–2.605)
Domestic wholesale lamb Price $\left(P_L^{dw}\right)$		–0.281 (–1.836)
Meat binary variable (MD)		–0.150 (–1.602)
Lagged domestic ewe demand $\left(Q_{Lt-1}^{de}\right)$		0.385 (3.877)
Regression Statistics:		
Adjusted R^2	0.980	0.919
Standard error of the regression	0.035	0.108
Log mean of the dependent variable	6.484	3.687

Table 6-7. SUR Double Log Estimates of Domestic Feeder Lamb, Domestic Wool, and Imported Wool Demand

Regressors	Dependent Variables		
	Domestic Feeder Lamb Demand $\left(Q_L^{df}\right)$	Domestic Wholesale Wool Demand $\left(Q_w^{dw}\right)$	Imported Wholesale Wool Demand $\left(Q_L^{df}\right)$
Constant	1.297 (2.907)	7.983 (1.058)	11.039 (1.361)
Domestic feeder lamb price $\left(P_L^{df}\right)$	–0.112 (–2.339)		
Lagged lamb-corn price ratio $\left(R_{t-1}^{f}\right)$	0.055 (1.828)		
Trend (*T*)	–0.015 (–3.612)	0.029 (1.112)	–0.024 (–0.671)
Lagged domestic feeder lamb demand $\left(Q_{Lt-1}^{df}\right)$	0.606 (5.615)		
Lagged domestic wholesale wool price $\left(P_{w\,t-1}^{dw}\right)$		–0.126 (–1.390)	0.522 (2.731)
Lagged cotton price ($P_{c\ t-1}$)		0.255 (2.047)	0.256 (1.420)
Expenditures (Y_x)		–1.080 (–1.105)	–1.148 (–1.046)
Lagged domestic wholesale wool demand $\left(Q_{w\,t-1}^{dw}\right)$		0.922 (9.480)	
Imported wholesale wool price $\left(P_w^{iw}\right)$			–0.647 (–3.215)
Exchange rate $\left(E_z^{u}\right)$			–0.811 (–3.890)
Meat binary variable (*MD*)			0.329 (1.581)
Lagged imported wholesale wool $\left(Q_{w\,t-1}^{iw}\right)$			0.661 (6.961)
Regression Statistics:			
Adjusted R^2	0.98	0.739	0.793
Standard error of the regression	0.043	0.184	0.220
Log mean of the dependent variable	1.973	4.694	4.153

appropriate lagged dependent variables. The short-run and long-run retail demand elasticities for lamb are –0.523 and –1.108, respectively. This estimate is similar to other elasticities in the literature with the exception of Whipple and Menkhaus (1989), who reported a retail lamb demand elasticity of –3.96. The TAMRC industry study (1991) reported a retail lamb demand elasticity of –0.62, while the ITC (1999) used retail demand elasticities for lamb ranging from –0.75 to –1.25 for assessing the impact of lamb imports. Babula (1997) reported a similar estimate of –0.78. The cross elasticity of retail import price on retail domestic lamb consumption was inelastic at 0.293 in the short run and 0.621 in the long run. Other studies did not report this cross effect at the retail level. However, Babula (1997) reported a cross elasticity of domestic wholesale lamb demand with respect to the price of New Zealand lamb imports of 0.017.

The short-run and long-run demand elasticities at the wholesale level were –0.350 and –1.032, respectively. Both were more inelastic than the retail demand elasticities, which is consistent with Gardner's (1975) relative price spread theory. Whipple and Menkhaus (1989) reported a wholesale elasticity also consistent with margin theory, but the elasticity was highly elastic at –3.78. Our estimate is similar to that of Babula (1997), who reported a wholesale demand elasticity estimate of –0.78.

At the slaughter level, the short-run and long-run derived demand elasticities were both inelastic. For fed slaughter lambs, the elasticities were –0.333 and –0.865. For culled ewes, the short-run and long-run slaughter demand elasticities were –0.245 and –0.398. Whipple and Menkhaus (1989) reported a slaughter-level demand elasticity of –3.28, while Babula (1996) used simulated multipliers from a VAR model and obtained a slaughter demand elasticity of –0.699. The derived demand for feeder lambs represents the major input demanded by lamb finishers. The short-run and long-run demand elasticities at this level are relatively inelastic (–0.112 in the short run and –0.285 in the long run). Note that the lamb slaughter price/corn price ratio (a proxy for lamb finishing profitability) is also quite inelastic at 0.055 (see Table 6-7). The inelasticity of these coefficients suggests lamb feeders attempt to fully use feedlot capacities and feed lambs to specific slaughter weights and grades required by meat packers.

6.5.2 Lamb Import Demand

The retail and wholesale import demands for lamb are characterized by statistically significant coefficients with signs that meet a priori expectations for the own-price and cross-price effects (Tables 6-4 and 6-5). For the retail import demand equation, the short-run own-price (or import price) and cross-price (with respect to U.S. price) elasticities of demand were –0.407 and 0.775 (Table 6-4). The respective long-run elasticities were –0.631 and 1.202. For the wholesale import demand equation, the short-run own-price and cross-price elasticities of demand were –0.228 and 0.555 (Table 6-5). The long-run own-price and cross-price elasticities of demand were –0.407 and 0.991. Babula (1997) estimated U.S. wholesale import demands for New Zealand lamb and Australian lamb. Import own-price elasticity was estimated as –0.08 for New Zealand and –1.14 for Australia. Babula's cross-price elasticity of demand for New Zealand lamb with respect to U.S. lamb price was 2.20. However, his cross-price elasticity of demand estimate Australian lamb with respect to U.S. lamb price was –1.69, which has an a priori incorrect sign. Overall, Babula's (1997) relative magnitudes of own-price and cross-price effects (especially for New Zealand lamb) are similar to those found in our model at the wholesale level. He concluded that the U.S. market considers imports from Australia and New Zealand as close substitutes, but his study was not definitive concerning the degrees to which U.S. consumers differentiate between U.S.-produced lamb and imported lamb.

6.5.3 Wool Demand

Wool demand in the model comprises domestic and import demands for clean, graded scoured wool that is used for processing into apparel, carpets, etc. (USDA/NASS, 2004a). U.S. wool production and wool imports have significantly declined because of a combination of declining sheep numbers and increased demand for synthetic and cotton fibers. For example, from 1970 to 2003 U.S. wool production declined from 161.6 million pounds to 38.5 million pounds, or 76%, while imports of wool (primarily from Australia) declined from 126.9 million pounds to 21.8 million pounds, or 83%. In 2003, imported wool accounted for 36% of U.S. clean wool supplies, which compares to a 44% market share in 1970.

Although estimated wool elasticities are not used in the equilibrium displacement model, they are briefly discussed in this section for comparison with those reported in other published research. The short-run demand elasticity for domestic wool is estimated to be –0.126 (Table 6-7), and the long-run demand elasticity is –1.615. Babula's (1996) simulated multipliers from a VAR lamb and wool model indicated a domestic wool demand elasticity of –0.385.[2] The price of upland cotton was statistically significant with elasticity coefficients of 0.255 in the short run and 1.540 in the long run. This result indicates the importance of the price of fiber substitutes on the demand for wool.

The own-price elasticity of demand for U.S. wool imports is –0.647 in the short run and –1.909 in the long run. The cross effect of U.S. cotton price on import wool demand is statistically weak with a short-run elasticity coefficient of 0.256 and a long-run elasticity coefficient of 0.755.

6.5.4 Demand Quantity Transmission Elasticities

Estimates of quantity transmission elasticities are used in the equilibrium displacement model to provide linkage between the vertically connected demand sectors. These estimates are obtained from the SUR estimation of four equations separate from the structural model. The transmissions elasticity estimates are summarized in Table 6-3. Table 6-8 provides the complete SUR estimation results of regressing the appropriate quantity variable at each level onto the appropriate upstream quantity variable. Double log specifications are used so that resulting parameter estimates are interpreted as transmission elasticities.

6.5.5 Supply

The supply block of the lamb model consists of equations for breeding stock, lamb crop, lamb slaughter, culled ewe slaughter, wholesale lamb, and domestic wool production (Tables 6-9 through 6-11). Retail lamb supply is based on primary feeder lamb supply and a price transmission relationship. A majority of the slope coefficients are statistically

[2] As noted in Section 6.2, contemporaneous and lagged values of the independent variable were included in initial specifications. For each variable, if either estimated coefficient was found to be not significantly different from zero, it was omitted from the final specification.

Table 6-8. SUR (Double Log) Demand Quantity Transmission Elasticities

	Dependent Variables			
Regressors	**Domestic Wholesale Lamb Quantity** $\left(Q_L^{dw}\right)$	**Imported Wholesale Lamb Quantity** $\left(Q_L^{iw}\right)$	**Domestic Slaughter Lamb Quantity** $\left(Q_L^{ds}\right)$	**Domestic Feeder Lamb Quantity** $\left(Q_L^{df}\right)$
Constant	–1.429 (–47.099)	1.121 (11.646)	7.616 (826.479)	–0.903 (–2.303)
Domestic retail lamb quantity $\left(Q_L^{dr}\right)$	0.839 (12.794)			
Imported retail lamb quantity $\left(Q_L^{ir}\right)$		1.027 (42.632)		
Domestic wholesale lamb quantity $\left(Q_L^{dw}\right)$			0.999 (124.265)	
Domestic slaughter lamb quantity $\left(Q_L^{ds}\right)$				1.075 (17.849)
Regression Statistics:				
Adjusted R^2	0.882	0.977	0.998	0.897
Standard error of the regression	0.109	0.098	0.012	0.101
Log mean of the dependent variable	–1.117	–2.926	6.550	6.086

significant at the α = 0.10 level (trend variables were omitted). All own-price supply elasticities are significant at the α = 0.05 level. The rational lag structure resulted in substantial differences between short-run and long-run supply elasticities. For livestock production, biological rigidities are generally manifest in relatively inelastic short-run supply responses. However, in the long run, relaxed biological constraints and near constant-returns-to-scale technologies cause relatively large supply responses (Marsh, 2003; Wohlgenant, 1989). The following discussion primarily focuses on those supply elasticities that are used in the equilibrium displacement model.

The primary supply of lambs consists of two equations: the breeding inventory equation and lamb crop equation. Breeding inventories represent the production base for producing young lambs. Thus, the breeding ewe function recursively determines the lamb crop. The short-run and long-run sheep breeding inventory elasticities are 0.096 and 2.526, respectively

Table 6-9. SUR (Double Log) Estimates of Domestic Lamb Crop and Breeding Ewe Supply

Regressors	Dependent Variables	
	Domestic Feeder Lamb Supply $\left(Q_L^{df}\right)$	Domestic Breeding Ewe Supply $\left(Q_{be}\right)$
Constant	0.209 (1.695)	0.069 (0.521)
Breeding sheep inventory $\left(Q_{be}\right)$	0.895 (18.632)	
Trend (T)	0.001 (0.514)	
Lagged domestic feeder lamb price $\left(Q_{Lt-1}^{df}\right)$		0.096 (2.878)
Lagged hay price $\left(P_{hy\,t-1}\right)$		–0.107 (–2.670)
Lagged domestic wool price $\left(P_{w\,t-1}\right)$		0.031 (1.827)
Lagged price of slaughter ewes $\left(P_{L\,t-1}^{de}\right)$		–0.029 (–0.846)
Lagged domestic breeding ewe supply $\left(Q_{be\,t-1}\right)$		1.309 (11.972)
Lagged domestic breeding ewe supply $\left(Q_{be\,t-2}\right)$		–0.347 (–3.224)
Regression Statistics:		
Adjusted R^2	0.991	0.991
Standard error of the regression	0.029	0.031
Log mean of the dependent variable	1.991	1.936

(Table 6-9). The long-run period corresponds to Van Tassell and Whipple's (1994) 8- to 10-year sheep cycle. Whipple and Menkhaus (1989) reported a 3-year sheep breeding supply elasticity of 0.87 and a long-run supply breeding elasticity of 3.05. Vere, Griffith, and Jones (2000) reported short-run and long-run supply elasticities for Australian breeding stock inventories of 0.095 and 2.530, respectively.

The model's lamb crop equation is specified as a static function of the breeding herd inventory. However, the dynamics of breeding stock imply dynamics in the lamb crop. The comparative static relationship between the two functions can be demonstrated by

Table 6-10. SUR (Double Log) Estimates of Domestic Slaughter Lamb and Slaughter Ewe Supply

Regressors	Dependent Variables: Domestic Slaughter Lamb Supply (Q_L^{ds})	Dependent Variables: Domestic Slaughter Ewe Supply (Q_L^{de})
Constant	0.255 (0.947)	2.025 (4.472)
Lagged domestic slaughter lamb price (P_{Lt-1}^{ds})	0.118 (2.255)	
Domestic feeder lamb price (P_L^{df})	–0.166 (–4.829)	
Lagged corn price (P_{nt-1})	–0.046 (–2.383)	
Domestic wool price (P_w)	0.054 (2.540)	0.085 (1.550)
Lagged domestic slaughter lamb supply (Q_{Lt-1}^{ds})	0.960 (25.536)	
Domestic slaughter ewe price (P_L^{de})		–0.306 (–3.814)
Hay price (P_{hy})		–0.032 (–0.262)
Breeding sheep inventory (Q_{be})		0.687 (5.419)
Lagged slaughter ewe supply (Q_{Lt-1}^{de})		0.298 (3.040)
Regression Statistics:		
Adjusted R^2	0.960	0.933
Standard error of the regression	0.049	0.097
Log mean of the dependent variable	6.484	3.687

Table 6-11. SUR (Double Log) Estimates of Domestic Wholesale Lamb and Wool Supply

Regressors	Dependent Variables: Domestic Wholesale Lamb Supply (Q_L^{dw})	Dependent Variables: Domestic Wholesale Wool Supply (Q_w^{dw})
Constant	0.098 (0.130)	2.491 (8.525)
Domestic wholesale lamb price (P_L^{dw})	0.158 (2.281)	
Domestic slaughter lamb price (P_L^{ds})	–0.235 (–4.080)	
Lamb by product price (P_{bp})	0.055 (2.498)	
Food labor costs (L_c)	–0.035 (–0.236)	
Lagged domestic wholesale lamb supply $(Q_{L\,t-1}^{dw})$	0.959 (26.243)	
Domestic wholesale wool price (P_w^{dw})		0.032 (2.868)
Wool support price (P_{sw})		0.133 (5.932)
Domestic feeder lamb supply (Q_L^{df})		0.767 (10.294)
Wool binary variable (*WD*)		–1.584 (–5.869)
Lagged domestic wholesale wool supply $(Q_{w\,t-1}^{dw})$		0.273 (3.980)
Regression Statistics:		
Adjusted R^2	0.957	0.995
Standard error of the regression	0.051	0.028
Log mean of the dependent variable	–1.132	4.418

$$Q_t^b = \alpha_0 + \alpha_1 P_{t-1} + \alpha_2 Z_t + \lambda Q_{t-1}^b \tag{6.88}$$

$$Q_t^L = \beta_0 + \beta_1 Q_t^b + \beta_2 T \, , \tag{6.89}$$

where Q_t^b is quantity supplied of breeding stock, P_{t-1} is lagged output price, Z_t is a vector of relevant exogenous variables, Q_t^L is quantity of lamb crop, and T is trend. For the first-order difference equation, Eq. (6.88), the dynamic adjustment to a shock in P_{t-1} is

$$\partial Q_t^b \;/\; \partial P_{t-1-j} = \alpha_1 \left(1 + \lambda + \lambda^2 + \lambda^3 + \ldots\right) \quad j = 0, 1, 2, \ldots \tag{6.90}$$

with the short-run elasticity of supply given as α_1 and the long-run elasticity of supply solved as $\alpha_1/(1-\lambda)$ (Pindyck and Rubinfeld, 1998). Because the marginal (first-derivative) relationship between the two functions is

$$\partial Q_t^L \;/\; \partial Q_t^b = \beta_t\ , \tag{6.91}$$

multiplying α_1 and $\alpha_1/(1-\lambda)$ by β_1 provides estimates of short-run and long-run lamb crop supply elasticities. Specifically, the short-run lamb supply elasticity of 0.086 is obtained by multiplying the breeding sheep inventory elasticity of 0.895 by the lagged feeder lamb price coefficient of 0.096 (Table 6-9). The long-run feeder lamb supply elasticity is obtained by first adding the two difference equation estimates in the ewe supply equation (1.309 + (–0.347)). The sum (0.962) is then subtracted from 1.0 to obtain 0.038. The short-run feeder lamb supply elasticity is then divided by 0.038 to obtain a long-run estimate of 2.261. Wool price is a significant factor in the breeding inventory equation. The short-run and long-run elasticity of sheep breeding inventory with respect to wool price is 0.031 and 0.821, respectively. Vere, Griffith, and Jones (2000) normalized feeder lamb price by wool price in the Australian breeding inventory equation. However, Whipple and Menkhaus (1989) explicitly measured wool price in the breeding stock equation and obtained a wool elasticity of 1.38. In our model, the support price of wool was not statistically significant and, therefore, was omitted from the breeding inventory equation.

The slaughter supply of fed lambs is positively affected by slaughter lamb price, with short-run and long-run own-price supply elasticities of 0.118 and 2.950, respectively (Table 6-10). Whipple and Menkhaus (1989) estimated short-run and long-run supply elasticities for slaughter lamb as 0.01 and 2.83, respectively. Note that pelt (by-product) price is statistically significant with short-run and long-run price elasticities of 0.054 and 1.35. Whipple and Menkhaus (1989) also indicated that the elasticity of lamb slaughter with respect to pelt price (using wool price as a proxy) was significant with a long-run estimate of 1.38 for a 10-year sheep cycle.

The price elasticities in the ewe slaughter supply equation are statistically significant, but the negative coefficients are contrary to theoretical expectations (Table 6-10). For example, the short-run and long-run supply elasticities are –0.306 and –0.436, respectively.[3] Negative supply elasticities often occur in models of livestock-meat supply relationships because of problems created by multicollinearity, units of observation, or the withholding or acceleration of marketings because of changing price expectations (Nelson and Spreen, 1978; Marsh, 1994). Pelt price shows a positive effect on cull slaughter but is statistically weak.

The wholesale supply of lamb (carcass weight) is derived from primary production of lambs and dressed weights of slaughter lambs. The behavioral relationship indicates lamb packers positively respond to wholesale price changes and negatively respond to changes in the input price of slaughter lambs (Table 6-11). The coefficient for food labor costs was not statistically significant. The short-run and long-run own-price elasticities of wholesale supply are 0.158 and 3.854, respectively, while the slaughter price elasticities were –0.235 and –5.875, respectively. Babula (1997) estimated an inverse lamb supply elasticity of 0.352 at the wholesale level. Inverting this estimate results in a wholesale lamb supply elasticity estimate of 2.84.

The retail supply elasticity could not be estimated because of multicollinearity problems. Therefore, a retail supply elasticity of lamb ϵ^{dr} was imputed using Gardner's (1975) model assuming fixed input proportions between primary farm supply and derived retail supply. Gardner's formula is

$$\epsilon^{dr} = \left(\partial \ln Q_L^{df} \ / \ \partial \ln P_L^{df}\right) \times \left(\partial \ln P_L^{df} \ / \ \partial \ln P_L^{df}\right), \tag{6.92}$$

where the first term on the right-hand side is the primary elasticity of feeder lamb supply (short run = 0.086, long run = 2.261), and the second term is the estimated price transmission elasticity of lamb feeder supply price with respect

[3] Although these elasticities do not meet *a priori* expectations, the inclusion of the ewe supply equation is used to avoid omitted variable bias. These supply elasticities, however, are not needed for the equilibrium displacement model.

to lamb retail supply price. The following nonlinear least squares regression was used to estimate the price transmission elasticity:

$$\ln P_L^{df} = -4.726 + 1.569 \ln P_L^{dr} + 0.703 u_{t-1}, \tag{6.93}$$

where u_{t-1} is a first-order autoregressive error term. The price transmission estimate of 1.569 was used in Eq. (6.92) to obtain short-run (0.151) and long-run (3.963) retail supply elasticities.

A wholesale supply function for wool was estimated to account for the equilibrium relationship in the wool market (wholesale wool demand estimated above). Because wool is a co-product of lamb production, lamb crop, wool price, and wool support price were specified in the supply equation. The lamb crop elasticity coefficient is 0.767, indicating that for every 1% increase in the lamb crop, wool supplies increase by 0.77% (Table 6-11). The short-run and long-run wool supply elasticities with respect to wool market price are 0.032 and 0.044, respectively, while the commensurate length-of-run elasticities for wool support price payments are 0.133 and 0.183. Whipple and Menkhaus (1990) did not estimate a support price elasticity for wool, but their free market price elasticity for wool supply was 1.38. Babula's (1996) VAR and simulated multiplier analysis yielded a wool supply elasticity of 0.27. Vere, Griffith, and Jones (2000) estimated the Australian wool supply elasticities to be about 0.05 in the short run and 0.24 in the long run.

Supply functions for U.S. imports of wholesale and retail lamb meat and imports of wholesale wool were not estimated. It is assumed that under the Tariff Rate Quotas (TRQ) established by GATT and the WTO, import supplies facing the United States are highly elastic (i.e., changes in U.S. demand for these imports would have negligible effects on import prices up to the TRQ) (Babula, 1997). Consequently, for the equilibrium displacement model, an arbitrary large supply elasticity coefficient of 10.0 was assumed for wholesale- and retail-level lamb import supplies.

6.5.6 Supply Quantity Transmission Elasticities

Estimates of quantity transmission elasticities are used in the equilibrium displacement model to provide a linkage between the vertically connected supply sectors. These estimates were obtained from the SUR estimation of four equations separate from the structural model. The supply quantity transmission elasticities are summarized in Table 6-3. Table 6-12 provides the complete SUR results of regressing the appropriate quantity variable at each level onto the appropriate downstream quantity variable. Double log specifications are used so that resulting parameter estimates are interpreted as transmission elasticities.

Table 6-12. SUR (Double Log) Supply Quantity Transmission Elasticities

	Dependent Variables			
Regressors	**Domestic Retail Lamb Quantity** $\left(Q_L^{dr}\right)$	**Imported Retail Lamb Quantity** $\left(Q_L^{i}\right)$	**Domestic Wholesale Lamb Quantity** $\left(Q_L^{dw}\right)$	**Domestic Slaughter Lamb Quantity** $\left(Q_L^{ds}\right)$
Constant	1.313 (16.612)	–1.329 (–20.920)	–7.670 (–145.490)	1.737 (6.755)
Domestic wholesale lamb quantity $\left(Q_L^{dw}\right)$	0.843 (12.285)			
Imported wholesale lamb quantity $\left(Q_L^{iw}\right)$		0.892 (42.286)		
Domestic slaughter lamb quantity $\left(Q_L^{ds}\right)$			1.008 (124.265)	
Domestic feeder lamb quantity $\left(Q_L^{df}\right)$				0.783 (18.550)
Regression Statistics:				
Adjusted R^2	0.806	0.977	0.998	0.904
Standard error of the regression	0.121	0.093	0.013	0.080
Log mean of the dependent variable	0.372	–3.940	–1.117	6.550

6.5.7 Elasticity Summary

SUR estimation of annual rational distributed lag demand and supply equations in the lamb marketing channel yielded statistically significant price elasticity estimates that were generally consistent with *a priori* expectations. That is, coefficient signs were consistent with theoretical constructs, and long-run elasticities were more elastic than short-run elasticities because technical, biological, and institutional constraints are less restrictive over time. Some of the market-level elasticities were comparable to other lamb studies. For some of the data series, missing observations were imputed from observed data.

The estimated model also yielded price elasticities across sectors that conform to relative price spreads and primary and derived demand and supply expectations. That is, regardless of whether agricultural markets are characterized by fixed or variable input proportions, margin theory would indicate smaller demand elasticities proceeding from primary demand to derived demands and larger elasticities proceeding from primary supply to derived supplies (Gardner, 1975; Wohlgenant, 1989). The consistency of these results lends credibility to the market-level economic surplus measurements in the equilibrium displacement model (Brester, Marsh, and Atwood, 2004).

6.6 OLIGOPSONY MARKDOWN PRICING

Eq. (6.25) in the equilibrium displacement model indicates that potential oligopsony power in the domestic wholesale processing sector may drive a price wedge between the derived demand price of slaughter lambs (P_L^{dsd}) and the derived supply price of slaughter lambs (P_L^{dss}). The variable ρ represents the ratio P_L^{dsd} / P_L^{dss}. Thus, in the absence of oligopsony markdown power, the value of ρ equals 1 as $P_L^{dsd} = P_L^{dss}$. The value of ρ increases as oligopsony power increases. As illustrated in Figure 6-4, increases in potential market power would cause a larger price wedge between P_L^{dsd} and P_L^{dss} and reductions in quantity from the perfectly competitive market equilibrium.

6.6.1 Estimates of Oligopsony Markdown Price Distortions

Published estimates of the degree of oligopsony markdown power are not available for the lamb industry. In addition, the direct estimation of a markdown model is not possible because of data limitations. Therefore, we use estimates of markdown pricing from the beef industry as a proxy for markdown pricing in the lamb industry within the equilibrium displacement model. The beef and lamb processing industries have approximately the same concentration ratios and use similar technologies. Hence, estimates from the beef industry should be reasonable proxies for the lamb processing industry.

Schroeter (1988) extended Appelbaum's (1979, 1982) model for estimating monopoly market power to the estimation of monopsony price distortions in the slaughter cattle market. Using annual data from 1951 to 1983, Schroeter reported markdown price distortions ranging from 0.009 to 0.025 depending on the year. The average price distortion for the reported years was 0.013. This corresponds to an estimate of ρ of 1.013.

Azzam and Schroeter (1991) considered the degree of oligopsony price distortions across 13 regional slaughter cattle markets in 1986. Their estimate of markdown price distortions was less than 1%. This was a lower estimate of price distortions than the 1.2% to 2.5% estimates reported by earlier research (Menkaus, St. Clair, and Ahmaddaud, 1981; Quail et al., 1986; Ward, 1981). Koontz, Garcia, and Hudson (1993) used data from 1980 to 1986 and estimated slaughter cattle price distortions of 0.5% to 0.8% in a dynamic model of two-phase collusive pricing strategies. Muth and Wohlgenant's (1999) estimate of oligopsony markdown price behavior was not statistically different from zero using a variety of functional forms for the beef industry. Using quarterly data from 1978 to 1993, Weliwita and Azzam (1996) estimated oligopsony price distortions of 2.7% for fed cattle markets during a time of declining beef demand. Stiegert, Azzam, and Brorsen (1993) reported monopsony markdown pricing estimates ranging from 0% to 3.8% depending on the year considered. The average of their annual estimates was 1.31%.

6.6.2 Effects of Oligopsony Markdowns

The above estimates of oligopsony markdown price distortions in slaughter cattle prices range from 0% to 3.8%. However, some have postulated that data limitations result in estimates of ρ that are biased downward. Hence, we assume that ρ ranges from 1.0 to 1.05. Because estimates vary, the equilibrium displacement model will treat ρ as a random variable that ranges between 1.0 and 1.05 with most of the mass centered over 1.015 (the median of reported estimates for the beef industry) for the slaughter lamb sector.

To allow for the possibility of market power, we assume the data used in the model have been generated by a lamb processing industry that has exercised small amounts of oligopsony pricing power in the slaughter lamb sector.

Therefore, although a restriction on the amount of a given AMA is likely to increase processing costs, it could also have an offsetting effect by reducing potential market power.

To illustrate this case, we use the elasticity estimates presented above to parameterize the equilibrium displacement model. Note that this is merely a simplified illustration. Simulations are presented in Section 6.10 that use actual estimates of changes in AMAs. For this illustration, assume that a reduction in an AMA increases processing costs by 5%. We further assume that ρ is equal to 1.015. The short-run (year 1) changes in equilibrium prices and quantities from a nonstochastic simulation are presented in the first column of Table 6-13. Prices and quantities change in the expected directions. For example, retail domestic lamb prices increase by 7.71%, while retail domestic lamb quantities decline by 4.02%. Imported retail and wholesale lamb prices and quantities all increase. Slaughter and feeder lamb prices and quantities all decline.

Table 6-13. Short-Run Percentage Changes in Prices and Quantities Given a 5% Increase in Wholesale Domestic Processing Costs (a Decrease in the Wholesale Domestic Derived Lamb Supply Function) and a 0.5 Percentage Point Reduction in Potential Market Power using a Nonstochastic Simulation

Endogenous Variables	No Change in Potential Market Power	A Reduction in Potential Market Power
Retail domestic lamb price	7.71%	7.62%
Retail domestic lamb quantity	–4.02%	–3.97%
Retail imported lamb price	0.06%	0.06%
Retail imported lamb quantity	5.95%	5.88%
Wholesale domestic lamb price	7.51%	7.42%
Wholesale domestic lamb quantity	–6.00%	–5.93%
Wholesale imported lamb price	0.60%	0.59%
Wholesale imported lamb quantity	5.98%	5.90%
Slaughter lamb demand price	–11.48%	–11.53%
Slaughter lamb supply price	–11.66%	–11.20%
Slaughter lamb quantity	–2.17%	–2.08%
Feeder lamb price	–11.77%	–11.31%
Feeder lamb quantity	–1.01%	–0.97%

The second column of Table 6-13 presents changes in equilibrium prices and quantities caused by a 5% increase in processing costs coupled with a 0.005 percentage point reduction in potential market power (i.e., a reduction in ρ from 1.015 to 1.01). The accompanying reduction in potential market power offsets some of the effects of the cost increases. Note that price and quantity changes are slightly smaller in this second case. The only exception is that the slaughter lamb demand price declines by 11.53% in this case rather than 11.48% in the preceding case. This represents a loss of potential market power by the processing sector.

6.7 QUALITY CHANGES CAUSED BY CHANGES IN PROCUREMENT METHODS

Restrictions on slaughter lamb procurement methods may potentially affect the quality of lamb meat. Changes in AMAs may influence genetic development, lamb feeding, nutrition, logistics, and price incentives related to quality. Changes in lamb meat quality are manifest in consumer demand. If domestic lamb quality is reduced, then consumer demand for domestic lamb meat will decline relative to other lamb (i.e., imported lamb) and lamb meat substitutes. Such a decline is then transferred to upstream derived demands for wholesale lamb meat, slaughter lambs, and feeder lambs. Although no direct measure of lamb meat quality is available at the retail level, MPR data provide measures of lamb carcass quality in terms of yield grades. Therefore, the impacts of changes in AMAs on carcass yield grades are used to proxy changes in lamb meat quality at the retail level.

Eq. (2.28) in Section 2.5 presented estimates of changes in yield grade on domestic retail demand prices. Eq. (4.2) in Section 4.3 presented the estimates of the effects of AMAs on carcass lamb quality. The results indicated that the procurement of slaughter lambs through packer ownership did not have a statistically significant effect on carcass quality. However, formula procurement directly influenced quality. These results are combined in the next section to calculate the impacts of a 25% and a 100% reduction in the use of AMAs to procure slaughter lambs.

6.7.1 Changes in Retail Demand (Meat Quality) Resulting from a 25% Reduction in Formula Slaughter Lamb Procurement

A comparative statics procedure is used to estimate the impacts on retail demand of a reduction in formula lamb procurement. Packer ownership did not have a statistically significant effect on lamb quality. The impacts are obtained by using the product of elasticities presented in Table 2-9 and Eq. (4.2). Specifically, the reduction in retail demand is given by

$$\frac{\%\Delta p_r}{\%\Delta pf} = \left(\frac{\%\Delta p_r}{\%\Delta YG}\right)\left(\frac{\%\Delta YG}{\%\Delta pf}\right) \times -25.0\,, \tag{6.94}$$

where the left-hand term is the percentage change in inverse retail lamb demand given a percentage change in formula procurement. The first term on the right side of Eq. (6.94) is the percentage change in retail price given a percentage change quality (yield grade, T_q), which was estimated based on Eq. (2.28). The second term on the right side represents the percentage change in yield grade caused by percentage change in formula procurement as presented in Eq. (4.2). The last term on the right side represents a 25% reduction in formula procurement.

Using estimates presented in Sections 2.5 and 4.3, a reduction in formula procurement is estimated to reduce retail lamb demand by 1.65% as calculated in Eq. (6.95):

$$(-0.422) \times (-0.157) \times (-25.0) = -1.65\%\,. \tag{6.95}$$

6.7.2 Changes in Retail Demand (Meat Quality) Resulting from a 100% Reduction in Formula Slaughter Lamb Procurement

Eq. (6.94) is also applied to the case in which formula lamb procurement is reduced by 100% (i.e., eliminated). Eq. (6.96) indicates that this scenario would result in a reduction of retail demand for domestic lamb meat of 6.63%:

$$(-0.422) \times (-0.157) \times (-100.0) = -6.63\%\,. \tag{6.96}$$

6.8 COST CHANGES CAUSED BY CHANGES IN PROCUREMENT METHODS

Restrictions on slaughter lamb procurement methods necessarily impose additional costs on lamb packers. Costs increase because of changes in market risk, transactions costs, and logistics (i.e., utilization of plant capacities). These costs may be absorbed by packers and/or reflected as changes in output and input prices of wholesale lamb and slaughter lamb, respectively.

6.8.1 Simulation Inputs for a 25% Reduction in Formula and Packer Owner Slaughter Lamb Procurement

Consider a new requirement that forces lamb packers to reduce their formula and packer ownership procurement of slaughter lambs by 25%. Theoretically, this is illustrated by an upward shift in the domestic wholesale derived supply function (Eq. [6.55]). Comparative statics of the monthly structural model presented above are used to estimate the size of this shift. We assume that the 25% reduction in both formula and packer ownership procurement will be reallocated to cash procurement. However, given that packer ownership procurement was not statistically significant in Eq. (2.29), the marginal impact of the decrease in packer ownership procurement is zero.

The marginal impact of the 25% reduction in formula procurement (*pf*) and packer ownership (*po*) is calculated using the estimated coefficient of –0.265, which measures the effects of a reduction in the lamb cut-out price (Table 2-9). The resulting change in wholesale slaughter supply costs equals:

$$\begin{gathered}\left(\frac{\partial p_{bx}}{\partial pf}\times -25.00\right)+\left(\frac{\partial p_{bx}}{\partial po}\times -25.00\right)= \\ (-0.265\times -25.00)+(0.0\times -25.00)=6.63\% \end{gathered} \quad . \qquad (6.97)$$

Thus, slaughter costs are expected to increase by 6.63% because of the reduction in formula and packer ownership procurement methods. This is represented by a decrease in the domestic wholesale slaughter lamb supply function.

However, the reallocation of 25% of lamb procurement to the cash procurement (*pc*) will increase wholesale derived slaughter supply because of cost reductions. The marginal impact of this increase is calculated using the estimated coefficient (–0.217) for cash procurement (*pc*) (Table 2-9) such that wholesale slaughter supply equals:

$$\frac{\partial p_{bx}}{\partial pc} \times 25.0 = -0.217 \times 25.0 = -5.43\%. \tag{6.98}$$

Thus, slaughter lamb costs are expected to decrease by 5.43% because of the increase in cash procurement. This is represented by an increase in the domestic wholesale slaughter supply function.

In summary, the net effect of a 25% reallocation of lamb procurement from formula and packer ownership methods to cash procurement is to increase slaughter costs by 1.20% (6.63% minus 5.43%). Thus, the domestic wholesale slaughter supply curve is shifted vertically upward by 1.20%.

6.8.2 Simulation Inputs for a 100% Reduction in Formula and Packer Ownership Slaughter Lamb Procurement

A second scenario is used to estimate cost changes resulting from a total ban on formula and packer procurement of slaughter lambs. Following the above example, 100% of packer ownership lamb procurement is allocated to cash procurement but does not have a statistically significant effect on wholesale supply. However, the reallocation of 100% of formula procurement to cash procurement increases wholesale slaughter supply costs. The cost increase caused by this reallocation equals

$$\begin{gathered}\left(\frac{\partial p_{bx}}{\partial pf} \times -100.0\right) + \left(\frac{\partial p_{bx}}{\partial po} \times -100.0\right) = \\ (-0.265 \times -100.0) + (0.0 \times -100.0) = 26.5\%\end{gathered}. \tag{6.99}$$

The cost reduction caused by this reallocation equals

$$\frac{\partial p_{bx}}{\partial pc} \times 100.0 = -0.217 \times 100.0 = -21.7\%. \tag{6.100}$$

The net effect of a 100% reallocation of formula and packer ownership lamb procurement to the cash procurement method is to increase slaughter costs by 4.80% (26.5% minus 21.7%). Thus, the domestic wholesale slaughter supply curve is shifted upward and to the left by 4.80% in this scenario.

6.9 ESTIMATED CHANGES IN POTENTIAL MARKET POWER CAUSED BY CHANGES IN PROCUREMENT METHODS

If present, oligopsony power in the lamb packing sector is likely manifest in downward pressure on slaughter lamb prices. Figure 6-4 illustrated the hypothetical market power impacts as a wedge between slaughter lamb demand price and slaughter lamb supply price. The size of this wedge depends on the relative size of oligopsony power. Nonetheless, if oligopsony market power is related to AMAs, then reductions in formula and packer ownership procurement should reduce market power and narrow the difference between slaughter lamb demand and supply prices.

Eqs. (2.28) through (2.33) were used to obtain an estimate of the impact of formula procurement and packer ownership on potential market power. The following two sections present the calculations needed to use these estimates of changes in market power in the equilibrium displacement model.

6.9.1 Estimated Changes in Potential Market Power Caused by a 25% Reduction in Formula and Packer Ownership Procurement

The empirical estimation of Eq. (2.33) required the use of the residuals from Eq. (2.34) as a proxy for potential market power. Table 2-11 presents the empirical results of the estimation of Eq. (2.33). The results indicate that a 1% decrease in formula and packer ownership procurement is related to a 0.009 and a 0.002 percentage point decline in potential market power (ρ), respectively. Thus, Eq. (6.99) presents the calculations used to estimate the change in potential market power resulting from a 25% reduction in both formula and packer ownership procurement:

$$\left(\frac{\partial M_k}{\partial pf} \times -25.00\right) + \left(\frac{\partial M_k}{\partial po} \times -25.00\right) = \qquad (6.99)$$

$$\left(0.009 \times -25.00\right) + \left(0.002 \times -25.00\right) = -0.275\,\% \;.$$

Thus, a 25% reduction in formula and packer ownership procurement is expected to reduce potential market power by 0.275 percentage points.

6.9.2 Estimated Changes in Potential Market Power Caused by a 100% Reduction in Formula and Packer Ownership Procurement

An analogous procedure is followed to estimate the impact of a 100% reduction (i.e., complete elimination) of formula and packer ownership procurement on potential market power. The 100% reduction in both methods yields:

$$\left(\frac{\partial M_k}{\partial pf} \times -100.0\right) + \left(\frac{\partial M_k}{\partial po} \times -100.0\right) = \qquad . \quad (6.100)$$
$$(0.009 \times -100.0) + (0.002 \times -100.0) = -1.100\,\%$$

Thus, a 100% reduction in formula procurement is expected to reduce potential market power by 1.100 percentage points.

6.10 SIMULATION RESULTS

In this section, we present the results of simulations of potential changes in AMAs that would reduce or eliminate various procurement methods. The simulations are conducted using the inputs described in Sections 6.7, 6.8, and 6.9.

6.10.1 Results of a 25% Reduction in Formula and Packer Ownership Procurement

A 25% reduction in formula and packer ownership procurement is expected to have three initial effects on the lamb sector. First, lamb meat quality is expected to decline and decrease primary demand by 1.65% (Eq. 6.95). Second, processing costs would increase because of changes in procurement methods. Thus, the domestic wholesale derived supply function is expected to shift upwards and to the left by 1.20% (Section 6.8.1). Third, potential market power is expected to decline by 0.275 percentage points (Eq. 6.99). These three inputs are used in the equilibrium displacement model to estimate price, quantity, and producer and consumer surplus changes resulting from a 25% reduction in formula and packer ownership procurement.

Table 6-14 reports simulated mean changes in the endogenous price and quantity variables and associated 95% confidence intervals for a 25% reduction in formula and packer ownership procurement. All mean estimates are significantly different from zero at either the 5% or 10% level. The short-run time period represents changes in prices and quantities that occur at the end of Year 1.

Table 6-14. Percentage Changes in Prices and Quantities Given a 25% Reduction in Formula and Packer Ownership Lamb Procurement[a]

Endogenous Variables	Short Run	Long Run (Year 10)
Retail domestic lamb price	–0.53%[a] (–1.34, 0.33)	–0.06%[a] (–0.23, 0.15)
Retail domestic lamb quantity	–1.40% (–1.82, –1.10)	–1.59% (–1.83, –1.40)
Retail imported lamb price	–0.004%[a] (–0.02, 0.002)	–0.001%[a] (–0.004, 0.003)
Retail imported lamb quantity	–0.40[a] (–1.31, 0.21)	–0.07%[a] (–0.32, 0.17)
Wholesale domestic lamb price	1.17% (0.44, 2.08)	0.28% (0.12, 0.70)
Wholesale domestic lamb quantity	–1.57% (–2.05, –1.25)	–1.62% (–2.30, –1.27)
Wholesale imported lamb price	–0.04%[a] (–0.14, 0.02)	–0.007%[a] (–0.03, 0.02)
Wholesale imported lamb quantity	–0.41%[a] (–1.30, 0.21)	–0.07%[a] (–0.33, 0.17)
Slaughter lamb demand price	–3.10% (–4.22, –2.26)	–0.42% (–0.75, –0.31)
Slaughter lamb supply price	–2.88% (–4.00, –2.02)	–0.15% (–0.49, –0.04)
Slaughter lamb quantity	–0.55% (–1.12, –0.13)	–1.26% (–1.80, –0.90)
Feeder lamb price	–3.42% (–9.39, –0.70)	–0.61% (–1.39, –0.28)
Feeder lamb quantity	–0.29% (–0.87, –0.04)	–1.18% (–1.77, –0.74)

[a] This scenario corresponds to a 1.65% decrease in retail lamb demand, a 1.20% decrease in wholesale domestic derived lamb supply, and a 0.275% reduction in potential lamb packer oligopsony power.

[b] Significantly different from zero at the 10% level. All other values are significantly different from zero at the 5% level.

In the short run, all prices decline with the exception of a small increase in domestic wholesale lamb prices. Retail domestic lamb price declines by 0.53%, slaughter lamb supply price declines by 2.88%, and feeder lamb price declines by 3.42%. In addition, all quantities (except import retail and wholesale lamb, which are not statistically affected) decline by a small amount. Essentially, these results reflect that the positive effect of reduced potential oligopsony processor market power is unable to offset the negative effects of increased processing costs and decreased retail demand.

To estimate long-run effects, we assume that the lamb market would return to an equilibrium after 10 years of adjustments to the change in lamb procurement. We multiplicatively increase supply and demand elasticities between the short-run estimates (year 1) and long-run estimates (year 10). The long-run results represent changes in prices and quantities that would occur in year 10 relative to initial levels. The long-run price effects follow the short-run results in terms of direction. However, the long-run changes in prices are much smaller than the short-run changes because of increasing supply and demand elasticities. For example, slaughter lamb supply price declines by 0.15%, and feeder lamb prices decline by 0.61% in the long run. However, the long-run quantity declines are slightly larger than the short-run declines because of, again, more elastic supply responses over time.

Table 6-15 presents changes in producer surplus at each level of the marketing chain and changes in consumer surplus at the retail level. In general, most estimates are at least significantly different from zero at the α = 0.10 level. Short-run results are presented in the first column, and long-run results are presented in the second column. Changes in producer surplus contain a dynamic element in that producer surplus increases or decreases over time. Therefore, it is appropriate to consider *cumulative* changes in producer surplus that accrue as an industry adjusts from a short-run to a long-run equilibrium. To simulate these cumulative effects, we assume that it takes 10 years to adjust from the short run to the long run in the meat industry.

The third column of Table 6-15 presents the simple summation of producer and consumer surplus changes over 10 years for each market level. The fourth column presents the present value of these changes in producer and consumer surplus assuming a 5% discount rate. Over the 10-year adjustment period, all sectors except wholesale domestic lamb producers lose surplus.

The fifth column of Table 6-15 presents changes in cumulative net present value of producer and consumer surplus for each sector as a percentage of the total net present value of

Table 6-15. Changes in Producer and Consumer Surplus Given a Given a 25% Reduction in Formula and Packer Ownership Lamb Procurement, Million $[a,b]

	Short Run	Long Run (Year 10)	Cumulative	Cumulative Present Value	Percent of Total Present Value Cumulative Surplus
Producer Surplus					
Retail domestic lamb producer surplus	–$17.18	–$5.18	–$125.06	–$100.55	–1.72%
Retail imported lamb producer surplus	–0.16[c]	–0.003[c]	–0.51[d]	–0.43[d]	–0.15[d]
Wholesale domestic lamb producer surplus	–2.23[c]	0.003	8.02	6.49[c]	0.29[c]
Wholesale imported lamb producer surplus	–0.14[c]	–0.02[c]	–0.43[d]	–0.37[d]	–0.28[d]
Slaughter lamb producer surplus	–13.53	–1.26	–65.05	–54.65	–2.79
Feeder lamb producer surplus	–8.44	–1.51	–53.84	–44.24	–3.81
Total change in domestic producer surplus	–41.40	–7.92	–235.93	–192.95	–1.73
Total change in imported producer surplus	–0.30[c]	–0.05[c]	–0.94[d]	–0.80[d]	–0.19[d]
Total change in producer surplus	–41.70	–7.97	–236.87	–193.75	–1.67
Consumer Surplus					
Retail domestic lamb consumer surplus	–27.98	–16.30	–230.43	–182.09	–2.07
Retail imported lamb consumer surplus	–14.15[c]	–1.39[c]	–39.33[d]	–34.14[d]	–0.76[d]
Total change in consumer surplus	–42.13	–17.69	–269.76	–216.23	–1.63

[a] Producer and consumer surplus are calculated relative to 2000–2003 average quantities and prices.

[b] This scenario corresponds to a 1.65% decrease in retail demand, a 1.20% decrease in wholesale domestic derived lamb supply, and a 0.275% reduction in potential lamb packer oligopsony power.

[c] Significantly different from zero at the 10% level.

[d] Not significantly different from zero.

cumulative producer and consumer surplus. In total, consumers lose 1.63% cumulative surplus over the 10-year adjustment period. In addition, domestic slaughter lamb producer surplus declines by 2.79% and domestic feeder lamb producer surplus declines by 3.81% over the same period.

6.10.2 Results of a 100% Reduction in Formula and Packer Ownership Procurement

A 100% reduction in formula and packer ownership procurement is expected to: (1) reduce retail demand for domestic lamb by 6.63% (Eq. [6.96]), (2) increase wholesale processing costs by 4.80% (Section 6.8.2) (Eq. [6.98]), and reduce potential market power by 1.10 percentage points (Eq. [6.100]). Table 6-16 reports mean changes in the endogenous price and quantity variables and associated 95% confidence intervals for a 100% reduction in formula and packer ownership procurement. All mean estimates are at least significantly different from zero at the 10% level. With the exception of wholesale domestic lamb prices, all prices and quantities decline in the short run. Retail domestic lamb price declines by 2.15%, and retail domestic lamb quantities decline by 5.60%. Slaughter and feeder lamb prices decline by 11.51% and 13.65%, respectively.

The long-run price and quantity results follow the short-run results in terms of direction with generally smaller price declines and larger quantity declines. Again, these results are consistent with increasing supply and demand elasticities over time. For example, slaughter lamb supply prices decline by 0.60%, and feeder lamb prices decline by 2.46% in the long run. However, slaughter and feeder lamb quantities decline by 5.04% and 4.74% in the long run.

Table 6-17 presents changes in producer surplus at each level of the marketing chain and changes in consumer surplus at the retail level. In general, most estimates are at least significantly different from zero at the $\alpha = 0.10$ level. Short-run results are presented in the first column, and long-run results are presented in the second column. The third column of Table 6-17 presents the simple summation of producer and consumer surplus changes over 10 years for each market level.

Table 6-16. Percentage Changes in Prices and Quantities Given a 100% Reduction in Formula and Packer Ownership Lamb Procurement[a]

Endogenous Variables	Short Run	Long Run (Year 10)
Retail domestic lamb price	–2.15%[b] (–5.45, 1.29)	–0.23%[b] (–0.92, 0.59)
Retail domestic lamb quantity	–5.60% (–7.29, –4.39)	–6.38% (–7.36, –5.63)
Retail imported lamb price	–0.02%[b] (–0.06, 0.009)	–0.003%[b] (–0.02, 0.01)
Retail imported lamb quantity	–1.66[b] (–5.29 0.77)	–0.27%[b] (–1.31, 0.69)
Wholesale domestic lamb price	4.66% (1.74, 8.32)	1.10% (0.49, 2.81)
Wholesale domestic lamb quantity	–6.30% (–8.19, –4.99)	–6.49% (–9.20, –5.09)
Wholesale imported lamb price	–0.17%[b] (–0.56, 0.09)	–0.03%[b] (–0.13, 0.07)
Wholesale imported lamb quantity	–1.66%[b] (–5.28, 0.76)	–0.26%[b] (–1.31, 0.68)
Slaughter lamb demand price	–12.42% (–16.88, –9.06)	–1.67% (–3.01, –1.23)
Slaughter lamb supply price	–11.53% (–16.02, –8.09)	–0.60% (–1.95, –0.15)
Slaughter lamb quantity	–2.21% (–4.47, –0.53)	–5.04% (–7.23, –3.61)
Feeder lamb price	–13.67% (–37.61, –2.79)	–2.46% (–5.60, –1.13)
Feeder lamb quantity	–1.15% (–3.49, –0.16)	–4.75% (–7.10, –2.99)

[a] This scenario corresponds to a 6.63% decrease in retail lamb demand, a 4.80% decrease in wholesale domestic derived lamb supply, and a 1.10% reduction in potential lamb packer oligopsony power.

[b] Significant from zero at the 10% level.

Table 6-17. Changes in Producer and Consumer Surplus Given a 100% Reduction in Formula and Packer Ownership Lamb Procurement, Million $[a,b]

	Short Run	Long Run (Year 10)	Cumulative	Cumulative Present Value	Percent of Total Present Value Cumulative Surplus
Producer Surplus					
Retail domestic lamb producer surplus	–$68.43	–$20.41	–$498.68	–$401.11	–7.36%
Retail imported lamb producer surplus	–0.66[c]	–0.11[c]	–2.10[d]	–1.79[d]	–0.64[d]
Wholesale domestic lamb producer surplus	–9.86	0.12	30.61	24.66[c]	1.10[c]
Wholesale imported lamb producer surplus	–0.56[c]	–0.01[c]	–1.76[d]	–1.50[d]	–1.16[d]
Slaughter lamb producer surplus	–53.91	–5.04	–258.42	–217.11	–12.29
Feeder lamb producer surplus	–33.55	–5.94	–213.06	–175.15	–16.05
Total change in domestic producer surplus	–165.75	–31.27	–939.55	–768.72	–7.28
Total change in imported producer surplus	–1.22[c]	–0.20[c]	–3.85[d]	–3.28[d]	–0.81[d]
Total change in producer surplus	–166.96	–31.47	–943.40	–772.00	–7.04
Consumer Surplus					
Retail domestic lamb consumer surplus	–109.66	–63.86	–902.15	–712.90	–8.92
Retail imported lamb consumer surplus	–57.28[c]	–5.63[c]	–160.63[d]	–139.40[d]	–3.18[d]
Total change in consumer surplus	–166.94	–69.49	–1,062.78	–852.30	–6.88

[a] Producer and consumer surplus are calculated relative to 2000–2003 average quantities and prices.

[b] This scenario corresponds to a 6.63% decrease in retail lamb demand, a 4.80% decrease in wholesale domestic derived lamb supply, and a 1.10% reduction in potential lamb packer oligopsony power.

[c] Significant from zero at the 10% level.

[d] Not significantly different from zero.

The fourth column of Table 6-17 presents the present value of 10 years of changes in producer and consumer surplus assuming a 5% discount rate. Over the 10-year adjustment period, the only sector that does not lose producer surplus is the wholesale domestic lamb sector.

The fifth column of Table 6-15 presents changes in cumulative net present value of producer and consumer surplus for each sector as a percentage of the total net present value of cumulative producer and consumer surplus. All consumers lose 6.88% of cumulative surplus over the 10-year adjustment period. In addition, domestic slaughter lamb producer surplus declines by 12.29% and domestic feeder lamb producer surplus declines by 16.05% over the same period.

6.10.3 Results of a 100% Reduction in Formula and Packer Ownership Procurement Assuming the Elimination of Potential Oligopsony Power

For illustration purposes, it is instructive to consider a case in which a 100% reduction in formula and packer ownership procurement would completely eliminate potential oligopsony market power. The research presented above does not support such a scenario. However, if the goal of a complete elimination of formula and packer ownership procurement is to eliminate potential oligopsony power, it is interesting to consider a hypothetical situation in which that actually occurs. Note that oligopsony power could still occur within cash markets. However, we abstract from that possibility in this simulation.

This simulation follows that of Section 6.10.2, except that the potential market power parameter (ρ) is assumed to decline from a mean value of 1.015 (and variations between 1.0 and 1.05) to a value of 1.0 that contains no variation. That is, no price wedge would exist between the demand and supply prices for slaughter lambs after the 100% reduction in formula and packer ownership procurement.

Table 6-18 reports mean changes in the endogenous price and quantity variables and associated 95% confidence intervals for this scenario. All short-run estimates are significantly different from zero at the 5% level as are most of the long-run estimates.

Table 6-18. Percentage Changes in Prices and Quantities Given a 100% Reduction in Formula and Packer Ownership Lamb Procurement and Elimination of Potential Oligopsony Power[a]

Endogenous Variables	Short Run	Long Run (Year 10)
Retail domestic lamb price	–2.23% (–5.54, 1.16)	–0.26%[b] (–0.96, 0.44)
Retail domestic lamb quantity	–5.56% (–7.21, –4.37)	–6.35% (–7.19, –5.57)
Retail imported lamb price	–0.02% (–0.06, 0.01)	–0.001%[b] (–0.02, 0.001)
Retail imported lamb quantity	–1.72 (–5.39, 0.62)	–0.31%[b] (–1.38, 0.50)
Wholesale domestic lamb price	4.59% (1.71, 8.22)	1.00% (0.45, 2.61)
Wholesale domestic lamb quantity	–6.23% (–8.08, –4.97)	–6.36% (–8.68, –5.01)
Wholesale imported lamb price	–0.17% (–0.56, 0.07)	–0.03%[b] (–0.14, 0.05)
Wholesale imported lamb quantity	–1.72% (–5.36, 0.63)	–0.31%[b] (–1.40, 0.51)
Slaughter lamb demand price	–12.46% (–16.90, –9.13)	–2.02% (–3.25, –1.61)
Slaughter lamb supply price	–11.15% (–15.66, –7.76)	–0.55% (–1.80, –0.13)
Slaughter lamb quantity	–2.14% (–4.36, –0.51)	–4.61% (–6.58, –3.21)
Feeder lamb price	–13.23% (–36.80, –2.71)	–2.25% (–5.16, –1.01)
Feeder lamb quantity	–1.11% (–3.42, –0.16)	–4.34% (–6.53, –2.71)

[a] This scenario corresponds to a 6.63% decrease in retail lamb demand and a 4.80% decrease in wholesale domestic derived lamb supply.

[b] Not significantly different from zero.

The results reported in Table 6-18 are almost identical to those reported in Table 6-16. That is, even if eliminating formula and packer ownership lamb procurement would completely eliminate potential oligopsony power, the net effects would be to reduce price and quantities in almost all sectors because of additional processing costs and reductions in lamb meat quality.

Table 6-19 presents changes in producer surplus at each level of the marketing chain and changes in consumer surplus at the retail level in response to this hypothetical scenario. Again, the results are virtually identical to those reported in Table 6-17.

6.10.4 Potential Market Power, Processing Costs, and AMAs

Section 6.10.3 illustrates a hypothetical case in which a 100% reduction in formula and packer ownership procurement would completely eliminate potential oligopsony market power. However, these results are dependent upon the assumption of the initial size of oligopsony markdown pricing behavior. That is, if such market power is large enough initially, then elimination of that market power could theoretically offset increased processing costs and reduced lamb quality in terms of changes in producer surplus.

Therefore, the equilibrium displacement model was used in a static simulation to determine the minimum size of initial market power for which, upon its removal through the complete elimination of AMAs, slaughter lamb producers would be invariant to such an action. The model indicates that an initial oligopsony markdown pricing of fed lambs of 10.5% would have to exist in order for benefits and costs of reducing AMAs to be equivalent. Although empirical estimates of oligopsony markdowns in the lamb industry do not exist, the largest of such estimates in the beef industry have generally been less than 3.8%.

Finally, it is interesting to consider relative magnitudes of negative effects of changes in AMAs in processing costs and lamb quality versus the positive effects of reductions in potential market power. A static simulation was conducted to further investigate these tradeoffs. The above simulation was repeated (a 100% reduction in AMAs and the complete elimination of market power), and the negative impacts on processing costs and lamb quality were altered until the discounted net present value of fed lamb producer surplus was unaffected by changes in AMAs. The results indicate that fed lamb producers would be

Table 6-19. Changes in Producer and Consumer Surplus Given a 100% Reduction in Formula and Packer Ownership Lamb Procurement and Elimination of Potential Oligopsony Power, Million $[a,b]

	Short Run	Long Run (Year 10)	Cumulative	Cumulative Present Value	Percent of Total Present Value Cumulative Surplus
Producer Surplus					
Retail domestic lamb producer surplus	–$68.71	–$20.24	–$497.79	–$400.63	–7.36%
Retail imported lamb producer surplus	–0.69	–0.13[c]	–2.41[d]	–2.03[d]	–0.74[d]
Wholesale domestic lamb producer surplus	–9.84	0.11	29.35[c]	23.63[c]	1.05[c]
Wholesale imported lamb producer surplus	–0.58	–0.10[c]	–2.02[d]	–0.17[d]	–1.32[d]
Slaughter lamb producer surplus	–52.15	–4.61	–246.72	–207.58	–11.68
Feeder lamb producer surplus	–32.46	–5.45	–202.99	–167.14	–15.26
Total change in domestic producer surplus	–163.15	–30.19	–918.15	–751.72	–7.12
Total change in imported producer surplus	–1.27	–0.23[c]	–4.44[d]	–3.74[d]	–0.92
Total change in producer surplus	–164.42	–30.42	–922.59	–755.46	–6.89
Consumer Surplus					
Retail domestic lamb consumer surplus	–108.91	–63.44	–894.30	–706.73	–8.83
Retail imported lamb consumer surplus	–59.77	–6.66[c]	–184.24	–158.22[d]	–3.62[d]
Total change in consumer surplus	–168.88	–70.10	–1,078.54	–864.95	–6.99

[a] This scenario corresponds to a 6.63% decrease in retail lamb demand and a 4.80% decrease in wholesale domestic derived lamb supply.

[b] Producer and consumer surplus are calculated relative to 2000–2003 average quantities and prices.

[c] Significant from zero at the 10% level.

[d] Not significantly different from zero.

indifferent to the elimination of AMAs if that action would cause no change in retail lamb quality and only a 1% increase in processing costs. Note that Section 6.7.2 estimates that the complete elimination of AMAs would reduce retail demand because of a reduction in lamb meat quality by 6.63%, and Section 6.8.2 indicates that this action would increase processing costs by 4.80%.

6.11 SUMMARY OF CHANGES IN PROCUREMENT METHODS ON PRICES, QUANTITIES, AND PRODUCER SURPLUS

We developed a stochastic, dynamic, equilibrium displacement model of the U.S. lamb industry. The model includes supply and demand relations for the feeder lamb, fed lamb, lamb slaughter, domestic and import wholesale carcasses, and domestic and import retail demand sectors. The model explicitly considers oligopsony markdown pricing behavior by lamb packers and correlations among elasticity estimates. We do not directly estimate whether such market power actually exists; rather, we consider a variety of impacts that would result from changes in AMAs if market power were being exercised in the industry. The model is parameterized by econometrically estimating a structural demand and supply system of equations using publicly available annual data from 1970 to 2003.

The equilibrium displacement model also requires estimates of changes in costs that may occur if restrictions are placed on specific AMAs. We estimated a monthly, reduced form model of retail lamb, boxed lamb, slaughter lamb, slaughter ewe, and feeder lamb prices. A potential market power equation based on packer concentration ratios is included. The system is estimated using monthly MPR data. The monthly model is used to estimate changes in marginal costs at the packer level and changes in potential oligopsony market power in response to assumed restrictions on the use of AMAs. In addition, we incorporate the potential change in lamb meat quality resulting from potential changes in AMAs.

Specifically, we simulate the results of a 25% reduction in the procurement of fed lambs by formula and packer ownership procurement methods. We also simulate changes caused by a 100% reduction in formula and packer ownership procurement of fed lambs. In both cases, it is assumed these reductions cause increased procurement via other methods.

The equilibrium displacement model quantifies the effects of the above changes in AMAs on annual equilibrium prices, quantities, producer surplus, and consumer surplus over a 10-year period. In addition, Monte Carlo simulations (1,000) are used to construct empirical probability distributions so that the statistical significance of each endogenous variable can be evaluated. Empirical results are reported for short-term (1 year), long-term (10 years), and cumulative effects.

In general, the simulations indicate that the only sector that does not lose producer (consumer) surplus in the long run is the wholesale domestic lamb sector.

For illustration purposes, a third simulation was conducted in which a 100% reduction in formula and packer ownership procurement was assumed to completely eliminate potential oligopsony market power. The results were not significantly different from those reported above. That is, even if eliminating formula and packer ownership lamb procurement would completely eliminate potential oligopsony power, the net effects would be to reduce price, quantities, and producer and consumer surplus in almost all sectors because of additional processing costs and reductions in lamb meat quality.

Finally, two additional simulations were conducted. The first these evaluated the amount of oligopsony markdown pricing that must currently exist so that the complete elimination of that potential market power (by eliminating the use of AMAs) would result in no change in producer surplus at the slaughter lamb level. The analysis indicates that the current level of markdown pricing would have to be 10.5%, which is much larger than empirical estimates from the beef industry. The second additional simulation evaluated the amount of increased processing costs that could be offset by reductions in potential market power so that producer surplus in the slaughter lamb sector would be unaffected. The simulation indicates that a 1% increase in processing costs could be offset by reductions in potential market power. However, under the scenario in which a 100% reduction in AMAs occurs, we estimate that processing costs would increase by 4.80%.

7 Implications of Alternative Marketing Arrangements

Based on the evidence from this study, we expect the use of AMAs in the lamb industry to increase somewhat over the next several years.

In this section, we describe the implications of AMAs based on the outcome of the combined set of research activities conducted for the study. Based on the industry interviews, surveys, and analyses of MPR data, we expect the use of AMAs in the lamb industry to increase somewhat over the next several years for three reasons. First, the domestic lamb industry continues to contract. Hence, AMAs will likely be used to a greater extent so that lamb packers can maintain fed lamb procurement. Second, the domestic lamb industry faces strong competition from lamb imports. Therefore, AMAs will likely be used to improve quality as the industry tries to address import competition. Third, if a country of origin labeling (COOL) requirement or a national animal identification system is implemented, the cost of lamb production will increase and likely cause some small producers to exit. In an effort to improve traceability, the use of AMAs may increase.

In the subsections below, we assess the economic incentives for and implications of changes in the use of AMAs. This discussion is within the context of hypothetical restrictions on the use of AMAs given the current levels of use of AMAs and the current institutional structures within the lamb industry.

7.1 ASSESSMENT OF ECONOMIC INCENTIVES FOR INCREASED OR DECREASED USE OF ALTERNATIVE MARKETING ARRANGEMENTS

In this section, we summarize our findings related to the economic incentives for changes in the use of AMAs in the lamb industry. This discussion is within the context of expected changes and hypothetical restrictions on the use of AMAs.

***Summary measure* of the economic incentives associated with the use of AMAs.** Buyers and sellers of livestock and meat face a number of economic incentives associated with using alternative marketing arrangements versus cash markets. Buyers of livestock and meat may choose to use specific marketing arrangements because they reduce the cost of procurement, improve the quality of animals and products purchased, aid in risk management, and improve logistics. Likewise, sellers of livestock and meat may choose to use specific marketing arrangements to improve market access, reduce transactions costs, increase prices, and reduce risk.

Empirical analyses indicate that small but statistically significant effects result from restrictions on the use of AMAs.

Empirical analyses indicate that small but statistically significant effects result from restrictions on the use of AMAs. Depending on the size of restrictions on the use of AMAs, lamb meat quality declines and reduces the demand for domestic lamb meat between 1.65% and 6.63%. In addition, processing costs increase between 1.20% and 4.80%. Finally, oligopsony markdowns decline from an assumed initial level of 1.5% to between 1.22% and 0.4% depending on the size of AMA reductions.

Section 6 presented measures of the economic incentives associated with the use of AMAs based on consumer and producer surplus changes that would result if their use were restricted. Several scenarios were evaluated under the assumption that reductions in AMAs would reduce retail lamb quality, increase packer processing costs, and reduce potential oligopsony markdown pricing (market power) of fed lambs.

One scenario assumed that the use of AMAs might be reduced by 25%. For the lamb industry, this is modeled as a 25% reduction in both formula and packer ownership procurement methods. A second scenario considers the effects of a 100%

These results indicate that, in the short run, the positive effect of reduced potential oligopsony processor market power that might result from restricting AMAs is unable to offset the negative effects of increased processing costs and decreased retail demand.

reduction in formula and packer ownership procurement methods. For both scenarios, short-run (1 year) results indicate that all prices decline with the exception of a small increase in domestic wholesale lamb prices, and almost all live lamb and lamb meat quantities decline. Furthermore, consumer surplus and producer surplus declines for every sector except for a small increase in the producer surplus of wholesale domestic lamb production. These results indicate that, in the short run, the positive effect of reduced potential oligopsony processor market power that might result from restricting AMAs is unable to offset the negative effects of increased processing costs and decreased retail demand.

***System-wide long-run effects* of major types of marketing arrangements on the livestock and meat industries.** To examine the long-run effects of AMAs, we calculated the consumer and producer surplus changes due to hypothetical restrictions over a 10-year period. Again, two primary scenarios are considered: (1) a 25% reduction in formula and packer ownership fed lamb procurement and (2) a 100% reduction in formula and packer ownership procurement.

These results indicate that, in the long run, the positive effect of reduced potential oligopsony processor market power that might result from restricting AMAs is unable to offset the negative effects of increased processing costs and decreased retail demand.

For both scenarios, long-run results indicate that all prices decline with the exception of a small increase in domestic wholesale lamb prices, and almost all live lamb and lamb meat quantities decline. Furthermore, consumer surplus and producer surplus decline for every sector except for a small increase in the producer surplus of wholesale domestic lamb production. These results indicate that, in the long run, the positive effect of reduced potential oligopsony processor market power that might result from restricting AMAs is unable to offset the negative effects of increased processing costs and decreased retail demand.

The *most significant* types of spot and AMAs based on the likelihood that the arrangement is or will be used extensively in the livestock and meat industries, including the types of marketing arrangements that are likely to *grow in importance* and usage and those that are likely to decrease in importance. Based on MPR data, about one-half of fed lambs are procured through cash means (auctions and negotiations), and most of the remainder are procured through formulas and contracts. Only about 5% of fed lambs are procured through packer ownership. In contrast, the survey results indicate that approximately 80% of fed lambs are procured through cash means.

Continued demands for higher quality lamb and competition from imports is likely to increase the use of formula procurement methods in an attempt to provide incentives for quality improvements.

It is unlikely that packer ownership of lambs will increase in the future. Lamb packers have yet to embrace this method, and it is unlikely that such a change will occur in this small, niche market. However, if the domestic lamb industry continues to contract, contracts will likely be used to a greater extent as lamb packers attempt to secure fed lamb supplies. In addition, continued demands for higher quality lamb and competition from imports is likely to increase the use of formula procurement methods in an attempt to provide incentives for quality improvements. As a result, the use of auctions is likely to decline, although direct negotiations between producers and packers may increase.

Summary effects of *combinations of marketing arrangements* across different stages of the supply chain (e.g., used by a combination of producers, packers, retailers, food service operators, exporters). At a strategic level, producers, packers, meat processors, and retailers decide to procure inputs that will satisfy the quality, volume, and price requirements of their buyers. For example, based on the industry interviews, some marketing arrangements are used upstream (e.g., between the producer and packer) to meet requirements for meat products downstream (e.g., between the packer and retailer). However, based on the data maintained by packers and processors, it is difficult to specifically model the relationship among marketing arrangements across multiples stages of production. The available lamb transactions data do not allow for a comparison of the use of AMAs for fed lamb purchases with AMAs used for lamb meat sales.

Based on the analysis of the MPR data, we found that the use of AMAs is associated with higher quality fed lamb purchased by packers.

Major summary effects of AMAs on consumer demand. Consumer demand for meat is affected by the use of AMAs if those arrangements allow for the production of higher quality products and/or sale of lamb products at lower prices. Based on the analysis of the MPR data, we found that the use of AMAs is associated with higher quality fed lamb purchased by packers. Thus, restrictions on the use of AMAs are likely to reduce the quality of retail lamb meat and increase competitive pressure from lamb imports.

7.2 IMPLICATIONS OF EXPECTED CHANGES IN USE OF ALTERNATIVE MARKETING ARRANGEMENTS OVER TIME

In this subsection, we summarize our findings related to the implications of expected changes in the use of AMAs in the fed lamb and lamb meat industry. This discussion is within the context of expected changes and hypothetical restrictions on the use of AMAs.

Implications changes in the use of marketing arrangements on *price discovery*. Price discovery refers to the process by which a buyer and a seller agree on a price for a specific transaction. Thus, price discovery depends on the pricing method used for each type of marketing arrangement. The association between types of marketing arrangements and types of pricing methods in the lamb industry is as follows:

- Auction barns: auction (open bid) pricing
- Negotiations or direct trade: individually negotiated pricing
- Marketing agreements: formula pricing
- Forward contracts: formula pricing
- Packer ownership: internal transfer pricing

In the case of formula pricing, base prices are generally established by those reported in an earlier week by the AMS or, in some cases, plant averages. AMS prices were historical averages obtained from voluntary price reporting from auction markets. For several years, AMS prices were those developed from MPR data obtained from the largest packers.

Because prices are reported under MPR for different types of marketing arrangements, the effect of marketing arrangement use on the price discovery process is minimal.

In either case, if the base price does not reflect current and expected supply and demand conditions, then the price discovery process is impeded. However, because prices are reported under MPR for different types of marketing arrangements, the effect of marketing arrangement use on the price discovery process is minimal. This may not have been the case under voluntary price reporting.

Over the MPR sample period, formula procurement volumes trended downward, while auction procurement volumes trended upward (each about 0.26 percentage points per month). The means and standard deviations of formula and cash fed lamb prices using MPR data were similar during the sample period.

The price series were highly correlated with an estimated correlation coefficient of 0.970.

Approximately 60% of the difference between formula and cash lamb prices is explained by variations in formula/carcass price differences, carcass price risk, sheep and lamb inventories, differences between formula and cash lamb procurement volumes, and seasonality. An important result consistent with *a priori* expectations is that an increase in output price risk increases the price difference between formula and cash prices.

Implications of expected changes in the use of marketing arrangements on *thin markets*. Markets are considered thin when the volume of transactions is so small that prices are highly volatile and may not reflect supply and demand conditions or livestock and meat quality. Of course, animals that are procured using AMAs are not sold in auction markets. More importantly, most of the price, quantity, and quality information in these cases was not publicly reported in the past. Thus, without publicly reported data, AMAs can cause cash markets to become relatively thin.

Historically, most livestock prices were determined in spot markets either through auctions or direct negotiations between buyers and sellers. Traditionally, spot market prices were voluntarily reported to AMS' Market News system by buyers and sellers. These reported prices were often the basis for negotiating other prices among buyers and sellers.

In 1999, the Livestock Mandatory Reporting Act was passed by Congress with implementation beginning in April 2001 and ending in 2005 for lamb prices. The Mandatory Reporting Act has recently been reauthorized, but implementation will not likely occur until late 2007. The purposes of MPR were to provide market price and quantity information for cattle, hogs, lamb, and meat products that (1) could be readily understood by market participants; (2) provide information on price discovery, quantity, and quality of livestock and livestock products procured and sold under AMAs; (3) improve USDA price-reporting services; and (4) encourage competition. Azzam (2003) notes that the driving force for MPR was the assumption that market price transparency would promote competition. The comparative statics of his theoretical model suggest that livestock producers may not *directly* benefit from the increased transparency of reported prices. Rather, if the pooling of information among packers is a relatively low-cost activity, then MPR may increase competition among packers in procuring fed livestock inputs.

MPR differed from voluntary reporting in that large lamb packers (those with average annual slaughter capacity exceeding 75,000 head) and importers were now required to submit summary information electronically to the USDA AMS. In addition, MPR required that prices and terms of sales be reported beyond those transactions that occur in spot markets, and that premiums and discounts for quality characteristics be reported. MPR required not only the usual reporting of prices, but also the method of procurement.

Although empirical research seems to suggest an inverse relationship between captive supplies and cash-market prices, establishing a causal link has been elusive. Xia and Sexton (2004) note that removing a share of cattle from the cash market affects both supply and demand in that market. In a competitive market, the effect on price is ambiguous because it depends on the relative magnitudes of the shifts and on demand and supply elasticities.

It should be noted that formal commodity futures markets for lamb meat and fed lambs do not exist. Thus, AMAs may be the only price risk management tool available for lamb producers.

Implications of expected changes in the use of marketing arrangements on *risk management*. The use of AMAs for fed lamb marketing does not appear to shift risk between producers and packers. However, the implementation of MPR in 2001 was intended to increase pricing efficiency through improved market price transparency (Perry et al., 2005). Our research indicates that the Mandatory Reporting Act had a statistically significant, albeit economically small, effect on slaughter lamb prices. The implementation of the Act increased slaughter lamb price by 0.129%. Given that lamb markets are relatively thin, the primary impact of the Act may have been to reduce price risk rather than influence price levels (Marsh and McDonnell, 2005).

Finally, it should be noted that formal commodity futures markets for lamb meat and fed lambs do not exist. Thus, AMAs may be the only price risk management tool available for lamb producers.

Restrictions on the use of AMAs would likely put lamb at a competitive disadvantage relative to other meat and to imported lamb.

Implications of expected changes in the use of marketing arrangements on *competitiveness among meats*. Competitiveness among meats changes if prices or quality of products change. Based on the simulations conducted in this volume, restrictions on the use of AMAs appear to decrease the quality of lamb meat more than that of beef and pork. Although lamb is not a strong substitute for beef and pork, restrictions on the use of AMAs do place it at a competitive disadvantage to these other meats.

More importantly, however, it appears that imported lamb is a strong substitute for domestic lamb. Hence, the loss of competitiveness in response to restrictions on the use of AMAs is much more pronounced with respect to lamb imports.

If AMAs reduce the viability of public auctions, it may be that small producers will not be able to obtain market access.

Implications of expected changes in the use of marketing arrangements on *ease of entry* into each stage of the livestock and meat industries. Ease of entry (or the extent of entry barriers) refers to whether individuals who would like to enter the lamb production industry are able to do so. Ease of entry may be affected by the availability of AMAs because financing of production operations often depends on the assurance of market access and price risk management. However, for small producers, it may be more difficult to secure AMAs because it is more costly for packers to negotiate with many small producers relative to fewer large producers. Hence, if AMAs reduce the viability of public auctions, it may be that small producers will not be able to obtain market access.

If restrictions on AMAs reduce the competitiveness of domestic lamb meat relative to lamb imports, then concentration in the lamb packing and processing industry is likely to increase in response to declining domestic demand.

Implications of expected changes in the use of marketing arrangements on *concentration* in livestock production and feeding and in meatpacking, *structure* of the livestock industry, and *structure* of the meatpacking industry. Based on the analyses conducted for this study, there are no clear effects of the changes in the use of AMAs on concentration in the lamb industry. Concentration as measured by the four-firm concentration ratio (CR4) has been relatively flat while the use of AMAs has increased. However, as noted above, increased use of AMAs may reduce the viability of auctions. Thus, one could expect increases in the concentration of the livestock feeding sector. In addition, if restrictions on AMAs reduce the competitiveness of domestic lamb meat relative to lamb imports, then concentration in the lamb packing and processing industry is likely to increase in response to declining domestic demand.

8 References

American Sheep Industry Association. *U.S. Sheep Industry Market Situation and Report, 2003–2004*. Available at www.sheepusa.org.

Appelbaum, E. 1979. "Testing Price Taking Behavior." *Journal of Econometrics* 9:283-294.

Appelbaum, E. 1982 "The Estimation of the Degree of Oligopoly Power." *Journal of Econometrics* 19:287-299.

Azzam, A.M., and D.G Anderson. 1996. "*Assessing Competition in Meatpacking: Economic History, Theory, and Evidence.*" GIPSA-RR 96-6. Washington, DC: Packers and Stockyards Programs, Grain Inspection, Packers and Stockyards Administration, U.S. Department of Agriculture.

Azzam, A.M., and J.R. Schroeter. 1991. "Implications of Increased Regional Concentration and Oligopsonistic Coordination in the Beef Packing Industry." *Western Journal of Agricultural Economics* 16:374-381.

Azzam, A. 2003. "Market Transparency and Market Structure: The Livestock Mandatory Reporting Act of 1999." *American Journal of Agricultural Economics* 83(2):387-398.

Babula, R.A. 1996. "An Empirical Examination of U.S. Lamb-Related Import and Domestic Market Relationships near the Farmgate." *Journal of International Food & Agribusiness Marketing* 8(2):65-82.

Babula, R.A. 1997. "Economic Effects of a Countervailing Duty Order on the U.S. Lamb Meat Industry." *Agricultural and Resource Economics Review* 26(1):82-93.

Boland, M.A., A.M. Bosse, and G.W. Brester. 2005. "Mountain States Lamb Cooperative: Vertical Integration into Lamb Processing." Case study.

Boland, M.A, A.M. Bosse, and G.W. Brester. Forthcoming. "The Mountain States Lamb Cooperative: Can Vertical Integration Keep Lamb Producers from Being Fleeced?" *Review of Agricultural Economics*.

Brester, G.W., and J.M. Marsh. 1983. "A Statistical Model of the Primary and Derived Market Levels in the U.S. Beef Industry." *Western Journal of Agricultural Economics* 8:34-49.

Brester, G.W., and J.M. Marsh. 2001. "The Effects of U.S. Meat Packing and Livestock Production Technologies on Marketing Margins and Prices." *Journal of Agricultural and Resource Economics* 26(2):445-462.

Brester, G.W., and D.C. Musick. 1995. "The Effect of Market Concentration on Lamb Marketing Margins." *Journal of Agricultural and Applied Economics* 27:172-183.

Brester, G.W., and M.K. Wohlgenant. 1997. "Impacts of the GATT/Uruguay Round Trade Negotiations on U.S. Beef and Cattle Prices." *Journal of Agricultural and Resource Economics* 22:145-156.

Brester, G.W, J.M. Marsh, and J. Atwood. 2004. "Distributional Impacts of Country-of-Origin Labeling in the U.S. Meat Industry." *Journal of Agricultural and Resource Economics* 29(2):206-227.

Brown, B.J., J. Durbin, and J. Evans. 1975. "Techniques for Testing the Constancy of Regression Relationships over Time." *Journal of the Royal Statistical Society* Series B, 37:149-172.

Capps, O. Jr., P.J. Byrne, and G.W. Williams. 1995. "Analysis of Marketing Margins in the U.S. Lamb Industry." *Agricultural and Resource Economics Review* 25(1):233-240.

Crespi, J.M., Z. Gao, and H.H. Peterson. 2005. "A Simple Test of Oligopsony Behavior with an Application to Rice Milling." *Journal of Agricultural & Food Industrial Organization* 3:1-17.

Davis, G.C., and M.C. Espinoza. 1998. "A Unified Approach to Sensitivity Analysis in Equilibrium Displacement Models." *American Journal of Agricultural Economics* 80:868-879.

Eales, J.S. 1996. "A Symmetric Approach to Canadian Meat Demand Estimation." *Journal of Agricultural and Resource Economics* 21:368-380.

Eales, J.S., and L.J. Unnevehr. 1993. "Simultaneity and Structural Change in U.S. Meat Demand." *American Journal of Agricultural Economics* 75:259-268.

Economic Report of the President. Washington, DC: Government Printing Office, various issues.

Gardner, B.L. 1975. "The Farm-Retail Price Spread in a Competitive Food Industry." *American Journal of Agricultural Economics* 57:399-409.

Gardner, B.L. 1982. "Effects of U.S. Wool Policy." GAO/CED-82-86CR. Washington, DC.

Greene, W.H. 2003. *Econometric Analysis*, 5th ed. Upper Saddle River, NJ: Prentice-Hall, Inc.

Griliches, Z. 1967. "Distributed Lags: A Survey." *Econometrica* 35:16-49.

Iman, R.L., and W.J. Conover. 1982. "A Distribution-Free Approach to Inducing Rank Correlation among Input Variables." *Communications in Statistics: Simulation and Computation* 11(3):311-334.

International Monetary Fund. "International Financial Statistics." Washington, DC, various issues.

Johnston, J., and J. DiNardo. 1997. *Econometric Models, Fourth Edition*. New York:McGraw-Hill Companies, Inc.

Jones, Keithly. February 2004a. "Marketing Could Boost the U.S. Sheep Industry." *Amber Waves*. Washington, DC: U.S. Department of Agriculture, Economic Research Service.

Jones, K.G. 2004b. *Trends in the U.S. Sheep Industry.* Agricultural Information Bulletin Number 787. Washington, DC: U.S. Department of Agriculture, Economic Research Service.

Knutson, R.O., J.B. Penn, and W.T. Boehm. 1990. *Agricultural and Food Policy, Second Edition*. New Jersey: Prentice Hall.

Koontz, S.R., P. Garcia, and M.A. Hudson. 1993. "Meatpacker Conduct in Fed Cattle Pricing: An Investigation of Oligopsony Power." *American Journal of Agricultural Economics* 75:537-548.

Kott, R. 2004. Montana Farm Flock Sheep Production Handbook. Montana State University. Animal and Range Sciences Extension Service. <http://animalrange extension.montana.edu/Articles/Sheep/Flock%20 Handbook/Reproduction.htm>. As obtained 2005.

Lusk, J.L., and J.D. Anderson. 2004. "Effects of Country-of-Origin Labeling on Meat Producers and Consumers." *Journal of Agricultural and Resource Economics* 29:185-205.

Malecky, J.M. 1975. "Price Elasticity of Wool Supply." *Quarterly Review of Agricultural Economics* 28(4):240-258.

Marsh, J.M., and T. McDonnell. 2005. "Livestock Mandatory Price Reporting: Estimated Effects on U.S. Lamb Carcass Prices." Montana State University, working paper submitted to U.S Senate Agricultural Committee on Mandatory Price Reporting.

Marsh, John M., and G.W. Brester. 2004. "Wholesale-Retail Marketing Margin Behavior in the Beef and Pork Industries." *Journal of Agricultural and Resource Economics* 29(1):45-64.

Marsh, J.M. 1994. "Estimating Intertemporal Supply Response in the Fed Beef Market." *American Journal of Agricultural Economics* 76:444-453.

Marsh, J.M. 1999. "Economic Factors Determining Changes in Dressed Weights of Live Cattle and Hogs." *Journal of Agricultural and Resource Economics* 24(2):313-326.

Marsh, J.M. 2003. "Impacts of Declining U.S. Retail Beef Demand on Farm-Level Beef Prices and Production." *American Journal of Agricultural Economics* 85:902-913.

McDonnell, T. 2005–2006. Personal communication.

Menkhaus, D.J., G.D. Whipple, and C.E. Ward. 1989. "Concentration in the Lamb Slaughtering Industry: Impact on Lamb Prices." *SID Sheep Research Journal* 6:25-29.

Menkhaus, D.J., J.S. St. Clair, and A.Z. Ahmaddaud. 1981. "The Effects of Industry Structure on Price: A Case in the Beef Industry." *Western Journal of Agricultural Economics* 6(2):147-153.

Morrison-Paul, C.J. 2001. "Market and Cost Structure in the U.S. Beef Packing Industry: A Plant-Level Analysis." *American Journal of Agricultural Economics* 83:64-76.

Muth, M.K., and M.K. Wohlgenant. 1999. “Measuring the Degree of Oligosony Power in the Beef Packing Industry in the Absence of Marketing Input Quantity Data.” *Journal of Agricultural and Resource Economics* 24(2):299-312.

Muth, M.K., G. Brester, J. Del Roccili, S. Koontz, B. Martin, N. Piggott, J. Taylor, T. Vukina, and M. Wohlgenant. July 2005. “Spot and Alternative Marketing Arrangements in the Livestock and Meat Industries: Interim Report.” Prepared for the U.S. Department of Agriculture, Grain Inspection, Packers and Stockyards Administration.

Nelson, G., and T. Spreen. 1978. “Monthly Steer and Heifer Supply.” *American Journal of Agricultural Economics* 60:117-125.

Nerlove, M. 1963. “Returns to Scale in Electricity Supply.” *Measurement in Economics: Studies in Mathematical Economics and Econometrics in Memory of Yehuda Grunfeld*. C. Christ, ed. Stanford, CA: Stanford University Press.

Perry, J., J. MacDonald, K. Nelson, W. Hahn, C. Arnande, and G. Plato. September 2005. “Did Mandatory Requirement Aid the Market? Impact of the Livestock Mandatory Reporting Act.” LDP-M-135-01. Washington, DC: U.S. Department of Agriculture.

Pindyck, R.S., and D.L. Rubinfeld. 1998. *Econometric Models and Economic Forecasts,* 4th Edition. Boston: Irwin, McGraw-Hill.

Pollack, R.A. 1970. “Habit Formation and Dynamic Demand Functions.” *Journal of Political Economy* 78:745-763.

Purcell, W.D. 1998. “Demand and Consumer Issues.” *Sheep and Goat Research Journal* 14:76-82.

Purcell, W.D., J. Reaves, and W. Preston. 1991. *Economics of Past, Current, and Pending Change in the U.S. Sheep Industry with an Emphasis on Supply Response*. Research Institute on Livestock Pricing, Virginia Tech University, Res. Bull. 6-91. Blacksburg, VA: Virginia Tech University.

Quail, G., B. Marion, F. Geithman, and J. Marquardt. 1986. “The Impact of Packer Buyer Concentration on Live Cattle Prices.” University of Wisconsin, NC-117, working paper 89. Madison, WI: University of Wisconsin.

Quantitative Micro Software, LLC. March 2004. *Eviews 5.1*. Irvine, CA: Quantitative Micro Software, LLC.

Reynolds, E.G., and B. Gardiner. 1980. “Supply Response in the Australian Sheep Industry: A Case of Disaggregation and Dynamics.” *Australian Journal of Agricultural Economics* 24:196-209.

Richie, M.M. 1979. “New Zealand Beef and Sheep Supply Relationships.” *Australian Journal of Agricultural Economics* 23:102-115.

RTI International. 2005. Enhanced Facilities Database. Prepared for the U.S. Department of Agriculture, Food Safety and Inspection Service. Research Triangle Park, NC: RTI.

Rucker, R.R., O.R. Burt, and J.T. LaFrance. 1984. “An Econometric Model of Cattle Inventories.” *American Journal of Agricultural Economics* 66:131-144.

Schroeder, T.C., R. Jones, J. Mintert, and A. Barkley. 1991. *The Impacts of Captive Supplies on the Fed Cattle Industry*. Research Institute on Livestock Pricing, Virginia Tech University, Res. Bull. 7-91. Blacksburg, VA: Virginia Tech University.

Schroeter, J.R. 1988. “Estimating the Degree of Market Power in the Beef Packing Industry.” *The Review of Economics and Statistics* 70:158-162.

Shin, C., and T. Vukina. March 31, 2006. “Risk Shifting in Alternative Marketing Arrangements in the Hog Industry.” Working Paper. Raleigh, NC: North Carolina State University.

Stiegert, K.W., A. Azzam, and B.W. Brorsen. 1993. “Markdown Pricing and Cattle Supply in the Beef Packing Industry.” *American Journal of Agricultural Economics* 75:549-558.

Texas Agricultural Market Research Center (TAMRC), Lamb Study Team. 1991. *Assessment of Marketing Strategies to Enhance Returns to Lamb Producers*, ed. G. Williams. Texas A&M University, TAMRC Commodity Market Research Report No. CM-1-91. College Station, TX: Texas A&M University.

Tomek, W.G., and K.L. Robinson. 1990. *Agricultural Product Prices*, 3rd edition. Ithaca, NY: Cornell University Press.

U.S. Department of Agriculture, Agricultural Marketing Service. 2000. Livestock and Grain Market News Branch: Livestock Mandatory Reporting: Final Rule. Federal Register 65(1 December 2000):75464-75542.

U.S. Department of Agriculture, Economic Research Service. 2004a. *Livestock, Dairy, and Poultry Situation and Outlook*. Washington, DC: USDA.

U.S. Department of Agriculture, Economic Research Service. 2004b. *Red Meat Yearbook Statistical Series, 1970–2003*. ERS Statistical Bulletin No. 921 and http://usda.mannlib.cornell.edu/datasets/livestock; 94006/. Washington, DC: USDA.

U.S. Department of Agriculture, Economic Research Service. 2004c. Sheep and Wool: Overview. <http://www.ers.usda.gov/Briefing/Sheep/overview.htm#background>. Last updated August 23, 2004.

U.S. Department of Agriculture, Economic Research Service, Market & Trade Economics Division. 2006. *Red Meat Yearbook*. Stock #94006. Washington, DC: USDA. <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354>.

U.S. Department of Agriculture, Grain Inspection, Packers and Stockyards Administration. January 2002. *Packers and Stockyards Statistical Report*, 1999 Reporting Year, GIPSA SR-02-1. Washington, DC: GIPSA.

U.S. Department of Agriculture, Grain Inspection, Packers and Stockyards Administration. 2006. *Packers and Stockyards Statistical Report*. SR-06-1. Washington, DC: GIPSA.

U.S. Department of Agriculture, National Agricultural Statistics Service. 1995-1996. “Agricultural Statistics.” ISBN 0-16-036158-3. Washington, DC: USDA.

U.S. Department of Agriculture, National Agricultural Statistics Service. 2002. “Sheep.” Agricultural Statistics Board, July 19.

U.S. Department of Agriculture, National Agricultural Statistics Service. 2003. “Agricultural Statistics.” Washington, DC: USDA.

U.S. Department of Agriculture, National Agricultural Statistics Service. 2004a. “Agricultural Statistics.” Washington, DC: USDA. <http://www.usda.gov/nass/pubs/agstats.htm>.

U.S. Department of Agriculture, National Agricultural Statistics Service. 2004b. “2002 Census of Agriculture.” Washington, DC: USDA. <http://www.nass.usda.gov/research/atlas02/>.

U.S. Department of Agriculture, National Agricultual Statistics Service. 2005. “Agricultural Statistics.” ISBN 0-16-036158-3. Washington, DC: USDA.

U.S. International Trade Commission (ITC). 1999. *Lamb Meat, Investigation No. TZ-201-68*. USITC publication 3176. Washington, DC: USITC.

Van Tassell, L.W., and G.D. Whipple. 1994. “The Cyclical Nature of the U.S. Sheep Industry.” *Journal of Agricultural and Resource Economics* 19:267-279.

Varian, H. 1992. *Microeconomic Analysis*, 3rd ed. New York: W.W. Norton and Co.

Vere, D., G. Griffiths, and R. Jones. 2000. “The Specification, Estimation, and Validation of a Quarterly Structural Econometric Model of the Australian Grazing Industries.” *Weed Management Systems*, Technical Series No. 5. Glen Osmond, Australia: CRC for Weed Management Systems.

Ward, C.E. 1981. “Short-period Pricing Models for Fed Cattle and Impacts of Wholesale Carcass Beef and Live Cattle Futures Market Prices.” *Southern Journal of Agricultural Economics* 13:125-132.

Weliwita, A., and A.M. Azzam. 1996. “Identifying Implicit Collusion Under Declining Output Demand.” *Journal of Agricultural and Resource Economics* 21:235-246.

Whipple, G.D., and D.J. Menkhaus. 1989. “Supply Response in the U.S. Sheep Industry.” *American Journal of Agricultural Economics* 71:126-135.

Whipple, G.D., and D.J. Menkhaus. 1990. “Welfare Implications of the Wool Act.” *Western Journal of Agricultural Economics* 15:126-135.

Williams, G.W., and O. Capps, Jr. 1991. *Assessment of Marketing Strategies to Enhance Returns to Lamb Producers*. TAMRC Commodity Research Report No. CM-1-91. College Station, TX: Texas A&M University.

Wohlgenant, M.K. 1989. “Demand for Farm Output in a Complete System of Demand Functions.” *American Journal of Agricultural Economics* 71:241-252.

Wohlgenant, M.K. 1993. “Distribution of Gains from Research and Promotion in Multi-State Production Systems: The Case of the U.S. Beef and Pork Industries.” *American Journal of Agricultural Economics* 75:642-651.

Xia, T. and R.J. Sexton. 2004. “The Competitive Implications of Top-of-the-Market and Related Contract-Pricing Clauses *American Journal of Agricultural Economics* 86(1):124-138.

Appendix A: Stochastic Equilibrium Displacement Models

Elasticity-based computable equilibria (equilibrium displacement models) or partial equilibria models are commonly used when assessing the effects and/or the costs of potential changes in economic policy or structure. Elasticity-based computable equilibria models are attractive in that they are obtained by simple manipulation or row operations of differential approximations to economic models and are accurate to the degree that the underlying system can be linearly approximated (Davis and Espinoza, 1998; Brester, Marsh, and Atwood, 2004).

In economic modeling, the system's actual parameters are usually unknown and must be estimated or assumed. Most studies use some combination of assumed, previously published, and/or statistically estimated shares and elasticities. In all cases, it should be recognized that uncertainty exists with respect to the model's actual parameters and, as a result, with respect to the policy effects derived using estimated parameters. Davis and Espinoza (1998) illustrate the importance of examining the sensitivity of changes in prices and quantities (as well as producer and consumer surplus) relative to variations in selected elasticity estimates. Also, as a practical matter, the amount of uncertainty with respect to model parameters may vary across parameters. For example, if a number of researchers and statistical methodologies have obtained similar estimates for a given elasticity, the degree of uncertainty with respect to the given elasticity will be less than for a parameter for which published estimates have varied widely across researchers and methodologies.

An additional complication in policy models is that subsets of the model's economic parameters are likely to be correlated, nonnormally distributed, and possibly intractable. For example, elasticities of supply in a vertically structured model might be positively correlated and restricted to be positive, while own-demand elasticities might be positively correlated and restricted to be negative (Davis and Espinoza, 1998). Brester, Marsh, and Atwood (2004) use Monte Carlo simulations of an equilibrium displacement model in which elasticities among vertical demand and supply sectors are correlated.

As indicated below, if independent marginal distributions of a model's parameters can be approximated, Monte Carlo simulation techniques can be used to introduce correlation between marginal pseudo-samples from possibly widely divergent statistical families of distributions. However, in such cases, the common methods for generating correlated multivariate normal random variates are inappropriate if applied directly to the marginal pseudo-samples themselves.

We use a variant of the Iman-Conover (1982) process for generating correlated random variables. The Iman-Conover process is attractive in that marginal distributions can be simulated independently from most continuous distributions. Each of the independently generated marginal samples is then merely reordered to obtain a rank correlation similar to the desired correlation structure. The Iman-Conover process is straightforward and easy to implement in most common spreadsheets and statistical packages. The following examples were developed in “R”—a free public source statistical modeling software package.

We first demonstrate why traditional procedures for generating correlated multivariate normal random variates are inappropriate for a general set of marginal distributions. We then demonstrate the use of Iman-Conover procedures for introducing correlation while preserving all marginal pseudo-samples.

A.1 GENERATING MULTIVARIATE NORMAL PSEUDO-SAMPLES

The most commonly used procedures for generating correlated multivariate normal samples exploit the fact that linear combinations of normal random variates are themselves normally distributed. Assume that an n by k multivariate normal “sample” Z_C with covariance matrix Σ is desired. A common procedure to generate such a sample matrix is to initially populate an n by k matrix Z_1 with randomly and independently generated normal (0,1) random variates. If the random variates in Z_1 are independently generated, the expected covariance matrix of Z_1 is a k by k identity matrix I_1. However, for finite samples the realized sample covariance matrix is computable as

$$\hat{\Sigma}_{Z_1} = Z_1' \left[\frac{1}{n-1} \left(I_n - \frac{1}{n} \underline{1}_n \underline{1}_n \right) \right] Z_1' \hat{C} Z_1 \tag{A.1}$$

and may not equal I_k. In the above expression, $\underline{1}_n$ is an n by 1 vector with each element equal to 1, and $\hat{C}$ is the sample covariance operator. Procedures similar to those presented in Greene (2003) can be used to easily demonstrate that $Y'\hat{C}Y$ is the sample covariance matrix of any corresponding sample matrix Y.

Before proceeding, we apply an Iman-Conover "whitening" process by factoring $\hat{\Sigma}_{Z_1} = U'U$ using a Cholesky or similar factorization algorithm. If Z_1 was generated randomly, the matrix U will be nonsingular and a "whitened" sample matrix Z_W can be constructed as $Z_W = Z_1U^{-1}$. Because the columns of Z_W are linear combinations of the columns of Z_1, the n by k sample Z_W will be multivariate normal with sample covariance matrix:

$$\hat{\Sigma}_{Z,W} = Z_W'\hat{C}Z_W = \left(U^{-1}\right)' Z_1'\hat{C}Z_1U^{-1} = \left(U^{-1}\right)' \hat{\Sigma}_{Z_1}U^{-1} = \left(U'\right)^{-1} U'UU^{-1} = I_k. \qquad \text{(A.2)}$$

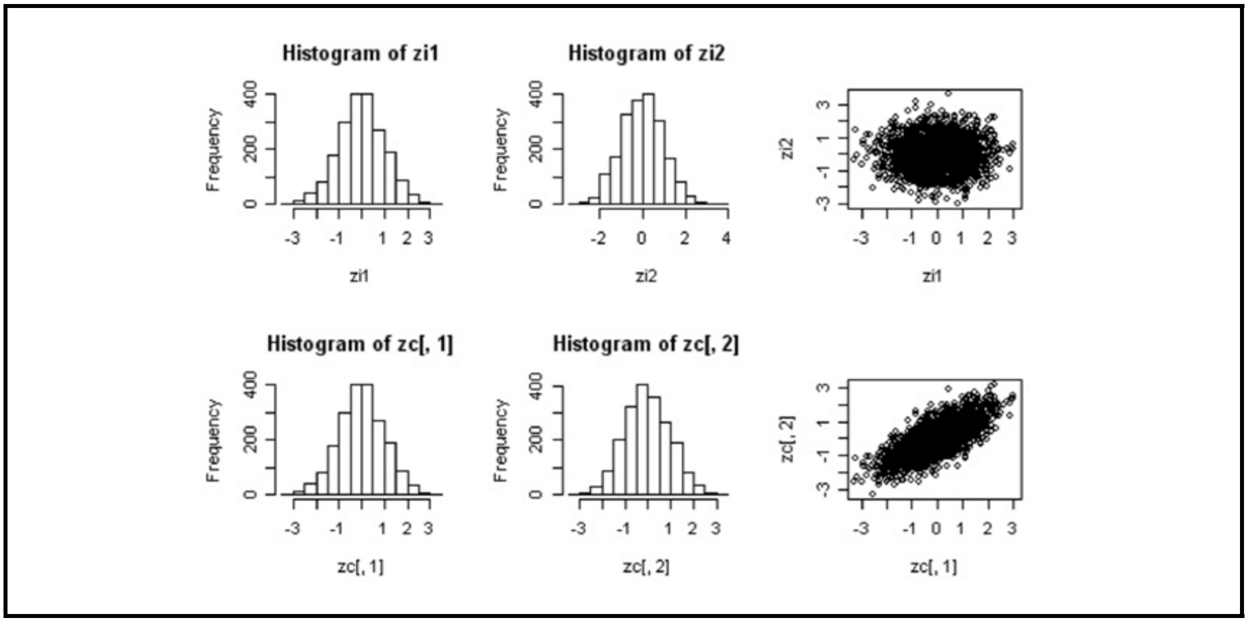
Obtaining a multivariate normal sample Z_C with sample covariance matrix Σ is accomplished by factoring $\Sigma = V'V$ and generating $Z_C = Z_WV$, which has sample covariance matrix:

$$\hat{\Sigma}_{Z_C} = Z_C'\hat{C}Z_C = V'Z_W'\hat{C}Z_WV = V'\hat{\Sigma}_{Z_W} = V'V = \Sigma. \qquad \text{(A.3)}$$

Because each column of Z_C is generated as linear combinations of the columns of Z_W, the columns in Z_C are distributed multivariate normal while having a sample covariance equal to the desired covariance matrix Σ. The panels in Figure A-1 plot the results of applying the above process with 2,000 observations on two normal variates with a target correlation of 0.7. The top three panels are histograms of the two independently generated normal (0,1) variates and a joint scatter plot. The bottom three panels in Figure A-1 present histograms and a joint scatter plot of the two marginals after the above transformations were applied. The resulting correlation between the two marginals is 0.7.

In the following discussion we return to the multivariate normal matrix Z_C because it is integral to the variant of the Iman-Conover procedure that we use. In the next section, we demonstrate why the above process for generating correlated random variables (taking linear combinations of independently generated marginals) is not appropriate when working with nonadditively regenerative marginal distributions.

Figure A-1. Plots of Normally Random Variates Before and After Transformation

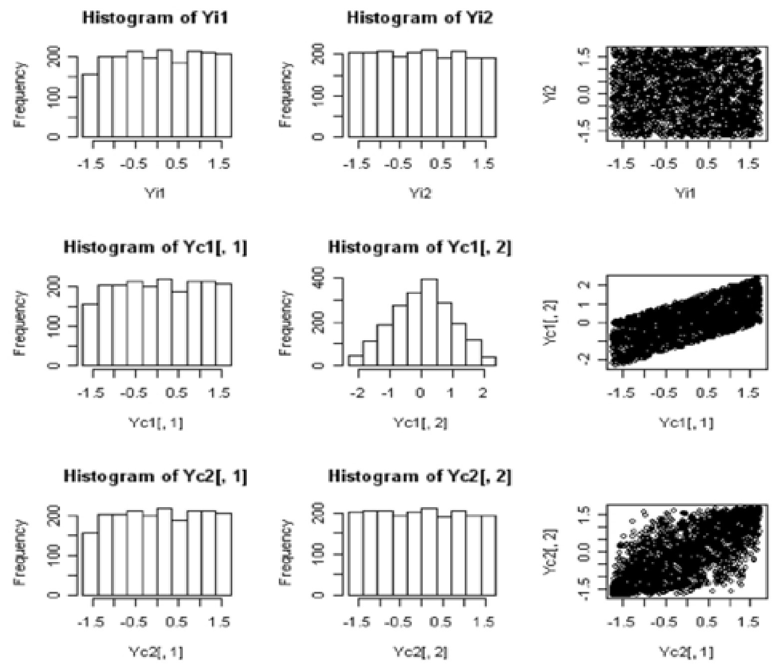


A.2 LINEAR COMBINATIONS OF NONREGENERATIVE DISTRIBUTIONS

The top three panels in Figure A-2 present histograms and a joint scatter plot from a 2,000 by 2 bivariate pseudo-sample Y_1 generated as two independent *uniform* $-\sqrt{3}, \sqrt{3}$ distributions with mean 0 and variance 1. The histograms and scatter plot of the marginal distributions indicate that the pseudo-samples appear to be uniformly and independently distributed over the $-\sqrt{3}, \sqrt{3}$ interval.

Assume that a correlated bivariate uniform distribution is desired with correlation 0.7. Because the uniform distribution is not additively regenerative, generating correlated variates using the Cholesky decomposition weighted-average procedure destroys the original marginal distributions. The middle three panels in Figure A-2 demonstrate this result. With a bivariate distribution, the Cholesky decomposition transformation leaves the first marginal unchanged. However, the second variate is reconstructed as a linear combination of both the original marginal samples. The second histogram in the middle set of panels clearly shows that the resulting variate is not uniformly

Figure A-2. Results of Generating Correlated Uniform Random Variates



distributed although the correlation between the two transformed random variates is 0.7. The scatter plot of the joint observations is presented in the third panel of Figure A-2.

The results of applying the Iman-Conover process to the uniform marginal samples are presented in the third panel of plots in Figure A-2.[1]

[1] As we indicate above, the Iman-Conover process can easily be implemented in Excel or other programming environments. Following is R code that can be used to compute the reordered correlated pseudo-sample. The user calls the function with the Y_I and SIGMA matrices. The function returns the correlated Y_C sample matrix.

```
ImanConover=function(yi,sigma) {
yc=yi
ydim=dim(yi)            # record the dimension of the YI matrix
zi=matrix(rnorm(ydim[1]*ydim[2]),ydim[1],ydim[2])   # populate the
   normal(0,1) ZI matrix
zc=(zi %*% (solve(chol(cov(zi)))) %*% (chol(sigma))  # create the
   correlated ZC matrix
for (j in 1:ncols) {
 ys=sort(yi[,j])
 yc[,j]=ys[rank(zc[,j])]              # create the correlated YC matrix
 }
yc
}
```

Because the Iman-Conover process merely involves reordering the original marginal pseudo-sample, the process has clearly not affected the histograms of the marginal distributions. The Pearson correlation of the transformed variates for this example is about 0.695. The third plot in panel three is a scatter plot of the joint distribution after the reordering process.

The Iman-Conover process can easily be used to generate correlated random variables over a wide range of possible functional forms for the marginal distributions in an economic policy simulation model.

A.3 GENERAL SIMULATION ISSUES

All simulations were conducted after selecting prior distributions for each of the elasticities used in the model. We apply nonstandard beta priors to the estimated demand and supply elasticities. The use of nonstandard beta distributions maintains original means and standard deviations for each elasticity. In addition, nonstandard beta distributions allow demand elasticities to be constrained to always be negative and supply elasticities to always be positive.

A sensitivity analysis of an equilibrium displacement model should consider both variations of elasticity estimates and correlations among these estimates (Davis and Espinoza, 1998). We assume that demand elasticities are uncorrelated with supply elasticities across the SUR block models. However, estimated correlations among the demand elasticities and among the supply elasticities are used in the simulation.

All of the Monte Carlo simulations conducted in Section 6 are the result of 1,000 iterations. Empirical distributions are generated for each endogenous variable and for all estimates of changes in consumer and producer surplus. We use these empirical distributions to develop reported means, confidence intervals, and P values for our results (Brester, Marsh, and Atwood, 2004).