ECONOMETRIC MODEL OF THE U.S. SHEEP AND MOHAIR INDUSTRIES FOR POLICY ANALYSIS

A Dissertation

by

LUIS ALEJANDRO RIBERA LANDIVAR

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2005

Major Subject: Agricultural Economics

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ABSTRACT

Econometric Model of the U.S. Sheep and Mohair Industries for Policy Analysis.

(May 2005)

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The U.S. sheep industry has been declining in size for many years. Many factors have contributed to the decline of the sheep industry including declining consumption of lamb and mutton, the growth in manmade fiber use, scarcity of labor, and predator losses.

In an effort to slow the rate of decline in the U.S. sheep industry, the U.S. Congress passed the Wool Act of 1954. In 1993, Congress passed a three-year phase out of the Wool Act incentive payments with the last payments occurring in 1996. The 2002 Farm Bill included a marketing loan program for wool. The loan rates are set to $0.40 per pound for un-graded wool, $1.00 per pound for graded wool. In recent years exchange rate changes have had a large impact on the industry affecting lamb and wool trade.

The U.S. is the second largest producer of mohair and Texas accounts for over 85 percent of the U.S. mohair production. Mohair also received incentive payments through the Wool Act. Mohair payments were also phased out along with the wool incentive payments. Moreover, the 2002 Farm Bill reinstated support for the industry by implementing a loan program with loan rates of $4.20 per pound of mohair.

This analysis uses capital stock inventory accounting methodology to model the supply side of the sheep industry. Demand is incorporated using traditional single equations and complete demand system estimation methods. OLS, 2SLS, and 3SLS models are developed and tested for the single equations estimation methods. The OLS model is used to model the impacts of three different levels of loan rates for wool. Also, an OLS mohair model is developed and used to examine the impacts of three different levels of loan rates for mohair.

Results indicate that the sheep industry will continue to decline even with the marketing loan program for wool in the 2002 Farm Bill. However, a higher loan rate for wool would reduce the decline rate of the industry. The Angora goat industry will continue to decline in size, but with a higher loan rate for mohair, the number of goats clipped would increase.

ACKNOWLEDGMENTS

No one attempts or accomplishes anything in life without the help and encouragement of family and friends. In my case, there are many to thank. First, I would like to thank my mom, dad, brother, sister, and grandmother who have unconditionally loved me, encouraged me, and supported me in so many ways for more than 28 years. Next, Kelli, who knows how difficult it is to be in a relationship where both are trying to accomplish our professional dream of getting a Ph.D. I would have accomplished nothing without your support and help.

I owe many thanks to Dr. James Richardson. He gave me a job at the AFPC, supported me through rough times, and guided me through the science of risk analysis and simulation so that I would be able to spread the word everywhere I go. His constant reviews and corrections made this study dissertation-worthy. I owe all of my professional accomplishments, so far, to him.

Thanks to Dr. David Anderson and Dr. Joe Outlaw, committee members, for their input in this dissertation. Dr. Anderson's extensive knowledge of the sheep and mohair industries and Dr. Outlaw's "go straight to the point" comments made this dissertation possible. Thanks also to Dr. Clair Nixon, committee member, for his views on agricultural policy that made me think out of the box.

I have been lucky to have made many friends along the way. Thank you for all your friendship and support. I especially want to thank Pablo, Cesar, and Iván. I will really miss our Friday evening discussions on Latin American politics, economics, and soccer at the Fox and Hound. I have enjoyed our friendship greatly.

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CHAPTER I

INTRODUCTION

Sheep were first domesticated in Central Asia about 10,000 years ago (Ensminger and Parker, 1986). Their use then was the same as today, to provide two products, meat and wool. Today, sheep production has evolved to include more than 200 breeds worldwide.

In the U.S. two areas dominate sheep production, the range state region and the farm flock region (Anderson, 1994). The range state region includes the 16 Western states and Texas. Commercial production in these states is made up of large concentrations of sheep grazing large areas of the range (Shapouri, 1991). In 2003, these states accounted for about 85 percent of the total U.S. sheep flock. The farm flock region includes the rest of the U.S. and accounts for the remaining 15 percent. These flocks generally use more meat-oriented breeds than wool producing breeds (USDA Sheep and Goats, 2003).

The U.S. sheep industry is very small compared to the rest of the world. In 2003, it accounted for 0.66 percent of the world's sheep inventory with 4.66 million head and about 1.41 percent of the world's wool production with about 38 million pounds of clean fleece (USDA Cotton and Wool Outlook, 2003). China is the world's largest sheep producer with 135 million head (in 2002), followed closely by Australia with 119

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million head and, in smaller scale, New Zealand, Argentina, Uruguay, and South Africa. In the world's wool production, Australia is the largest producer with 946 million pounds of clean fleece (in 2002), followed by New Zealand, China, Argentina, Uruguay and South Africa. Australia is the world's largest exporter of wool with 406 million pounds of clean fleece followed by New Zealand Argentina, Uruguay and South Africa. The U.S. is the 8th largest importer of wool with 75 million clean pounds (USDA Cotton and Wool Outlook, 2003).

Besides being a small producer of sheep internationally, the U.S. sheep industry has been declining for many years. From 1950 to 2003, the number of stock sheep has declined significantly, from 31 million head in 1960 to 4.66 million head in 2003 (USDA Agricultural Statistics, 2004).

Many factors have contributed to the decline of the sheep industry. The per capita consumption of lamb and mutton has fallen from 2.9 pounds in 1970 to 1.2 pounds in 2003 (USDA Livestock, Dairy and Poultry Outlook, 2003). During the same period of time, per capita consumption of poultry increased from 34.1 pounds to 93.1 pounds. Two other major factors contributing to the reduction in the U.S. sheep industry are: scarcity of labor and predator losses (Jones, 2004, and Stillman, et al., 1990). Moreover, the growth of manmade fiber is another major factor for this downward trend

In an effort to slow the rate of decline in the U.S. sheep industry, the U.S. Congress passed the Wool Act of 1954. Under the Wool Act, incentive payments were made to producers to encourage wool production (Anderson, 1994). These incentive payments have not halted the decline in sheep numbers (Figure 1.1). Moreover, in 1993,

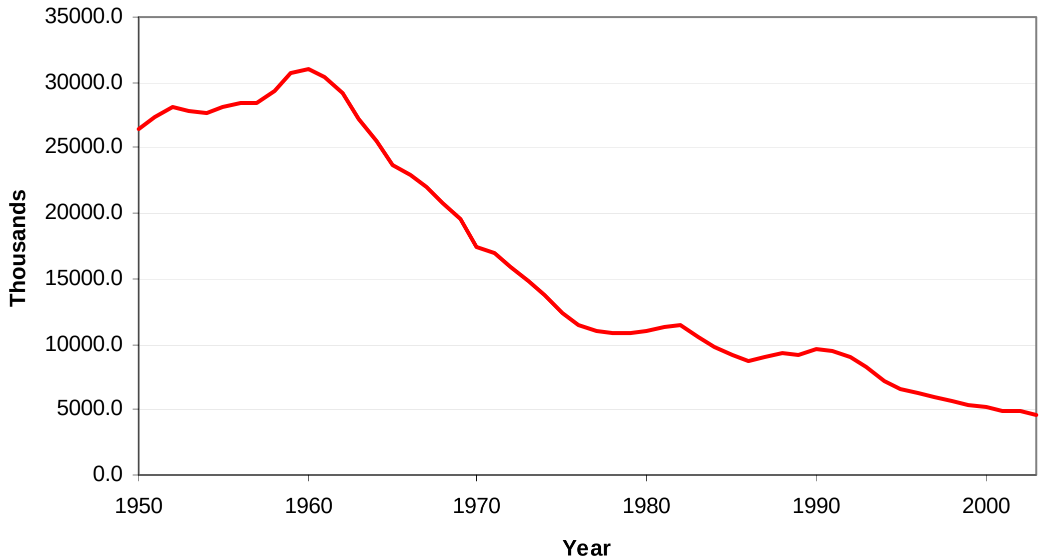


Figure 1.1. Number of stock sheep in the United States, 1950-2003

Congress passed a three-year phase out of Wool Act incentive payments with the last payments occurring in 1996 (Anderson, 2001). Since that program phase out, a series of ad hoc programs have been passed to support the industry due to a series of setbacks, caused in large part, by events beyond industry control such as strong U.S. dollar which encouraged an increase in imports, and financial difficulties of domestic mills. The 2002 Farm Bill reinstated support for the industry by implementing a loan program, similar to other commodities, with loan rates of $0.40 and $1.00 per pound for un-graded and graded wool, respectively (USDA Cotton and Wool Outlook, 2003).

Angora Goats

The major product of angora goats is the fleece, commonly known as mohair. They were first brought to the U.S. in 1849 and over time goat production has concentrated in the Edwards Plateau region of Texas (Anderson, 1994). In 2003, U.S.

production of angora goats was 285,000 head, Texas alone accounted for about 85 percent with the remaining 15 percent produced in Arizona and New Mexico.

The U.S. is the second largest producer of mohair, with production in 2003 of about 1.88 million pounds or 15 percent of total world production, only exceeded by South Africa with 9.46 million pounds or 63 percent of the total world mohair production (USDA Cotton and Wool Outlook, 2003). Other mohair producing countries are Turkey, Argentina, Australia, and New Zealand. In 2002, about 840,000 pounds or about 56.6 percent of the total U.S. mohair exports went to South Africa, followed by Spain (378,000 lbs), India (136,000 lbs), Germany (92,500 lbs) and other countries (38,500 lbs).

Like the sheep industry, the mohair industry has been declining for many years (Figure 1.2). The number of goats clipped has dropped from 4.6 million head in 1965 to 285,000 in 2003 (USDA Agricultural Statistics, 2004). Although mohair was part of the 1954 Wool Act, mohair prices were usually higher than the incentive price (USDA, ASCS Commodity Facts Sheet). Mohair industry prices have been highly volatile primarily due to fashion changes and world economic events.

The sale of angora goats for meat represents a very small portion, about 15 percent (Texas Livestock Prices and Situation, 2002), of returns to angora goat producers. Spanish goats are most often used for meat (Anderson, 1994). However, Spanish goats do not produce mohair.

A recent development in the goat industry is the introduction of the Boer goat from South Africa. These goats are larger framed with a much larger carcass than either

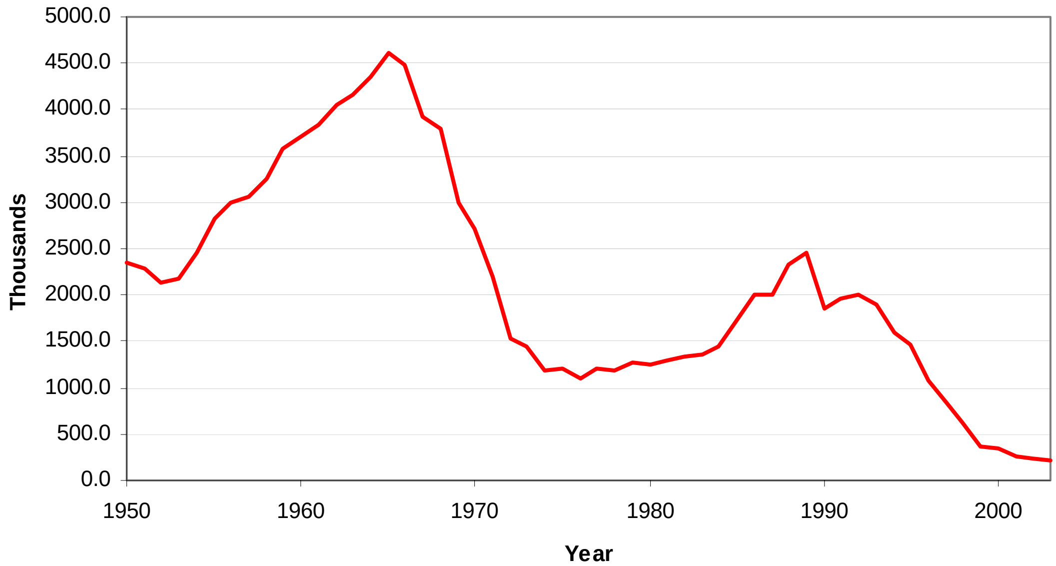


Figure 1.2. Number of Angora goats in the United States, 1950-2003

Spanish or Angora goats. As ethnic markets have expanded in the U.S., goat consumption has increased further encouraging goat meat production. The decline in the angora goat numbers has been largely offset by an increase in the number of meat goats.

Identification of Research Problem

As mentioned previously, government support for wool and mohair goes back to the incentive program in the Wool Act of 1954. In 1993, Congress passed a three-year phase out of the Wool Act incentive payments with the last payments occurring in 1996. The 2002 Farm Bill included a marketing loan program for wool and mohair. The loan rates are set to \$0.40 per pound for un-graded wool, \$1.00 per pound for graded wool, and \$4.20 per pound for mohair. In recent years exchange rate changes have had a large impact on the industry as they have affected lamb and wool trade.

The sheep and mohair industries have been in a downward trend since the early 1940s. Therefore, producers have been concerned about the industry's survival and programs to aid the industry. Due to the limited number of research studies on the sheep and mohair industries, there is a need to develop an econometric model of both industries for policy analysis purposes.

Objectives

The objective of this research is to analyze the impacts of different levels of loan rates on the U.S. sheep and mohair industries. Three different levels of loan rates will be analyzed for wool and mohair: $0, $0.50 and $2.00, and $0, $2.10 and $6.20 per pound for wool and mohair, respectively. The results of this research will be useful to sheep and mohair producers, as well as other stakeholders in the U.S. industry. By analyzing and providing information on the impacts of alternative policies, the industries will be better able to address the impacts of policy alternatives and craft policies to address emerging issues.

Organization of the Dissertation

Chapter I has presented the introduction, and the objective of this dissertation. Chapter II will review the sheep and goat industry literature. Chapter III will develop the methods of building the model and model specifications. Chapter IV presents the results of the empirical estimations of the model parameters and analysis of the policy alternatives. Finally, Chapter V will provide a summary, the main conclusions of the study, and suggestions for further research.

CHAPTER II

LITERATURE REVIEW

The livestock industry has a large body of research studies in agricultural economics. However, few studies have been performed on the sheep industry, either in the U.S. or the rest of the world. Moreover, economic research on angora goats is almost non-existent.

The literature review will be divided into four parts: supply, demand, policy and trade. Due to the lack of economic studies on mohair, the review of literature will primarily focus on the sheep industry, i.e., sheep products and wool.

Supply

Whipple and Menkhaus (1989) developed a dynamic supply model of the U.S. sheep industry. The model incorporates restrictions on fixed capital and demographic characteristics of the breeding flock. The characterization of the sheep population dynamics used in their study suggested that the size and age demography of the breeding flock are related to lamb slaughter/retention rates and stock sheep culling rates. Four equations were estimated: lamb slaughter/retention, stock sheep retention, lamb liveweight, and fleece weight, coupled with two identities for total outputs complete the sheep production model.

The model was estimated using U.S. annual data from 1924-83. The model was dynamically simulated over time using the Newton method to generate a matrix of short-run and intermediate-run (ten plus years) elasticity estimates. The R^2 of all four equations were high, ranging from 0.986 to 0.786 for the lamb liveweight and fleece weight equations, respectively. Their analysis had interesting implications for the U.S. sheep industry. The estimates of supply elasticity indicate that sheep supply is positively related to lamb price in the short run and the intermediate run. The supply elasticity is inelastic in the short run. The estimates of supply elasticity obtained in their study are higher than previous studies, 4.42 for long-run wool price elasticity compared to 0.35 obtained by Witherell (1969), and 11.38 for long-run lamb price elasticity compared to 2.00. As a consequence, the results of the study imply that both lamb and wool prices are important to the maintenance of the U.S. sheep industry.

Kalaitzandonakes (1994) considered the relationship between price protection and productivity growth in the context of a competitive firm. In this study, technical change, at the firm level, is assumed to involve the adoption of exogenously generated innovations through the use of new and improved inputs. In addition, gains in technical efficiency are assumed to result from improvements in productivity of existing rather than new resources through improved management.

The data used in the analysis was from the New Zealand beef and sheep industry during the 1960s to early 1980s. To measure the different levels of government assistance during this period, a total value of assistance to output, input, and value-added factors as percentage of the final value output (PSE) was used. The model follows the framework of a production function with endogenous technical change and efficiency. The independent variable for the model was output and the explanatory variables were divided into two categories, inputs and states. The input vector includes labor, land and improvements, material inputs, breeding stocks, and machinery. The state vector was separated into variables that are assumed to influence average technical efficiency, and variables that are assumed to affect the investment of variable and capital inputs. Variables that are assumed to influence average technical efficiency are expected income and level of protection, and variables that are assumed to affect the investment of variable and capital inputs are the level of expected protection, capital stock already in place lagged one year and a trend variable. Three-stage least squares regression analysis was used to estimate the production function.

The results of Kalaitzandonakes (1994) study shows that for firms with small capital stock and facing low prices, an increase in protection may yield an increase in productivity growth by encouraging investment and technical change. On the other hand, for firms with large capital stock and facing high prices, protectionism has a negative effect on productivity due to a reduction in efficiency.

Fraser and Hone (2001) developed a model to assess the value of technical efficiency and productivity growth as benchmarking tools and to measure the technical and allocative productivity of the Australian wool industry. Two methods were used: Data Envelope Analysis (DEA) and the Malmquist Total Factor Productivity (TFP) index. DEA allows the measurement of technical efficiency using either output-oriented or input-oriented specifications. Their study uses an output oriented measure of technical efficiency, which considers how much output can be increased while holding inputs constant. The Malmquist TFP index provides an assessment of productivity growth by measuring the change between two data points, where a data point consists of inputs and output. The Malmquist index is calculated by taking the ratio of the distance of each data point relative to a common technology.

The data used in their study was taken from the South West Victorian Monitor Farm Project (SWVMFP) survey in Australia. The sample of farms constructed compromises 26 wool producers in South-West Victoria, on farm sizes ranging from 120 to 3,110 hectares. The data set constructed is from 1990-91 to 1997-98. The importance of wool in the enterprise mix for their data set was very high, with an enterprise mix of 90 percent and 83 percent wool in 1991 and 1998, respectively. The findings of the paper show that farm-level DEA and TFP index results can display a lot of variability, which makes it very hard to compare them in a conventional benchmarking context. A farm that has no trend on technical efficiency and/or TFP growth would be very hard to compare with a predetermined benchmark farm.

Anderson (1994) estimated a supply and demand model of the U.S. sheep and mohair industries. Annual data from 1973 to 1992 was used to estimate the model using OLS estimation procedures. Two models were estimated for the sheep industry, an aggregate model and a regional model, to find out which model performs best. The aggregate model used national data while the regional model used state level data. For the regional model, the United States was divided into three sheep production regions, Western states, Texas, and Eastern states. Both models used econometric equations and biological identities. The supply and demand sides of the models were solved simultaneously to determine market clearing prices using the Lotus backsolver routine.

Results of the aggregate model will be discussed since it outperformed the regional model. Explanatory variables for the supply model for the sheep industry were lamb crop, ewe lambs, sheep death losses, lamb death losses, sheep slaughter, lamb dress weight, fleece weight, lamb slaughter, lamb import, and wool imports. The R^2 values for all equations were considerably high, ranging from 0.9871 to 0.6539 for lamb crop and fleece weight, respectively. The stock ewe elasticities of supply given a 10% increase in lamb price were 1.4 and –0.3, for the short and long run, respectively. Moreover, the stock ewe elasticities of supply due to a 10 percent increase in wool price were 0.0 and –0.1 for the short and long run, respectively.

An aggregate supply and demand model was estimated for the mohair industry. Explanatory variables for the supply model of the mohair industry were number of goats clipped, mohair yield, and ending stocks. The R^2 values for the number of goats clipped and ending stocks were high, 0.87 and 0.8094, respectively. However, the R^2 for mohair yield was very low, 0.3826.

Demand

Whipple and Menkhaus (1990) estimated price dependent farm, wholesale, and retail demand for lamb. Their retail price equation included per capita consumption, income prices of beef, pork, chicken, and two demand shifter variables for years prior to 1952 and years after 1981. The farm level equation included the wholesale lamb price, wages in the meat packing industry, and the number of lambs slaughtered as explanatory variables. The estimated own price elasticities of demand were elastic at the marketing level. Moreover, the results show that there was a downward shift in the demand during the 1981-87 period compared to the 1953-80 period.

The TAMRC group (1991) estimated the U.S. demand for lamb as part of a report on marketing strategies for lamb producers. The demand model in this study used bi-monthly data over the 1978-90 period. Explanatory variables included in the model were lagged lamb consumption, a time trend, seasonal dummy variables, and prices of lamb, beef, and pork. The results showed that all explanatory variables had the expected signs with lagged consumption, lamb price, and pork price being significant. The lamb short run own price elasticity of demand was estimated to be –0.62.

Anderson (1994), in a study discussed previously, included as explanatory variables for the aggregate U.S. demand model of the sheep industry, lamb consumption, U.S. mill demand for wool and sheep exports. The R^2 values for two of the equations were high, 0.9822 for lamb consumption and 0.8784 for sheep export. However, the R^2 of the third equation, U.S. mill demand, was very low, 0.2002. The estimated own price elasticity of U.S. mill demand was –0.05. The own price elasticity of demand for lamb consumption was estimated to be –0.297. In addition, the income elasticity of demand for lamb consumption was 2.22, indicating lamb is a luxury good.

Moreover, an aggregate demand model was estimated for the mohair industry. Explanatory variables included in the model are domestic mill demand, and mohair exports. The R^2 values for both variables were low, 0.5630 and 0.4851 for mill demand and mohair exports, respectively. The own price elasticity of domestic mill demand for mohair was estimated to be –0.051.

Policy

Conner, et al. (1969) used a partial adjustment model to examine the production response of mohair to the incentive program. Two models were specified, each using the number of goats clipped as the dependent variable. The first model used mohair revenues prior to the incentive program (pre 1954), mohair revenues after the incentive program began (post 1954), beef price, wool price, expected amount of rangeland available, and a dummy variable for the start of the incentive program as explanatory variables. The second model combined mohair revenues before and after the incentive program began plus the explanatory variables of the first equation.

The estimated short run own price elasticity of production for the free market period was 0.128 and 0.106 for the incentive price period. The results indicate that producers were less responsive to changes in expected revenue after the incentive program was enacted.

Anderson (1994) used the completed supply and demand models to perform an ex-ante simulation baseline projection for the 1994-2000 time horizon. This baseline projection was used to analyze the affects of various policy changes such as higher public land grazing fees, lamb import tariffs, a wool target price, and restoration of incentive programs for wool and mohair.

The results indicated that higher public land grazing fees resulted in a very small reduction in sheep numbers from the baseline forecast. The lamb import tariff increased stock ewe numbers 2 percent and decreased lamb and mutton imports 6 percent by the year 2000. The wool target price alternative had the greatest impact on the industry.

Stock ewes increased over the base by about 36 percent by the year 2000. The mohair model showed that the number of goats clipped will decline through 1997, rebound in 1998, and decline through the year 2000. The restoration of the incentive program for mohair was projected to steadily increase herd size through the year 2000.

Anderson et al. (2001) analyzed the effects of a marketing loan program on wool and mohair. An econometric model of the sheep and angora goat industries was created to estimate and project supply, demand, and price. Projections were made over the 2001-2005 period. Moreover, simulation modeling techniques were used to develop probabilities of outcomes. Loan rates were evaluated at $1.00 and $1.20 per pound for grade, based on the weighted annual average price for wool. The loan rates were developed by keeping the same level of support relative to variable costs for cotton.

A loan rate for wool of $1.20 per pound resulted in stabilizing stock ewe numbers at about 3.75 million head by 2005, or about 160,000 head above baseline levels. Loan deficiency payments were made in about 75 percent of the years in simulation with government costs averaging about $10 million per year.

In addition, a loan rate for mohair of $4.20 and $5.26 per pound was also analyzed. The result was an increase in angora goat numbers to about 500,000 head from baseline projections of 350,000 head. Government costs averaged between $2 and $3 million per year when payments were made. However, payments were made only 50 percent of the time.

Trade

The U.S. sheep industry is very small compared to the rest of the world. On the other hand, the U.S. is the second largest producer of mohair. In either case, trade is a major part of both industries, mainly with wool imports and mohair exports. Therefore, the affect of exchange rate fluctuations becomes a major variable to explain trade variations. Chambers and Just (1986) reported one of the first econometric models concentrated in examining the dynamic affects of exchange rate fluctuations on U.S. commodity markets. The econometric model developed included the wheat, corn, and soybean markets. The results indicate that exchange rate fluctuation has had a significant real impact on agricultural markets by altering the volume of exports and the relative split between exports and domestic use of the three commodities. To illustrate, a 10 percent exchange rate devaluation would cause roughly an 18, 40, and 8 percent increase on exports for wheat, corn, and soybeans, respectively.

Kristinek (2001) estimated vector autoregressive time series models to determine the role that exchange rates have on cattle trade in North America. Exchange rates expressed in terms of foreign currency per U.S. dollar were used in her study to test its impact on beef exports to Canada, and Mexico, beef imports from Canada, cattle imports from Canada, and cattle imports from Mexico. Beef production and cattle slaughter were used as a proxy for the cyclical nature of the industry, and price was used as well. In addition, impulse response functions were developed to examine the magnitude and length of the impact of the exchange rate changes.

Ordinary least squares was used to estimate the autoregressive models. In each model, exchange rate was significant and had expected sign supporting the hypothesis that exchange rate changes affect beef and cattle trade. The results of the study also showed that the affect of exchange rates is short lived since there was a lack of significance on the impact in higher lagged periods. Moreover, a shock in exchange rates showed to have affects that trickle through all parts of the beef and cattle market, i.e., prices, production, and imports and exports. Therefore, this research suggested that exchange rates have an important, but short-lived impact on the U.S. beef and cattle trade.

The impact of stocks on trade is important in the wool trade because of the large Australian wool stocks hanging over the market. Whipple and Menkhaus (1990) estimated the equations for lamb and wool imports. Explanatory variables in the lamb import equation were the U.S. lamb price, New Zealand and Australian exports weighted by the share of U.S. lamb imports by origin. Wool imports were modeled as a function of U.S. and world market wool prices, Australian wool exports, the U.S. wool tariff, a time trend, and a dummy variable for the Korean War. No studies of U.S. export models for wool and mohair have been found by the researcher.

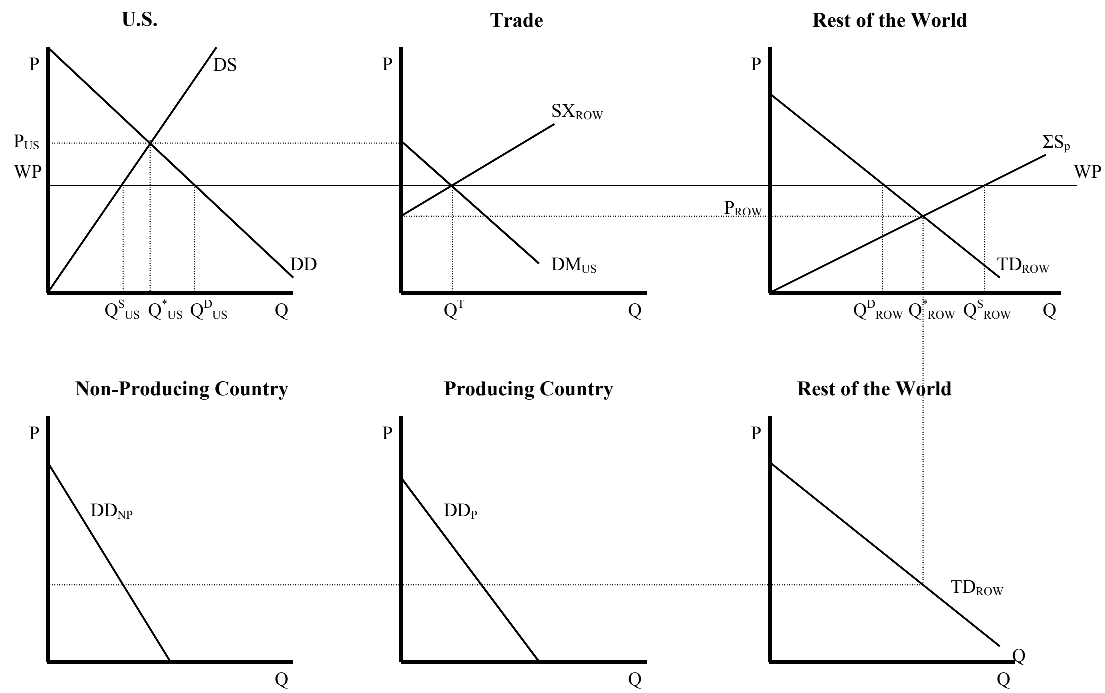
CHAPTER III

METHODS

The review of past literature provides important information on how to develop an econometric model of the sheep industry. However, the only known published studies of the mohair industry were done by Conner et al. (1969), and Anderson (1994). Figure 3.1 illustrates a theoretical model of the world supply and demand for lamb and wool, as well as a summary of econometric models developed for different parts of the sheep industry, and trade. The conceptual model used in this study builds on the work done by Anderson (1994) and to some extent the studies by Debertin, et al. (1983), and Whipple and Menkhaus (1989). Two major changes are made to Anderson's approach. First, eight different regions or countries will be modeled in order to better estimate the impacts of exchange rates on trade. Second, "complete demand systems" will be use to model the demand for U.S. lamb meat. The results of the demand systems will be compared to the results of the single demand equations for goodness of fit and forecasting ability.

Data

Annual data will be used to construct the models for the U.S. sheep and mohair industries. Table 3.1 contains the data variables and abbreviations used for all the equations included in the model development and estimation. The data was collected from the U.S. Department of Agriculture, the Livestock Marketing Information Center (2004), the Food and Agricultural Policy Research Institute (FAPRI, 2004), the



Where:

DS:	Domestic U.S. Supply	P_{ROW}:	Price in the Rest of the World if no trade
DD:	Domestic U.S. Demand	WP:	World Price
SX_{ROW}:	Export Supply from Rest of the World	Q^*_{US}:	Quantity Supplied in the U.S. at P_{US} (w/o trade)
DM_{US}:	Import Demand from the U.S.	Q^D_{US}:	Quantity Demanded in the U.S. at WP
DD_{NP}:	Domestic Demand from non-producing countries	Q^S_{US}:	Quantity Supplied in the U.S. at WP
DD_p:	Domestic Demand from producing countries	Q_T:	Quantity Traded
TD_{ROW}:	Total demand from Rest of the World	Q^*_{ROW}:	Quantity Supplied in the ROW at P_{ROW} (w/o trade)
ΣS_p:	Sum of Domestic Supply from producing countries	Q^D_{ROW}:	Quantity Demanded in the ROW at WP
P_{US}:	Price in the U.S if no trade	Q^S_{ROW}:	Quantity Supplied in the ROW at WP

Summary of selected previous theoretical models of supply and demand for lamb and wool

U.S. supply:
Langmeier (1967), Debertin, et al. (1983), Whipple and Menkaus (1989), and Anderson (1994)

U.S. demand:
Debertin, et al. (1983), Whipple and Menkaus (1990), TAMRC (1991), and Anderson (1994)

Trade:
Chambers and Just (1986), Whipple and Menkaus (1990), Meyer and Anderson (1998), and Kristinek (2001)

Producing countries
Rayner (1968), and Withrell (1969)

Figure 3.1. Theoretical model of world supply and demand for lamb and wool

Table 3.1. Variables for the Sheep and Mohair Industry Model

Data	Variable Name	Data	Variable Name
Ewes	SEWE	Australia Lamb Consumption	AUSCON
Lamb Crop	LCRP	Australia Lamb Production	AUSL
Replacements	EWEL	Australia Lamb Slaughter	AUSSLGT
Death Loss (Sheep &Lamb)	SDIE & LDIE	Australia Carcass Weight	AUSCW
Ewe Slaughter	SSLT	Australia Total Sheep	AUSTS
Lamb Slaughter	LSLT	Australia Exchange Rate	AUSXR
Lamb Exports	LEXP	Australia Lamb Price	AUSLP
Wool Production	WPRD	Australia Ewe Price	AUSEP
Fleece Weight	FLEC	Australia Wool Price	AUSWP
Carcass Weight	CWGT	Australia Beef Price	AUSBP
Lamb Price	LAMBP	Australia Chicken Price	AUSCHP
Sheep Price	EWEP	Australia Pork Price	AUSPP
Wool Price	WOOLP	Australian Wool Production	AUSW
Wool Incentive Price	WINCP	Australia Fleece Weight	AUSFW
Income Per Capita	INC	Australia Wool Export	AUSWX
Population	POP	Australia Wool Stock	AUSSTK
Beef Price	BP	Australia GDP	AUSGDP
Pork Price	PP	Australia Population	AUSPOP
Chicken Price	CP	Australia Mill Use	AUSMIL
Live Sheep Exports	SEXP	New Zealand Lamb Production	NZL
Lamb Consumption	LCON	New Zealand Lamb Consumption	NZCON
Wool Exports	WEXP	New Zealand Lamb Slaughter	NZSLGT
Wool Imports	WIMP	New Zealand Carcass Weight	NZCW
U.S. Mill Use	MILL	New Zealand Stock Ewe	NZEW
Wool Stocks	WSTK	New Zealand Exchange Rate	NZXR
Palmer Drought Index	PDI	New Zealand Lamb Price	NZLP
Feed Concentrate Cost	FEED	New Zealand Ewe Price	NZEP
Live Sheep Import	SIMP	New Zealand Wool Price	NZWP
Rayon Price	RAYP	New Zealand Beef Price	NZBP
Acrylic Price	ACRP	New Zealand Pork Price	NZPP
Polyster Price	POLP	New Zealand Wool Production	NZW
Cotton Price	COTP	New Zealand Fleece Weight	NZFW
Canada Lamb Production	CANL	New Zealand GDP	NZGDP
Canada Lamb Slaughter	CANSLGT	New Zealand Population	NZPOP
Canada Carcass Weight	CANCW	New Zealand Mill Use	NZMIL
Canada Exchange Rate	CANXR	Mexico Lamb Production	MXL
Canada Lamb Price	CANLP	Mexico Carcass Weight	MXCW
Canada Beef Price	CANBP	Mexico Exchange Rate	MXXR
Canada Pork Price	CANPP	Mexico Lamb Price	MXLP
Canada GDP	CANGDP	Mexico Beef Price	MXBP
Canada Population	CANPOP	Mexico Chicken Price	MXCHP
Canada Lamb Consumption	CANCON	Mexico Pork Price	MXPP

Table 3.1. continued

Data	Variable Name	Data	Variable Name
Mexico GDP	MXGDP	South Africa GDP	SAGDP
Mexico Population	MXPOP	South Africa Population	SAPOP
Mexico Lamb Consumption	MXCON	Angora Goats Clipped	SHORN
Argentina Wool Production	ARW	Mohair Fleece Weight	MOFW
Argentina Fleece Weight	ARFW	Mohair Production	MOPR
Argentina Total Sheep	ARTS	Mohair Exports	MOEXP
Argentina Exchange Rate	ARXR	Mohair Imports	MOIMP
Argentina Mill Use	ARMIL	Mohair Mill Use	MOMIL
Argentina GDP	ARGDP	Mohair Price	MOP
Argentina Population	ARPOP	Mohair Incentive Price	MOINCP
Uruguay Wool Production	URW	Mohair Beginning Stocks	MOSTK
Uruguay Fleece Weight	URFW	Mohair Cost of Production	MOCST
Uruguay Total Sheep	URTS	Mohair Gross Return	MOGR
Uruguay Exchange Rate	URXR	Total Meat Expenditures	TE
Uruguay Mill Use	URMIL	Beef Consumption	DB
Uruguay GDP	URGDP	Pork Consumption	DP
Uruguay Population	URPOP	Lamb Consumption	DL
United Kingdom Wool Production	UKW	Chicken Consumption	DC
United Kingdom Fleece Weight	UKFW	Beef Retail Price	RPB
United Kingdom Total Sheep	UKTS	Pork Retail Price	RPP
United Kingdom Exchange Rate	UKXR	Lamb Retail Price	RPL
United Kingdom Mill Use	UKMIL	Chicken Retail Price	RPC
United Kingdom GDP	UKGDP	Beef Budget Share	BSB
United Kingdom Population	UKPOP	Pork Budget Share	BSP
South Africa Wool Production	SAW	Lamb Budget Share	BSL
South Africa Fleece Weight	SAFW	Chicken Budget Share	BSC
South Africa Wool Price	SAWP	Stone Price Index	SPI
South Africa Total Sheep	SATS	Beef Average Budget Share	WB
South Africa Exchange Rate	SAXR	Pork Average Budget Share	WP
South Africa Cotton Price	SACTP	Lamb Average Budget Share	WL
South Africa Mill Use	SAMIL	Chicken Average Budget Share	WC

Department of Agriculture of each of the eight trading partners, the Food and Agricultural Organization (FAO, 2004) and the International Monetary Fund (IMF, 2004). The sheep industry has been declining for roughly the past 50 years, so a time trend will have a large impact in the model. Therefore, following Anderson's (1994) approach, shortening the data period to the last 24 years (1980-2003) will show the different structure of the industries while allowing an adequate number of degrees of freedom. In addition, this will give about three production cycles for sheep, as each cycle lasts about seven years.

The angora goat data is very limited. Goats are shorn twice per year, in spring and fall. Goats shorn include goats shorn twice and new kids shorn once. There is no published information on the number of kids born or weaned. Costs and gross returns data were provided by a panel of producers (Agricultural and Food Policy Center, AFPC) and inflated by producer price indices for each category. The cost categories include shearing, labor, and purchased inputs.

Model Development

Figure 3.2 shows a flow chart of the U.S. sheep industry. The number of stock sheep (ewes) represents stock breeding ewes in the herd. Ewes are the starting point of the sheep industry and all the other variables will revolve around ewe numbers. The number of stock sheep is reduced by death loss, slaughter, and lamb crop. Replacements and imports increase the number of ewes. Ewe and lamb slaughter, along with lamb and mutton imports make up the total domestic meat production. Total sheep numbers multiplied by wool yield gives the total wool production and adding the wool imports gives the total wool use.

The models for the sheep and mohair industries will use single econometric equations and biological identities. As mentioned above, some changes are made to Anderson's approach to better incorporate the impacts of exchange rates on trade. Specifically, eight different regions or countries will be modeled to provide estimates of the impacts of exchange rates on imports and exports. The eight different regions or

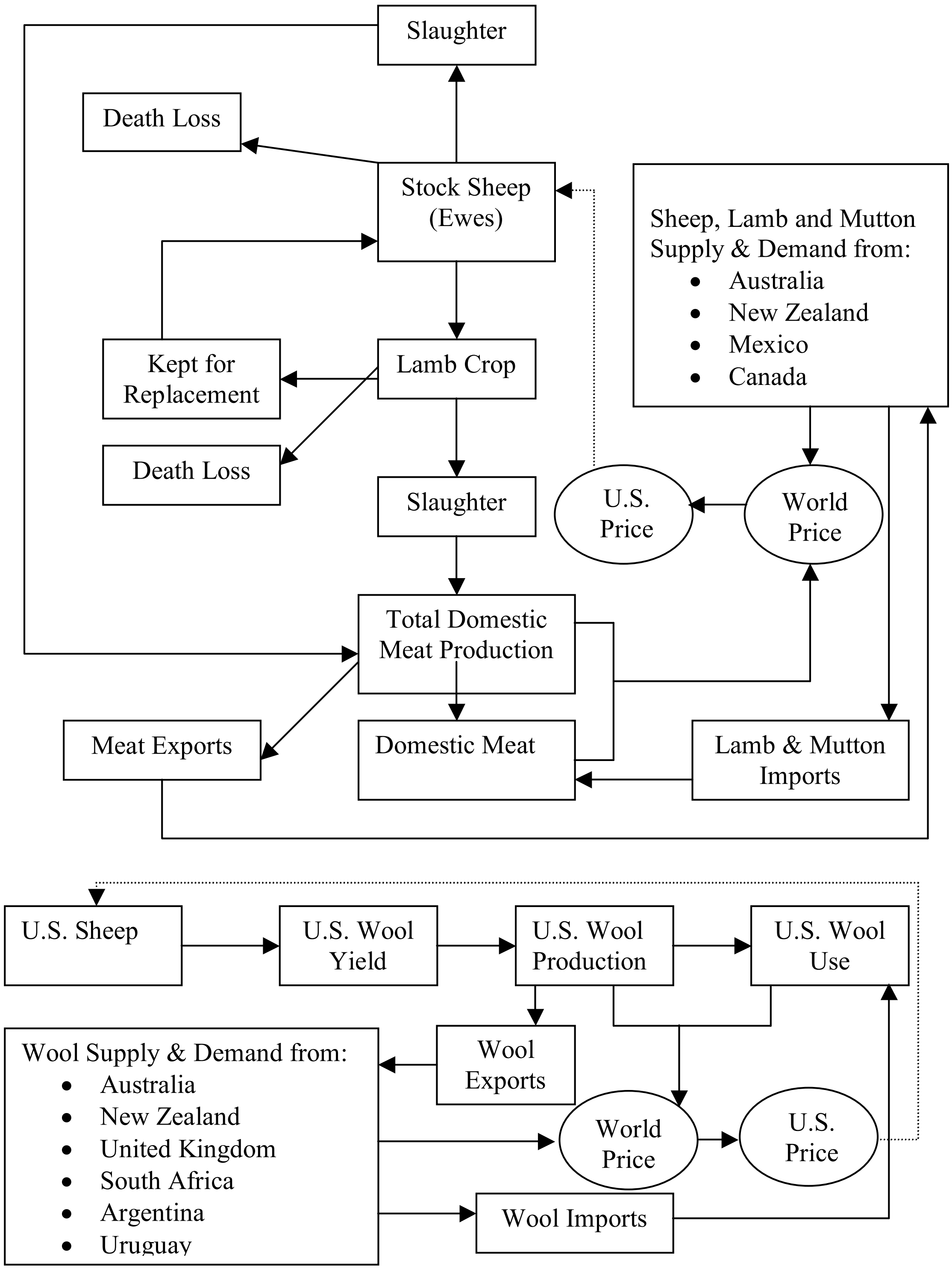


Figure 3.2. Flow chart of the U.S. sheep industry model

countries will be Australia, United Kingdom, South Africa, New Zealand, Argentina, Uruguay, Canada, and Mexico. Canada and Mexico, while being smaller markets, are the main recipients of the U.S. lamb and live sheep.

Supply and demand models for each one of these regions or countries will be estimated. The model will be estimated using ordinary least squares (OLS), two stage least squares (2SLS), and three stage least squares (3SLS), independently. The models estimated with these three estimation procedures will be validated through historical simulation. The mohair supply and demand model will be estimated only with OLS due to the scarcity of data.

On the demand side, agricultural modeling has been evolving toward the use of a theoretically sound "complete demand system" approach. Such demand systems are appropriate to deal with interdependence relationships among demands and make a formal attempt to incorporate the restrictions of modern consumer behavior (Malaga, 1997). The demand system models that will be used in this study are the Rotterdam and Linear Approximation Almost Ideal Demand System (LA/AIDS). Both demand system models will be estimated for the U.S. lamb consumption, and compared for goodness-of-fit.

The best complete demand system model will be used with the supply equation for lamb and the parameters of the entire system will be estimated using the estimation procedure that performs best, i.e. OLS, 2SLS, or 3SLS. The alternative model using a complete demand system will also be validated through historical simulation. Each demand representation will be tested to determine its suitability in the sector model.

Complete Demand Systems

According to demand theory, Marshallian demand equations obtained by maximizing the utility function subject to a budget constraint and Hicksian demand derived from the cost minimization principles must satisfy four principles: (a) adding-up, (b) homogeneity, (c) symmetry, and (d) negativity (Capps, 2002).

The property or restriction of adding-up implies that the sum of expenditures on alternative commodities within a demand system must be equal to the total expenditure on commodities in that system in both Marchallian and Hicksian demands. That is, the following equation must hold:

(3.1) $$\Sigma p_i h_i(u,p) = \Sigma p_i q_i(e,p) = e,$$

where:
p_i = price of good I,
h_i = Hicksian demand for good I,
q_i = Marshallian demand good I,
u = utility, and
e = total expenditure.

The Engel aggregation condition is derived from the adding-up property. The property of homogeneity of degree 0 in prices and total expenditures for Marshallian demands implies that for any positive constant $\boldsymbol{\Theta} > 0$, changing all prices and expenditures by $\boldsymbol{\Theta}$ will not affect the quantities demanded. The property of homogeneity of degree 0 in prices for Hicksian demands implies that for any positive constant $\boldsymbol{\Theta} > 0$, changing all prices by $\boldsymbol{\Theta}$ will not affect the quantities demanded. Expressed in equation form:

(3.2) $$h_i(u,\boldsymbol{\Theta}p) = h_i(h,p) = q_i(\boldsymbol{\Theta}x, \boldsymbol{\Theta}p) = q_i(e,p)$$

The symmetry property of the cross-price derivatives of the Hicksian demands is implied by Young's theorem (Capps, 2002). In a Hicksian constant utility demand system, the effect of the price commodity j on the demand for commodity I is equal to the effect of the price of commodity I on the demand for commodity I, or:

(3.3) $$\partial h_i(u,p)/\partial p_j = \partial h_j(u,p)/\partial p_i, \ \forall I \neq j$$

The negativity condition of Hicksian demand implies that the own-price derivatives will be negative because the Slutsky matrix of elements $\partial h_i/\partial p_j = s_{ij}$ is negative semi-definite, a condition derived from the concavity of well-behaved cost functions (Capps, 2002).

A demand system approach usually incorporates these restrictions into one model to ensure that consumer behavior in the model is consistent with theory (Malaga, 1997). Additionally, imposing the classical restrictions allows economies of parameterization, always important when dealing with time series data. Moreover, these restrictions when appropriately imposed, are useful in an econometric sense, permitting gains in the efficiency of the estimation and likely reducing multicollinearity. These advantages have encouraged agricultural economist to use complete demand systems instead of the more conventional "ad-hoc" single demand equation approach for empirical representations of consumer behavior (Malaga, 1997). However, when modeling involves simultaneous dynamic linkages demand and supply, demand systems may demonstrate performance difficulties.

Unfortunately, even when the demand system approach is selected, theory does not provide much information about the "true" form of the demand functions (Malaga, 1997). Several approaches have developed specifications that approximate the true form and allow some of the theoretical properties of demand to be imposed or tested. The most common approaches in the agricultural economics literature are: (a) the "Almost Ideal Demand System" or "AIDS," and (b) the Rotterdam model.

Almost Ideal Demand System (AIDS)

The AIDS model of Deaton and Muellbauer (1980) has been very popular in applied demand analysis. It is derived from a specific cost function and consists of the share equations in an n-good system. The AIDS linear approximation suggested by Stone (1954) is usually used (LA/AIDS) and can be specified as:

(3.4) $$w_{it} = \alpha_i + \Sigma_j \gamma_{ij} \, ln p_{jt} + \beta_i \, ln[Y_t/P_t^*] + \varepsilon_{it}$$

where:
w_{it} = expenditure share of product I
p_{jt} = nominal price of product j
Y_t = expenditure on the set of products
ε_{it} = disturbance term
α,β, and γ = parameters to estimate
P_t^* = w_{kt} $ln p_{kt}$ = Stone's linear approximation

The classical properties of demand theory can be imposed on the system by the following restrictions:

(3.5) Adding-up: $\Sigma_i\alpha_i = 1$, $\Sigma_i\gamma_{ij} = 0$, and $\Sigma_i\beta_i = 0$;

(3.6) Homogeneity: $\Sigma_i\gamma_{ij} = 0$;

(3.7) Symmetry: $\gamma_{ij} = \gamma_{ji}$.

The Marshallian (uncompensated) and Hicksian (compensated) price elasticities, as well as the expenditure elasticities, can be computed from the LA/AIDS coefficient estimates as follows:

(3.8) Marshallian Price Elasticity: $-\delta_{ij} + \gamma_{ij}/w_i - \beta_i w_j/w_i$

(3.9) Hicksian Price Elasticity: $-\delta_{ij} + w_j + \gamma_{ij}/w_i$

(3.10) Expenditure Elasticity: $1 + \beta_j/w_i$

where:
δ is Kronecker delta equal to one if i=j and equal to zero otherwise.

Equations (3.16) to (3.20) in Table 3.2 represent the LA/AIDS model for the estimation of the U.S. lamb meat demand system. Equation (3.16) is the Stone price index formulation where the log of the lamb price index (SPI) is calculated as the sum of the budget shares of beef (BSB), pork (BSP), lamb (BSL), and chicken (BSC) multiplied by the log of their respective retail prices, i.e. RPB, RPP, RPL, and RPC.

Equations (3.17) to (3.20) describe the AIDS relationships of budget shares as functions of the logs of their own prices, the logs of the other meat prices, and the log of the total meat expenditures (TE) deflated by the Stone price index. The estimation of this system requires that one equation be omitted from each system, usually the one accounting for the smallest budget share, in this case lamb. However, since lamb demand is the equations that we are interested on, chicken will be the one omitted.

Table 3.2. Complete Demand System Equations for Lamb Demand

General Terms

(3.11) TE = DB*RPB + DP*RPP + DL*RPL + DC*RPC
(3.12) BSB = DB*RPB/TE
(3.13) BSP = DP*RPP/TE
(3.14) BSL = DL*RPL/TE
(3.15) BSC = DC*RPC/TE

LA/AIDS

(3.16) *ln*SPI = BSB**ln*(RPB) + BSP**ln*(RPP) + BSL**ln*(RPL) + BSC**ln*(RPC)
(3.17) BSB = f (*ln*RPB, *ln*RPP, *ln*RPL, *ln*RPC, *ln*(TE/SPI))
(3.18) BSP = f (*ln*RPB, *ln*RPP, *ln*RPL, *ln*RPC, *ln*(TE/SPI))
(3.19) BSL = f (*ln*RPB, *ln*RPP, *ln*RPL, *ln*RPC, *ln*(TE/SPI))
(3.20) BSC = f (*ln*RPB, *ln*RPP, *ln*RPL, *ln*RPC, *ln*(TE/SPI))

Rotterdam

(3.21) WB = $(BSB + BSB_{t-1})/ 2$
(3.22) WP = $(BSP + BSP_{t-1})/ 2$
(3.23) WL = $(BSL + BSL_{t-1})/ 2$
(3.24) WC = $(BSC + BSC_{t-1})/ 2$
(3.25) QB = $WB^* \, ln(DB/DB_{t-1})$
(3.26) QP = $WP^* \, ln(DP/DP_{t-1})$
(3.27) QL = $WL^* \, ln(DL/DL_{t-1})$
(3.28) QC = $WC^* \, ln(DC/DC_{t-1})$
(3.29) DPB = $ln(RPB/RPB_{t-1})$
(3.30) DPP = $ln(RPP/RPP_{t-1})$
(3.31) DPL = $ln(RPL/RPL_{t-1})$
(3.32) DPC = $ln(RPC/RPC_{t-1})$
(3.33) QTOT = QB + QP + QL + QC
(3.34) QB = f (QTOT, DPB, DPP, DPL, DPC)
(3.35) QP = f (QTOT, DPB, DPP, DPL, DPC)
(3.36) QL = f (QTOT, DPB, DPP, DPL, DPC)
(3.37) QC = f (QTOT, DPB, DPP, DPL, DPC)

Variable names are defined in Table 3.1

Rotterdam Model

The Rotterdam Model, developed by Barten and Theil (1964), does not assume a particular utility function and allows the classical theoretical demand restrictions to be imposed. The absolute price version of the Rotterdam model may be written as:

(3.38) $\hat{w}_i \, d\mathit{ln}(q_i) = \theta_i \, d\mathit{ln}(Q) + \Sigma_i^n \, \pi_{ij} \, d\mathit{ln}(p_i) + \varepsilon_i$

where:
$d\mathit{ln}(Q) = \Sigma_i \hat{w}_i \, d\mathit{ln}(q_i)$ is the Divisia volume index;
q_i = per capita consumption of product i in period t;
p_j = the price of product j in period t;
θ and π = the parameters to be estimated;
ε = the disturbance term
$\hat{w}_i = (w_{it} + w_{it-1})/2$;
w_{it} = budget share of product I in period t; and
d*ln* represents log differentials which are replaced by log differences in empirical estimation.

The theoretical classical restrictions are depicted as:

(3.39) Adding-up: $\Sigma_j \theta_j = 1$;

(3.40) Homogeneity: $\Sigma_j \pi_{ij} = 0$; and

(3.41) Symmetry: $\pi_{ij} = \pi_{ji}$.

The set of Marshallian (non compensated) and Hicksian (compensated) price elasticities and the expenditure elasticity can be calculated from the estimated coefficients as follows:

(3.42) Marshallian Price Elasticity: $1/\ \hat{w}_i \, (\pi_{ij} - \hat{w}_j \theta_j)$;

(3.43) Hicksian Price Elasticity: $\pi_{ij} / \hat{w}_i$;

(3.44) Expenditure Elasticity: $\theta_j / \hat{w}_i$.

Equations (3.21) to (3.37) in Table 3.2 represent the Rotterdam model for the estimation of the lamb meat demand system. First, the $\hat{w}_i$ (i.e., the average budget shares) are calculated as W_i where i stands for beef, pork, lamb, and chicken. Then, the $\hat{w}_i d\,ln(q_i)$ are defined as Q_i in equations (3.25) to (3.28). The term $d\,ln(Q)$ (i.e., the summation of $\hat{w}_i d\,ln(q_i)$) is represented by QTOT in equation (3.33). Equations (3.29) to (3.32) represent the corresponding $d\,ln(p_i)$ which are the logs of the ratio of current and lagged prices and are defined as DP_i. Finally, Q_i corresponding to $\hat{w}_i d\,ln(q_i)$ are specified in equations (3.34) to (3.37) as function of QTOT and the DP_i, following the Rotterdam formulation.

As with the AIDS model, one equation needs to be omitted (i.e. chicken) from the Rotterdam system to avoid singularity of the variance-covariance matrix of disturbances. The parameters associated with the omitted equation can be recovered through use of classical restrictions.

Separability

Previous studies of the U.S sheep industry suggest that lamb consumption does not compete with consumption of other meats, i.e. beef, pork, and chicken. Debertin, et al. (1983) states that since per capita consumption of sheep and lamb is very low relatively to other meats, retail prices need not be considered simultaneously determined with retail prices for beef, pork, and chicken. Although changes in other retail meat prices may influence lamb prices, the converse is probably not true. Finally, he claims that lamb prices could double or halve without a significant impact on prices or consumption of other meats.

The demand systems deal with interdependence relationships among demands of goods in a group. Therefore, finding out if lamb meat should be included in the same group as other meats, i.e., beef, pork, and chicken, is imperative to use a complete demand system for this research. Fortunately, the available demand systems' methodologies allow for a separability test to determine whether lamb meat should be included in the U.S. meat demand system. A test based on the assumptions of weak separability of the direct utility function is normally used. Goldman and Uzawa (1964) showed that:

(3.45) $$S_{ij} = \Phi_{ij}(\partial q_i / \partial e)(\partial q_i / \partial e), \quad i \in I, j \in J,$$

where, in this case, I would refer to the group of meats other than lamb; J is a one commodity group of lamb meat; S_{ij} represents the Slutsky substitution term; Φ_{ij} is a substitutability parameter between commodities in groups I and J; and $\partial q_i / \partial e$ and $\partial q_i / \partial e$ are the derivatives of the demands for products i and j with respect to total expenditure. With some algebraic manipulation Goldman and Uzawa showed that:

(3.46) $$\varepsilon_{ij}^{*} = (\Phi_{ij} / e) n_i n_j w_j,$$

where ε_{ij}^{*} refers to the compensated cross price elasticity between commodities in groups I and J; n_i and n_j are the expenditure elasticities of products in the two respective groups; and w_j is the budget share of commodity j. Also, for i, k $\in$ I and j $\in$ J, using (3.46) it can be demonstrated that:

(3.47) $$\varepsilon_{ij}^{*} / \varepsilon_{kj}^{*} = n_i / n_k$$

In other words, under the assumption of weak separability of the direct utility function, the ratio of Hicksian and compensated cross-price elasticities of two commodities in the same group with respect to another third commodity in other group, is equal to the ratio of their respective expenditure elasticities (Malaga, 1997). In the context of the Rotterdam model, (3.48) implies a nonlinear restriction on the parameters π_{ij}, where the i and k $\in$ I, and j $\in$ J. The Rotterdam parameter can be written as:

(3.48) $$\pi_{ij} / \pi_{kj} = \theta_i / \theta_k,$$

In this particular case, i and k $\in$ I are the meat included in the study except lamb meat (i.e., beef, pork, and chicken) and j $\in$ J refers to lamb meat. In the case of the AIDS model, a similar case can be performed.

Single Demand and Supply Equations

Table 3.3 contains the single supply and demand equations, and identities for the sheep industry. Equation 3.49 is an identity and it represents the herd inventory. The number of breeding ewes equals the number of breeding ewes in the last period minus death loss, slaughter and exports, plus imports and replacement.

Equation 3.50 represents the death loss of ewes and is a function of the number of breeding ewes, Palmer Drought Index (PDI) for 11 western states (AZ, CA, CO, ID, MT, MN, OR, SD, TX, UT, and WY), prices of lamb, sheep and wool, incentive price, and time. Historical weighted PDIs for the months of June, July, and August were used as a proxy of drought ranging from 2.88, mild to moderate wetness, to –3.41, severe drought. The PDI is hypothesized to have a negative effect to death loss ewes, as well as prices and incentive price. Ewe slaughter (3.51) is a function of the number of ewes, prices of lamb, sheep and wool, and net returns per ewe. Higher sheep prices and net returns will increase the number of ewe slaughtered, while higher prices for lamb and wool are hypothesized to have a negative effect as producers try to build up the herd to increase lamb and wool production.

Table 3.3. Single Equations and Identities for Sheep Industry Model

(3.49)	Ewes$_t$	=	Ewes$_{t-1}$ – Death Loss$_{t-1}$ – Slaughter$_{t-1}$ – Exports$_{t-1}$ (live) + Imports$_{t-1}$ (live) + Replacements
(3.50)	Ewe Death Loss$_t$	=	f(Ewes$_t$, PDI$_t$, Lamb Price$_{t-1}$, Sheep Price$_{t-1}$, Wool Price$_{t-1}$, Time$_t$, Incentive Price$_t$)
(3.51)	Ewe Slaughter$_t$	=	f(Ewes$_t$, Lamb Price$_{t-1}$, Sheep Price$_{t-1}$, Wool Price$_{t-1}$, Net Returns$_t$)
(3.52)	Exports$_t$ (live)	=	f(Ewes$_t$, Lamb Price$_{t-1}$, Sheep Price$_{t-1}$, Wool Price$_{t-1}$, Mexico X-Rate$_t$, Mexico Consumption$_t$, Net Returns$_t$)
(3.53)	Imports$_t$ (live)	=	f(Canada Production$_t$, Canada X-Rate$_t$, Sheep Price$_t$, Lamb Price$_t$)
(3.54)	Lamb Crop$_t$	=	f(Ewes$_t$, PDI$_t$, Time$_t$)
(3.55)	Replacements$_t$	=	f(Lamb Crop$_t$, Ewes$_t$, Lamb Price$_{t-1}$, Sheep Price$_{t-1}$, Wool Price$_{t-1}$, Net Returns$_t$)
(3.56)	Lamb Death$_t$	=	f(Lamb Crop$_t$, PDI$_t$, Time$_t$)
(3.57)	Lamb Slaughter$_t$	=	f(Lamb Crop$_t$, Ewes$_t$, Lamb Price$_{t-1}$, Sheep Price$_{t-1}$, Wool Price$_{t-1}$, Sub Price$_{t-1}$, Net Returns$_t$, Incentive Price$_t$)
(3.58)	Carcass Weight$_t$	=	f(Time$_t$, Lamb Price$_{t-1}$, Feed Concentrate Cost$_{t-1}$)
(3.59)	Lamb Production$_t$ (meat)	=	Lamb Slaughter$_t$ * Carcass Weight$_t$
(3.60)	Lamb Consumption$_t$	=	f(Lamb Price$_t$, Income$_t$, Sub Price$_t$, Time$_t$)
(3.61)	Lamb Exports$_t$	=	f(Lamb Price$_t$, Mexico X-Rate$_t$, Mexico Domestic Demand$_t$)
(3.62)	Lamb Imports$_t$ (meat)	=	Lamb Consumption$_t$ – Lamb Production$_t$ (meat) + Lamb Exports$_t$ (meat)
(3.63)	Fleece Yield$_t$	=	f(Time$_t$, PDI$_t$, Wool Price$_{t-1}$, Lamb Price$_{t-1}$, Fleece Yield$_{t-1}$)
(3.64)	Total Raw Wool Prod$_t$	=	Ewes$_t$ * Fleece Yield$_t$
(3.65)	Wool Consumption$_t$	=	f(Wool Price$_t$, Income$_t$, Cotton Price$_t$, Polyester Price$_t$, Acrylic Price$_t$, Rayon Price$_t$, Incentive Price$_t$)
(3.66)	Wool Exports$_t$	=	f(Wool Price$_t$, Australia X-Rate$_t$, Incentive Price$_t$)
(3.67)	Wool Stocks$_t$	=	f(Wool Price$_t$, Income$_t$, Australia Wool Stocks$_t$, Big 6 Wool Production$_t$)
(3.68)	Wool Imports$_t$ (raw)	=	Wool Consumption$_t$ – Total Raw Wool Prod$_t$ + Wool Exports$_t$ – Wool Stocks$_t$
(3.69)	AUS Lamb Production$_t$	=	f(Australia (Lamb Slaughter$_t$, Carcass Weight$_t$, Total Sheep$_t$, Lamb Price$_{t-1}$, Wool Price$_{t-1}$, Sub Price$_{t-1}$))
(3.70)	NZ Lamb Production$_t$	=	f(New Zealand (Lamb Slaughter$_t$, Carcass Weight$_t$, Ewe$_t$, Lamb Price$_{t-1}$, Wool Price$_{t-1}$, Sub Price$_{t-1}$))
(3.71)	MX Lamb Production$_t$	=	f(Mexico (Carcass Weight$_t$, Lamb Price$_{t-1}$, Sub Price$_t$))
(3.72)	CAN Lamb Production$_t$	=	f(Canada (Lamb Slaughter$_t$, Carcass Weight$_t$, Lamb Price$_{t-1}$, Sub Price$_{t-1}$))
(3.73)	World Lamb Production$_t$	=	AUS Lamb Production$_t$ + NZ Lamb Production$_t$ + MX Lamb Production$_t$ + CAN Lamb Production$_t$
(3.74)	AUS Lamb Consumption$_t$	=	f(Australia (GDP$_t$, Lamb Price$_t$, Ewe Price$_t$, Wool Price$_t$, Sub Price$_t$, Population$_t$))
(3.75)	NZ Lamb Consumption$_t$	=	f(New Zealand (GDP$_t$, Lamb Price$_t$, Ewe Price$_t$, Wool Price$_t$, Sub Price$_t$, Population$_t$))
(3.76)	MX Lamb Consumption$_t$	=	f(Mexico (GDP$_t$, Lamb Price$_t$, Wool Price$_t$, Sub Price$_t$, Population$_t$))
(3.77)	CAN Lamb Consumption$_t$	=	f(Canada (GDP$_t$, Lamb Price$_t$, Wool Price$_t$, Sub Price$_t$, Population$_t$))
(3.78)	World Lamb Consumption$_t$	=	AUS Lamb Consumption$_t$ + NZ Lamb Consumption$_t$ + MX Lamb Consumption$_t$ + CAN Lamb Consumption$_t$
(3.79)	World Lamb Imports$_t$	=	Mexico Live Imports$_t$ + Canada Live Imports$_t$
(3.80)	World Lamb Exports$_t$	=	World Lamb Production$_t$ – World Lamb Consumption$_t$ + World Imports$_t$

Table 3.3. continued

(3.81)	AUS Wool Production$_t$	=	f(Australia (Fleece Weight$_t$, Cotton Price$_t$, Wool Price$_{t-1}$, Ewe Price$_{t-1}$, Lamb Price$_{t-1}$, Tot Sheep$_{t-1}$, Wool Stocks$_t$))
(3.82)	NZ Wool Production$_t$	=	f(New Zealand (Fleece Weight$_t$, Wool Price$_{t-1}$, Ewe Price$_{t-1}$, Lamb Price$_{t-1}$, Ewes$_{t-1}$, Lamb Slaughter$_{t-1}$))
(3.83)	AR Wool Production$_t$	=	f(Argentina (Fleece Weight$_t$, Wool Price$_{t-1}$, Ewes$_{t-1}$, Exchange Rate$_t$))
(3.84)	UR Wool Production$_t$	=	f(Uruguay (Fleece Weight$_t$, Wool Price$_{t-1}$, Ewes$_{t-1}$, Exchange Rate$_t$))
(3.85)	UK Wool Production$_t$	=	f(United Kingdom (Fleece Weight$_t$, Wool Price$_{t-1}$, Ewes$_{t-1}$, Exchange Rate$_t$))
(3.86)	SA Wool Production$_t$	=	f(South Africa (Fleece Weight$_t$, Wool Price$_{t-1}$, Ewes$_{t-1}$, Cotton Price$_{t-1}$, Exchange Rate$_t$))
(3.87)	World Wool Prod$_t$	=	AUS Wool Prod$_t$ + NZ Wool Prod$_t$ + AR Wool Prod$_t$ + UR Wool Prod$_t$ + UK Wool Prod$_t$ + SA Wool Prod$_t$
(3.88)	AUS Wool Cons$_t$	=	f(Australia (GDP$_t$, Lamb Price$_t$, Ewe Price$_t$, Wool Price$_t$, Population$_t$, Wool Stocks$_t$))
(3.89)	NZ Wool Cons$_t$	=	f(New Zealand (GDP$_t$, Lamb Price$_t$, Ewe Price$_t$, Wool Price$_t$, Population$_t$))
(3.90)	AR Wool Cons$_t$	=	f(Argentina (GDP$_t$, Exchange Rate$_t$, Wool Price$_t$, Population$_t$))
(3.91)	UR Wool Cons$_t$	=	f(Uruguay (GDP$_t$, Exchange Rate$_t$, Wool Price$_t$, Population$_t$))
(3.92)	UK Wool Cons$_t$	=	f(United Kingdom (GDP$_t$, Exchange Rate$_t$, Wool Price$_t$, Population$_t$))
(3.93)	SA Wool Cons$_t$	=	f(South Africa (GDP$_t$, Exchange Rate$_t$, Wool Price$_t$, Population$_t$))
(3.94)	World Wool Cons$_t$	=	AUS Wool Cons$_t$ + NZ Wool Cons$_t$ + AR Wool Cons$_t$ + UR Wool Cons$_t$ + UK Wool Cons$_t$ + SA Wool Cons$_t$
(3.95)	World Wool Imports$_t$	=	AR Wool Imports$_t$ +UR Wool Imports$_t$ + UK Wool Imports$_t$ + SA Wool Imports$_t$
(3.96)	AUS Wool Stocks$_t$	=	f(Australia (U.S. Wool Stocks$_t$, Wool Price$_{t,}$ Exchange Rate$_t$))
(3.97)	World Wool Exports$_t$	=	World Wool Production$_t$ – World Wool Consumption$_t$ + AUS Wool Stocks$_t$ + World Wool Imports$_t$

PDI = Palmer Drought Index for 11 western states: AZ, CA, CO, ID, MT, MN, OR, SD, TX, UT, and WY
Sub Price = Beef Price, Pork Price, and Chicken Price
Big 6 = Australia, United Kingdom, South Africa, New Zealand, Argentina, and Uruguay

The number of live sheep exported (3.52) is assumed to be a function of the number of ewes, prices, net returns, and Mexican consumption and exchange rate (Mex Pesos/1$US) because most of the live sheep are exported to Mexico. Lower lamb, sheep and wool prices will encourage herd liquidation, and exports. A strong dollar is hypothesized to reduce export levels while an increase in Mexican consumption will increase the level of exports. Live sheep import (3.53) is a function of Canadian sheep production (Canada is the main exporter to the U.S. for live sheep), exchange rate ($Can/1$US), and lamb and sheep prices. Higher Canada sheep production and/or higher lamb and sheep prices is hypothesized to increase live sheep imports. A strong U.S. dollar is expected to increase U.S. import levels.

Lamb crop (3.54) is a function of ewes, PDI and time. Drought is hypothesized to lower lamb crop and time is set to capture any change in technology. Lamb crop has three possible destinations: ewe replacement, lamb death, and lamb slaughter. Ewe replacement (3.55) is a function of lamb crop, number of ewes, prices, and net returns per ewe. Higher prices of lamb and wool, and net returns are hypothesized to have a positive affect on replacement numbers, while higher sheep prices should have a negative impact. Death loss of lamb (3.56) is a function of lamb crop, PDI and time. Lamb slaughter (3.57) is assumed to be a function of lamb crop, number of ewes, net returns, incentive price and prices of lamb sheep and wool, as well as lagged prices of beef, pork and chicken. Higher lamb prices are hypothesized to have a positive affect on the number of lamb slaughtered. Higher incentive price is expected to have a negative affect on lamb slaughter since producers will want to withhold more lamb to increase stock ewe numbers for higher wool production.

Carcass weight (3.58) is hypothesized to be a function of time, lamb price, and feed concentrate cost. Feed concentrate cost is the cost of feed to finish slaughter lambs and is expected to have a negative relationship with carcass weight. Total domestic lamb production (3.59) is an identity and is calculated as total lamb slaughtered times lamb carcass weight.

Domestic lamb consumption (3.60) is assumed to be a function of lamb, beef, pork and chicken prices, income, and time. Economic theory indicates that as the price of lamb increases, its demand will decrease and as the price of substitutes, beef, pork and chicken increase the demand for lamb will increase. Lamb exports (3.61) are a function of lamb price and Mexican domestic demand and exchange rate. Lamb import (3.62) is an identity and is calculated as lamb consumption minus lamb production plus lamb exports.

Fleece yield (3.63) is modeled as a function of PDI, time, wool and lamb prices, and itself lagged one period. Total raw wool production (3.64) is an identity calculated as the total number of sheep times the estimated fleece weight per sheep.

Wool consumption (3.65) is a function of wool price, income, incentive price, and cotton, polyester and acrylic prices. Income is hypothesized to have a positive affect on demand because wool is expected to be a normal or luxury good. Wool exports (3.66) are a function of wool price, incentive price, and Australia exchange rate, and wool stocks (3.67) are set to be a function of wool price, income, Australia wool stocks and wool production by the Big6[1]. Wool import (3.68) is an identity calculated as wool consumption plus wool exports minus total raw wool production and wool stocks.

Australia's lamb production (3.69) is a function of Australian lamb slaughter, carcass weight, total sheep, and lagged prices of lamb, wool and substitutes. New Zealand's lamb production (3.70) is modeled as a function of New Zealand's lamb slaughter, carcass weight, ewe numbers, lamb and wool prices lagged one year, as well as prices of substitutes. Mexico's lamb production (3.71) is assumed to be a function of Mexican carcass weight, lamb price, and prices of substitutes lagged one year. Canada's lamb production (3.72) is a function of Canadian lamb slaughter, carcass weight, lamb price and prices of substitutes lagged one period. World lamb production (3.73) is an identity calculated as the sum of lamb production for Australian, New Zealand, Canadian, and Mexican.

Australia's lamb consumption (3.74) and New Zealand's lamb consumption (3.75) are a function of their own gross domestic product (GDP), population, and lamb, sheep and wool prices, as well as prices of substitutes. Mexico's lamb production (3.76) and Canada's lamb consumption (3.77) are modeled to be a function of GDP, and prices of lamb, wool and substitutes from each country.

World lamb consumption (3.78) is an identity calculated as the sum of Australian, New Zealand, Canadian, and Mexican lamb consumption. World lamb import (3.79) is an identity calculated as the sum of Mexican and Canadian live imports.

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[1] Big6 = Australia, United Kingdom, South Africa, New Zealand, Argentina, and Uruguay

World lamb exports (3.80) are an identity calculated as world lamb production minus world lamb consumption plus world imports.

Australia's wool production (3.81) is a function of Australian fleece weight, prices of cotton, wool, sheep and lamb lagged one period, total sheep and U.S. wool stocks. New Zealand's wool production (3.82) is modeled as a function of New Zealand's fleece weight, number of ewe's lagged one period, lamb slaughter, and wool, lamb and sheep prices lagged one year. Argentina's wool production (3.83), Uruguay's wool production (3.84), and United Kingdom's wool production (3.85) are a function of their own fleece weight, exchange rate with respect to the U.S. dollar, ewe number and wool prices lagged one period. South Africa's wool production (3.86) is modeled as a function of South African fleece weight, wool, sheep and cotton prices lagged one period, and exchange rate (SA Rand/1$US). World wool production (3.87) is an identity calculated as the sum of the Big6 wool productions.

Australia's wool consumption (3.88) is a function of Australian GDP, lamb, sheep and wool prices, population, and stocks. New Zealand's wool consumption (3.89) is modeled as a function of New Zealand's GDP, lamb, wool and sheep prices, and population. Argentinean, Uruguayan, British, and South African wool consumption (3.90, 3.91, 3.92, and 3.93, respectively) are a function of own GDP, exchange rate with respect to the U.S. dollar, wool price, and population.

World wool consumption (3.94) is an identity calculated as the sum of the Big6 wool consumption. World wool import (3.95) is an identity calculated as the sum of the Big6 wool imports without Australia and New Zealand as they do not import any wool.

Australia's wool stock (3.96) is modeled as a function of Australian wool price, exchange rate ($AUS/1$US), and the U.S. wool stocks. World wool exports (3.97) is an identity calculated as the sum of world wool production, Australia's wool stocks, and world wool imports minus world wool consumption.

The equations for the Mohair model are listed in Table 3.4. Goats shorn (3.98) is modeled to be a function of, mohair price, incentive price, gross returns, production costs, and goats shorn lagged one period. Mohair price, incentive price and gross returns are hypothesized to have a positive impact on the number of goats shorn, while production costs are expected to have a negative impact. Mohair yield (3.99) is a function of mohair price, incentive price, PDI and time. Each one of these explanatory variables is thought to have a positive impact on mohair clip per animal. Total mohair production (3.100) equals animals shorn multiplied by the mohair yield.

U.S mill demand (3.101) is hypothesized to be a function of mohair price, incentive price and income. Mohair exports (3.102) and imports (3.103) are hypothesized to be a function of mohair price, incentive price, income, and South Africa exchange rate (SA Rand/$US). Mohair stocks (3.104) are assumed to be a function of mohair price, income, and incentive price.

Solving Supply and Demand

The supply and selected demand system will be solved simultaneously to determine the market-clearing price. It involves iterating on the price that equates the supply and demand model. The market clearing equation is:

$$\text{Supply} - \text{Demand} = 0$$

Table 3.4. Equations and Identities for Mohair Industry Model

(3.98)	Goats $Shorn_t$	=	f(Goats $Shorn_{t-1}$, Mohair $Price_{t-1}$, Incentive $Price_t$, Gross $Returns_{t-1}$, Production $Costs_{t-1}$)
(3.99)	Mohair $Yield_t$	=	f(Mohair $Yield_{t-1}$, Mohair $Price_{t-1}$, Incentive $Price_t$, PDI_t, $Time_t$)
(3.100)	Mohair $Production_t$	=	Goats $Shorn_t$ * Mohair $Yield_t$
(3.101)	Mohair $Exports_t$	=	f(Mohair $Price_t$, $Income_t$, Incentive $Price_t$, South Africa Exchange $Rate_t$)
(3.102)	U.S. Mill $Demand_t$ (raw)	=	f(Mohair $Price_t$, $Income_t$, Incentive $Price_t$)
(3.103)	Mohair $Imports_t$	=	f(Mohair $Price_t$, $Income_t$, South Africa Exchange $Rate_t$, Incentive $Price_t$)
(3.104)	Mohair $Stocks_t$	=	f(Mohair $Price_t$, $Income_t$, Incentive $Price_t$)

The estimated parameters will be used with the EViews© "Solver" routine to solve this nonlinear optimization. The routine then solves the equation, Supply – Demand = 0, and yields the market, or equation solving, price. Industry parameters and price will be projected as a baseline to compare policy alternatives.

Model Evaluation

Building a model of this type requires more than just putting the equations together. Often the single equations may fit very well statistically but the simultaneous equation model may not bear much resemblance to reality (Pindyck and Rubinfeld, 1991). The problem comes from the dynamic nature of the system.

There is not a method of evaluating a multiple model like and R^2 or F-test that evaluates the goodness-of-fit properties for the overall model. However, several criteria can be used to evaluate the models predictive ability. One is the root mean square error (RMSE). The RMSE is given by:

$$RMSE = [1/T\ (\Sigma\ (F_t - A_t)^2]^{1/2}$$

The RMSE is a measure of the deviation of the simulated variable (F_t) from its actual time path (A_t). The lower the RMSE the better the predictive power of the model.

Another important criterion is how well the model simulates turning points in the data (Anderson, 1994). How well the model duplicates rapid changes is important in evaluating its predictive ability.

Theil's inequality coefficient can be applied to the evaluation of historical simulations. It is calculated by:

$$U_2 = [\Sigma\ (F_t - A_t)^2]^{1/2} / [\Sigma\ A_t^2]^{1/2}$$

The U_2 can be interpreted as the RMSE of the proposed forecasting model divided by the RMSE of a no-change model (Theil, 1966). It has the no-change model (with $U_2 = 1$ for no-change forecasts) as the benchmark. U2 values lower then 1.0 show and improvement over the simple no-change forecast. Therefore, the lower the $U_{2,}$ the better the predictive power of the model. The Theil's U_2 coefficient will be used to evaluate the performance of each model for tracking the historical data.

CHAPTER IV

RESULTS

This chapter will be divided in two sections, the sheep industry and the mohair industry. Each section will consist on: (1) the results of the econometric analysis performed using the conceptual models depicted in Chapter III, (2) a discussion of ex-post simulation and model validation, and (3) ex-ante simulation, elasticities and policy analyses.

Sheep Industry

Complete Demand Systems

As discussed in Chapter III, the U.S sheep industry model integrates a demand system approach for lamb meat consumption with the rest of the single equations of the supply and demand system. However, to determine if lamb meat should be part of the meat group (i.e., beef, pork, and chicken) in the demand systems (i.e., LA/AIDS, and Rotterdam) a weak separability test is performed for each demand system. The results of the separability tests are critical for the study as it suggests whether or not a demand system approach is appropriate for lamb meat consumption.

The test failed to reject the null hypothesis of weak separability for lamb meat at the 0.05 significance level. This outcome suggested that lamb meat demand could be separated from the other meats demand for analytical purposes. This implied that a demand system approach will not be very useful to capture the interdependence relationship among lamb meat and the other meats. Therefore, the demand system approach will not be used it this study.

Single Equations

The econometric estimation results for each equation and for each model, i.e., OLS, 2SLS, and 3SLS are discussed in this section. Each equation was evaluated for goodness-of-fit during the estimation process. Adjusted R^2 statistics and p-values were the primary measure of goodness-of-fit. Variables, based upon economic theory, were retained if they were statistically significant at least at the 95 percent confidence level. However, prices of lamb, sheep and wool, as well as the incentive price for wool, were retained even if they were not significant so the model could be solved for the market-clearing price.

OLS Model

Sheep loss (SDIE) was estimated as a function of lagged stock ewe and sheep price, as well as incentive price, and two trend variables (Table 4.1). Stock ewe and the two trend variables were significant at the 95 percent confidence level as shown by their p-values lower than 0.05. The incentive price, and lagged sheep price were not significant at the 95 percent confidence level. However, all variables had their expected sign and a very high adjusted R^2, 0.9334. Stock ewe had a positive relationship with sheep loss, as the higher the number of stock ewes the higher the number of sheep lost. Lagged sheep price and wool incentive price had a negative affect on sheep loss, as the higher the sheep price and the incentive price, the higher the expected returns and the better the care for the herd.

Table 4.1. Regression Equations for Sheep Industry Model Estimated Using OLS Over the 1980-2003 Time Period

			Adjusted R^2
$SDIE_t$	=	$0.0378(SEWE_{t-1}) - 2.9745(EWEP_{t-1}) - 0.5187(WINCP_t) + 825.4941(1/TIME) - 563.682(1/TIME^2)$	0.933428
		(0.0002) (0.1513) (0.9718) (0.0248) (0.0499)	
$SSLT_t$	=	$430.9076 + 0.0224(SEWE_t) - 4.4452(EWEP_{t-1}) + 55.1914(D1998) - 8.2681(TIME)$	0.935274
		(0.0001) (0.0209) (0.0000) (0.0504) (0.0070)	
$SEXP_t$	=	$-2.7374(EWEP_{t-1}) + 5.5242(MXCON_t) + 304.1385(D1998) + 482.2252(D92\_94) - 11.9182(WINCP)$	0.795851
		(0.2726) (0.0000) (0.0140) (0.0000) (0.6262)	
$EWEL_t$	=	$-1918.703 + 0.3042(SEWE_t) + 7.5175(EWEP_{t-1}) + 2.0375(LAMBP_t) + 1.3384(TIME^2)$	0.988618
		(0.0000) (0.0000) (0.0000) (0.0250) (0.0000)	
$SIMP_t$	=	$-1.1811(CANL_t) + 0.2756(LAMBP_t) + 0.2731(TIME^2) - 35.2505(D96\_98)$	0.882470
		(0.0508) (0.0032) (0.0000) (0.0000)	
$LCRP_t$	=	$2661.688 + 0.5296(SEWE_t) - 1.9209(TIME^2)$	0.986908
		(0.0000) (0.0000) (0.0045)	
$LDIE_t$	=	$504.1722 + 0.0670(LCRP_t) - 17.1092(TIME) - 24.6571(WINCP_t)$	0.949406
		(0.0171) (0.0081) (0.0005) (0.0761)	
$LSLT_t$	=	$3966.217 - 19.0452(EWEP_{t-1}) - 57.2200(TIME) + 0.2364(SEWE_t) + 139.7936(WINCP)$	0.955048
		(0.0000) (0.0017) (0.0234) (0.0057) (0.0456)	
$CWGT_t$	=	$48.6632 + 1.2329(TIME) - 0.0235(TIME^2) + 0.3641(LAMBP_{t-1})$	0.927347
		(0.0000) (0.0000) (0.0003) (0.0739)	
$FLEC_t$	=	$2.9952 - 0.0159(PDI_t) + 0.5943(FLEC_{t-1}) + 0.1151(WOOLP_{t-1}) + 0.0156(LAMBP_{t-1})$	0.804497
		(0.0228) (0.0506) (0.0006) (0.0032) (0.3596)	
$LCON_t$	=	$-0.4951(LAMBP_t) + 0.0105(INC_t) - 4.5328(TIME) + 0.6549(LCON_{t-1})$	0.627195
		(0.0394) (0.0014) (0.0029) (0.0000)	
$LEXP_t$	=	$-0.0487(LAMBP_t) + 0.1144(MXCON_t) + 0.4300(WINCP_t)$	0.785566
		(0.0000) (0.0000) (0.0499)	
$MILL_t$	=	$-230.9168(POLP_t) + 262.6582(RAYP_t) + 118.6540(ACRP_t) - 72.5656(D98\_03)$	0.818489
		(0.0000) (0.0000) (0.0034) (0.0000)	
$WEXP_t$	=	$0.1813(WINCP_t) - 6.5540(D1998) - 0.0011(AUSWX) + 0.6004(TIME)$	0.794494
		(0.4633) (0.0024) (0.0468) (0.0000)	

Table 4.1. continued

			Adjusted R^2
$WSTK_t$	=	$0.0028(INC_t) + 3.8688(WINCP_t) + 0.3849(WSTK_{t-1}) - 1.2809(EWEP_t) + 0.0344(AUSW_t)$	0.485410
		(0.0289) (0.4039) (0.0590) (0.0254) (0.0584)	
$AUSL_t$	=	$22.5(AUSCW_t) + 5.0(AUSTS_t) + 2.2(WLP_{t-1}) - 72.2(AUSW_t) - 4.9(AUSCHP_t) + 4.4(AUSPP_t) - 136.6(D1996)$	0.719856
		(0.0000) (0.0000) (0.0656) (0.0231) (0.0016) (0.0318) (0.0500)	
NZL_t	=	$-1619.052 + 56.1952(NZCW_t) + 25.1608(NZEW_t) + 0.3422(WLP_{t-1}) - 1.7498(NZBP_t)$	0.817773
		(0.0011) (0.0000) (0.0000) (0.6466) (0.0462)	
MXL_t	=	$46.8001 + 2.4669(MXXR_t) + 0.0352(WLP_{t-1})$	0.834461
		(0.0000) (0.0000) (0.4712)	
$CANL_t$	=	$-20.7531 + 0.042(CANSLGT_t) + 0.4872(CANCW_t) + 0.0042(WLP_{t-1})$	0.998523
		(0.0000) (0.0000) (0.0000) (0.0002)	
$AUSCON_t$	=	$897.8 + 171.91(AUSXR_t) + 0.397(AUDGDP_t) + 0.204(WLP_t) - 4.274(AUSEP_t) + 1.815(AUSBP_t) - 35.8(AUSPOP_t)$	0.813648
		(0.0001) (0.0494) (0.0399) (0.8031) (0.0000) (0.0081) (0.0470)	
$NZCON_t$	=	$646.477 - 0.11(WLP_t) - 153.6226(NZPOP_t)$	0.795113
		(0.0000) (0.6112) (0.0000)	
$MXCON_t$	=	$-196.7269 - 5.5604(MXXR_t) + 0.2364(WLP_t) + 3.261(MEXPOP_t)$	0.839307
		(0.0000) (0.0003) (0.0048) (0.0000)	
$CANCON_t$	=	$52.6456 - 11.998(CANXR_t) - 0.0119(WLP_t) - 0.1567(CANBP_t)$	0.668446
		(0.0000) (0.0173) (0.6029) (0.0000)	
$AUSW_t$	=	$-1823.17 + 64.1184(AUSFW_t) + 5.9087(WWP_{t-1}) + 12.8602(AUSTS_t) + 26.3381(D89\_90)$	0.989078
		(0.0000) (0.0000) (0.1747) (0.0000) (0.0230)	
NZW_t	=	$-490.6982 + 21.0233(NZFW_t) + 3.7661(WWP_{t-1}) - 0.3329(NZLP_{t-1}) - 34.8188(NZXR_t)$	0.986107
		(0.0000) (0.0000) (0.1794) (0.0081) (0.0000)	
ARW_t	=	$-211.3215 + 19.7647(ARFW_t) + 3.883(WWP_{t-1}) + 0.0104(ARTS_t)$	0.996107
		(0.0000) (0.0000) (0.1254) (0.0000)	
URW_t	=	$-156.5184 + 18.1973(URFW_t) - 1.0137(WWP_{t-1}) + 0.0086(URTS_t)$	0.989446
		(0.0000) (0.0000) (0.5066) (0.0000)	
UKW_t	=	$-140.5896 + 19.3871(UKFW_t) + 0.4205(WWP_{t-1}) + 0.0072(UKTS_t)$	0.999248
		(0.0000) (0.0115) (0.0000) (0.0000)	

Table 4.1. continued

			Adjusted R^2
SAW_t	=	$-172.9277 + 20.1355(SAFW_t) - 1.3651(WWP_{t-1}) + 0.0087(SATS_t) + 0.7642(SAXR_t)$	0.998660
		(0.0000) (0.0000) (0.1135) (0.0000) (0.0125)	
$AUSMIL_t$	=	$2431.431 + 5.7133(AUSGDP_t) + 833.1593(AUSXR_t) - 2.4943(AUSLP_t) - 272.3504(WWP_t) - 267.2530(AUSPOP_t)$	0.645986
		(0.0046) (0.0085) (0.0501) (0.0231) (0.0027) (0.0391)	
$NZMIL_t$	=	$963.0792 + 2.1433(NZGDP_t) - 0.8121(NZLP_t) - 13.3838(WWP_t) - 151.366(NZPOP_t)$	0.466752
		(0.0000) (0.0023) (0.0111) (0.2931) (0.0010)	
$ARMIL_t$	=	$0.6769(ARGPOP_t) + 64.9328(WWP_t)$	0.581975
		(0.0231) (0.0000)	
$URMIL_t$	=	$-1135.183 - 6.6476(URXR_t) + 412.5297(URPOP_t) - 0.053(WWP_t)$	0.601833
		(0.0000) (0.0000) (0.0000) (0.9952)	
$UKMIL_t$	=	$3957.898 + 0.2341(UKGDP_t) + 433.3523(UKXR_t) - 73.9901(UKPOP_t) - 1.6807(WWP_t)$	0.343738
		(0.0114) (0.0506) (0.0424) (0.0189) (0.9159)	
$SAMIL_t$	=	$83.6421 - 3.6759(SAXR_t) + 4.6549(WWP_t)$	0.419247
		(0.0000) (0.0062) (0.3288)	
$AUSSTK_t$	=	$-717.8375 + 3.7112(WSTK_t) + 232.0795(WWP_t) + 0.0968(AUSSTK_{t-1})$	0.836638
		(0.0017) (0.0495) (0.0081) (0.0000)	

Variables are defined in Table 3.1
Values in parenthesis are p-value

Sheep slaughter (SSLT) was estimated to be a function of lagged stock ewe numbers and prices, a dummy variable for 1998, and trend. All variables in the equation were statistically significant at least at the 95 percent level with a very high adjuster R^2 of 0.9353. Also, all signs agreed with economic theory. Stock ewe had a positive relationship with sheep slaughter, as higher ewe numbers would lead to more sheep slaughtered. Sheep price had a negative relationship with sheep slaughter, as producers will try to build their stocks when prices are higher.

Replacement numbers (EWEL) yielded a high adjusted R^2 (0.9886). Number of stock ewes had a positive sign, as expected, because a fraction of the ewes must be replaced each year due to age or usefulness. The signs for sheep and lamb prices were also as expected since a higher sheep and/or lamb price would increase replacement numbers to build the herd.

Live sheep exports (SEXP) equation yielded a reasonable adjusted R^2 (0.7959) and was estimated as a function of sheep price, Mexico's domestic consumption, wool incentive price, and two dummy variables. All signs agreed with prior expectation, but sheep price and wool incentive price were the only variables not significant at least at the 0.05 level. Wool incentive price had a negative relationship with live sheep exports, as producers would build the herd and produce more wool to take advantage of a higher incentive price. Mexico is the major importer of U.S. sheep so a positive sign agreed with prior expectation. Live sheep imports (SIMP) yielded also a fairly high adjusted R^2 (0.8825), however, Canada sheep production had an opposite sign than expected.

Canada is the main exporter of live sheep to the U.S, so a positive sign was expected. Lamb price had a positive relationship with live sheep imports as expected.

Lamb crop (LCRP) was estimated to be a function of the number of stock ewes, and trend. Both variables were statistically significant at the 99 percent confidence level and the adjusted R^2 is very high, 0.9869. As expected, the number of ewes was the most important determinant of the size of the lamb crop, and also yielded the expected sign. Lamb death loss (LDIE) was a function of lamb crop, wool incentive price and trend. All variables were statistically significant at the 0.05 level, except for wool incentive price, and yielded a high adjusted R^2, 0.9494. Wool incentive price had a negative sign, as a higher incentive price would increase the care for lambs because of higher expected returns from wool, therefore, decreasing lamb death loss.

Lamb slaughter (LSLT) estimated results showed that all variables in the equation were statistically significant at least at the 95 percent level and all signs agreed with economic theory, except wool incentive price. Lagged sheep price had a negative sign, as producers reduce lamb slaughter to increase herd size. Stock ewe had a positive sign, as expected, as the higher the number of stock ewe the higher the lamb production. A negative relationship was expected between lamb slaughter and wool incentive price, as a higher incentive price would increase wool production and reduce lamb slaughter. However, the model showed a positive relationship.

The carcass weight (CWGT) equation showed that both trend variables were significant al the 0.01 level, but the lagged lamb price was only significant at the 0.1 level. All signs agreed with expectations, i.e. a higher lamb price is expected to yield a higher carcass weight. Fleece weight (FLEC) estimated parameters agreed with economic theory, except for PDI, however, the equation had a fairly good adjusted R^2, 0.8045.

Lamb consumption (LCON) was modeled as a function of lamb price, income, trend, and lamb consumption lagged one period. All variables were statistically significant at the 95 percent level and their signs agreed with economic theory. Lamb price (LAMBP) had a negative sign meaning that as price of lamb increases, lamb consumption decreases. Moreover, income had a positive sign, which agrees with economic theory for normal or luxury goods.

Lamb export (LEXP) was estimated as a function of lamb price, Mexico's domestic demand, and wool incentive price and all variables were significant at the 95 percent level. Moreover, all variables complied with prior expectation, except for wool incentive price. An increase in lamb price will reduce lamb exports, and as Mexico's domestic demand increases, lamb exports will increase.

U.S. mill demand for wool (MILL) was estimated as a function of polyester, rayon and acrylic prices, and a dummy variable for the introduction of polartec fleece. Wool price was dropped because it was not significant and it had the wrong sign. Polyester seems to be a complement to wool, as a higher polyester price decreases mill use, while rayon and acrylic seem to be substitutes to wool, as higher rayon and acrylic prices increase mill use.

Wool exports (WEXP) were modeled as a function of wool incentive price, Australia's exchange rate, trend and a dummy variable. This equation yielded a reasonable adjusted R^2, 0.7945 and all of its explanatory variables were significant at least at the 95 percent level, except for wool incentive price. Moreover, signs for all of the variables complied with prior expectation. Wool incentive price had a positive relationship with wool exports, as an increase on incentive prices will increase wool production and wool exports. In addition, Australia's exchange rate had a negative effect on wool export, as a strong U.S. dollar makes U.S. products more expensive to importers.

U.S. wool stock (WSTK) was estimated as a function of income, wool incentive price, sheep price, Australia's wool production, and wool stock lagged one period. This equation had a very low adjusted R^2 (0.4854), and only two of its five explanatory variables were significant at the 0.05 level. However, all variables had the expected signs. Higher wool incentive price will increase wool production and wool stock. Also, higher Australian wool production will increase their exports and reduce the U.S. wool exports, increasing U.S. wool stocks.

Australia's lamb production (AUSL) was modeled as a function of Australian carcass weight, total sheep, wool production, chicken price, pork price, a dummy variable, and lagged world lamb price. All variables were significant at least at the 95 percent level, except for world lamb price, and had their expected signs. World lamb price was calculated as the average domestic price from Australia, New Zealand, Canada and Mexico weighted on their individual participation in the world market. As expected, world lamb price had a positive relationship with Australian lamb production. Chicken and pork seem to have a complement and substitute relationship, respectively, to lamb production, as an increase in chicken price had a negative affect on lamb production and vice versa for pork price.

New Zealand's lamb production (NZL) was estimated as a function of New Zealand's carcass weight, stock ewes, lagged world lamb price, and beef price. This equation gave an adjusted R^2 of 0.8178, and all variables were significant at the 0.05 level, except for world lamb price. However, all variables had the expected signs.

Mexico's lamb production (MXL) equation was a function of Mexican exchange rate and lagged world lamb price. Both variables had the expected sign, although, world lamb price was not significant. Mexico's exchange rate to U.S. dollar had a positive relationship with lamb production, as a strong dollar will reduce the exports from the U.S. to Mexico and, as a consequence, increase Mexican lamb production. Canada's lamb production (CANL) estimated parameters agreed with economic theory, and all variables are significant at the 99 percent level.

Australia's lamb consumption (AUSCON) estimated results show that all variables in the equation were statistically significant at the 0.05 level, except for world lamb price. Moreover, all signs, except for world lamb price, agreed with economic theory and yielded an adjusted R^2 of 0.8136. Beef seems to be a substitute to lamb consumption, as an increase in beef price will increase lamb consumption. Also, there was a negative relationship between population and consumption, which suggests that per capita lamb consumption is decreasing.

New Zealand lamb consumption (NZCON) was estimated to be a function of New Zealand's population and world lamb price. World lamb price was not statistically significant, but had the expected sign. Mexico's lamb consumption (MXCON) was modeled as a function of Mexican's exchange rate, population and world lamb price. All variables were significant at the 0.01 level, but world lamb price had the wrong sign. Mexico's exchange rate to the U.S. dollar had a negative relationship to lamb consumption, which implies that a strong dollar reduces exports to Mexico. Canadian lamb consumption (CANCON) estimated parameters agreed with economic theory. All variables were significant at the 0.05 level, except for world lamb price. Canada's beef seems to be a complement to lamb, as beef price had a negative relationship with lamb consumption.

Australia's wool production (AUSW) was modeled as a function of Australian fleece weight, total sheep, dummy variable, and lagged world wool price. All variables were significant at least at the 0.95 percent level, except for lagged world wool price. However, all variables had the expected sign and a very high adjusted R^2, 0.9891. World lamb price was calculated as the average domestic price from Australia, New Zealand, and South Africa weighted on their individual participation in the world market. No wool prices were found for Argentina, Uruguay and United Kingdom.

New Zealand's wool production (NZW) was estimated as a function of New Zealand's fleece weight, exchange rate, and lagged lamb price and world wool price. All variables were significant at the 0.01 level, except for world wool price. All the varaibles' signs agreed with economic theory and yielded a very high adjusted R^2 of 0.9861. Lagged lamb price had a negative relationship with wool production, as higher lamb price will increase lamb production and, as a consequence, reduce wool production.

Wool production from Argentina (ARW), Uruguay (URW), and United Kingdom (UKW) were all estimated as a function of their own fleece weight, total sheep, and lagged world wool price. All variables were significant at least at the 95 percent level, except for lagged world wool price for wool production in Argentina and Uruguay. All signs were as expected except for world wool price for Uruguay's wool production. All three equations yielded very high adjusted R^2s ranging from 0.9961 to 0.9992, for Argentina's and United Kingdom's wool production, respectively. South Africa's wool production (SAW) estimated parameters agreed with economic theory, except for lagged world wool price, and it had a very high adjusted R^2, 0.9987.

Australia's mill demand (AUSMIL) was modeled as a function of Australian gross domestic product (GDP), exchange rate, lamb price, population, and world wool price. World wool price had a negative affect of mill demand, as expected. In addition, higher GDP lead to an increase in mill demand, implying that wool is a normal or luxury good. New Zealand's mill demand (NZMIL) was estimated as a function of New Zealand's GDP, lamb price, population, and world wool price. All variables were significant at the 0.05 level, except for world wool price, and had a low adjusted R^2, 0.4668. A negative relationship between wool demand and population implies a lower per capita wool consumption. Also, higher GDP leads to increase in mill demand, implying that wool is a normal or luxury good.

Argentina mill consumption (ARMIL) equation showed that both explanatory variables are significant at the 0.05 level, but the sign for world wool price did not comply with economic theory. Uruguay's mill consumption (URMIL) showed that all three explanatory variables agreed with economic theory, but world wool price was not significant and the equation had a low adjusted R^2, 0.6018. United Kingdom's mill consumption (UKMIL) showed that all variables complied with economic theory. Moreover, all explanatory variables were significant at the 0.05 level, except for world wool price, and yielded a very low adjusted R^2, 0.3437. South Africa's mill demand (SAMIL) was estimated as a function of South Africa's exchange rate and world wool price. World wool price was not significant at the 0.05 level and also has the wrong sign.

Finally, Australia's wool stock (AUSSTK) was modeled as a function of U.S. wool stock, world wool price, and lagged Australian wool stock. This equation yielded a fairly high adjusted R^2, and all variables were significant at the 95 percent level. All variables had the expected sign, except for U.S. wool stock, which was expected to have a negative relationship. World wool price had a positive relationship with wool stock, complying with economic theory, as an increase in wool price will lead to an increase in wool stocks.

2SLS Model

Table 4.2 shows the econometric results for the 2SLS model. Overall, the results from the 2SLS model did not change much from the OLS model. All explanatory variables from each equation had the same sign for both models. The level of

Table 4.2. Regression Equations for Sheep Industry Model Estimated Using 2SLS Over the 1980-2003 Time Period

			Adjusted R^2
$SDIE_t$	=	$0.0407(SEWE_{t-1}) - 2.4581(EWEP_{t-1}) - 0.2548(WINCP_t) + 905.0980(1/TIME) - 595.276(1/TIME^2)$	0.935510
		(0.0001) (0.2763) (0.9863) (0.0192) (0.0567)	
$SSLT_t$	=	$440.9058 + 0.0224(SEWE_t) - 4.3674(EWEP_{t-1}) + 45.8718(D1998) - 8.5954(TIME)$	0.934701
		(0.0001) (0.0309) (0.0000) (0.1509) (0.0055)	
$SEXP_t$	=	$-3.4419(EWEP_{t-1}) + 5.7667(MXCON_t) + 384.2625(D1998) + 460.7079(D92\_94) - 3.6468(WINCP)$	0.790656
		(0.1817) (0.0000) (0.0050) (0.0000) (0.8860)	
$EWEL_t$	=	$-1763.357 + 0.2954(SEWE_t) + 7.5569(EWEP_{t-1}) + 1.4322(LAMBP_t) + 1.1148(TIME^2)$	0.988483
		(0.0000) (0.0000) (0.0000) (0.0656) (0.0000)	
$SIMP_t$	=	$-1.6667(CANL_t) + 0.3787(LAMBP_t) + 0.2673(TIME^2) - 35.042(D96\_98)$	0.892256
		(0.0107) (0.0007) (0.0000) (0.0000)	
$LCRP_t$	=	$2489.235 + 0.5493(SEWE_t) - 1.7733(TIME^2)$	0.987974
		(0.0000) (0.0000) (0.0064)	
$LDIE_t$	=	$427.0576 + 0.0745(LCRP_t) - 14.9763(TIME) - 23.6392(WINCP_t)$	0.944662
		(0.0629) (0.0055) (0.0066) (0.0913)	
$LSLT_t$	=	$4005.622 - 18.9457(EWEP_{t-1}) - 58.4804(TIME) + 0.2325(SEWE_t) + 140.0265(WINCP)$	0.954581
		(0.0000) (0.0019) (0.0211) (0.0069) (0.0466)	
$CWGT_t$	=	$46.5966 + 1.4051(TIME) - 0.0313(TIME^2) + 0.0492(LAMBP_{t-1})$	0.936378
		(0.0000) (0.0000) (0.0000) (0.0107)	
$FLEC_t$	=	$2.0456 - 0.0349(PDI_t) + 0.7212(FLEC_{t-1}) + 0.1040(WOOLP_{t-1}) + 0.0054(LAMBP_{t-1})$	0.788836
		(0.1585) (0.0113) (0.0002) (0.0055) (0.7666)	
$LCON_t$	=	$-0.1534(LAMBP_t) + 0.0071(INC_t) - 2.6762(TIME) + 0.7002(LCON_{t-1})$	0.556422
		(0.5171) (0.0443) (0.0597) (0.0000)	
$LEXP_t$	=	$-0.0602(LAMBP_t) + 0.1352(MXCON_t) + 0.3052(WINCP_t)$	0.854071
		(0.0000) (0.0000) (0.0917)	
$MILL_t$	=	$-259.6599(POLP_t) + 266.6634(RAYP_t) + 141.7767(ACRP_t) - 74.0777(D98\_03)$	0.813869
		(0.0000) (0.0000) (0.0018) (0.0000)	
$WEXP_t$	=	$0.4888(WINCP_t) - 7.9668(D1998) - 0.0024(AUSWX) + 0.6945(TIME)$	0.813928
		(0.4272) (0.0003) (0.0599) (0.0000)	

Table 4.2. continued

Dependent		Equation	Adjusted R^2
$WSTK_t$	=	$0.0026(INC_t) + 3.572(WINCP_t) + 0.3964(WSTK_{t-1}) - 1.2513(EWEP_t) + 0.0352(AUSW_t)$	0.511559
		(0.0359) (0.4316) (0.0556) (0.0364) (0.0519)	
$AUSL_t$	=	$24.5(AUSCW_t) + 5.24(AUSTS_t) + 0.89(WLP_{t-1}) - 80.86(AUSW_t) - 5.76(AUSCHP_t) + 5.67(AUSPP_t) - 119.1(D1996)$	0.766487
		(0.0000) (0.0000) (0.4075) (0.0069) (0.0004) (0.0096) (0.1080)	
NZL_t	=	$-1600.192 + 53.4771(NZCW_t) + 25.1253(NZEW_t) + 0.8295(WLP_{t-1}) - 1.1635(NZBP_t)$	0.822838
		(0.0100) (0.0003) (0.0000) (0.2791) (0.2947)	
MXL_t	=	$44.5067 + 2.2797(MXXR_t) + 0.0733(WLP_{t-1})$	0.837660
		(0.0000) (0.0000) (0.1451)	
$CANL_t$	=	$-20.8049 + 0.0416(CANSLGT_t) + 0.4935(CANCW_t) + 0.0039(WLP_{t-1})$	0.999277
		(0.0000) (0.0000) (0.0000) (0.0038)	
$AUSCON_t$	=	$898.8 + 198.32(AUSXR_t) + 0.494(AUDGDP_t) + 0.245(WLP_t) - 4.236(AUSEP_t) + 1.91(AUSBP_t) - 41.08(AUSPOP_t)$	0.793297
		(0.0025) (0.1328) (0.0374) (0.7488) (0.0000) (0.0267) (0.2310)	
$NZCON_t$	=	$647.7872 - 0.131(WLP_t) - 156.7414(NZPOP_t)$	0.783650
		(0.0000) (0.8918) (0.0000)	
$MXCON_t$	=	$-183.4113 - 5.5561(MXXR_t) + 0.2037(WLP_t) + 3.1218(MEXPOP_t)$	0.819759
		(0.0001) (0.0007) (0.0128) (0.0000)	
$CANCON_t$	=	$46.4686 - 10.5861(CANXR_t) - 0.0158(WLP_t) - 0.1328(CANBP_t)$	0.545315
		(0.0000) (0.0360) (0.4448) (0.0000)	
$AUSW_t$	=	$-1816.245 + 63.8299(AUSFW_t) + 3.5756(WWP_{t-1}) + 12.9017(AUSTS_t) + 28.0962(D89\_90)$	0.999035
		(0.0000) (0.0000) (0.4224) (0.0000) (0.0870)	
NZW_t	=	$-514.2712 + 21.2979(NZFW_t) + 4.7383(WWP_{t-1}) - 0.2581(NZLP_{t-1}) - 31.1811(NZXR_t)$	0.996302
		(0.0000) (0.0000) (0.0827) (0.0477) (0.0000)	
ARW_t	=	$-204.2373 + 19.145(ARFW_t) + 2.8693(WWP_{t-1}) + 0.0104(ARTS_t)$	0.996445
		(0.0000) (0.0000) (0.2652) (0.0000)	
URW_t	=	$-154.0761 + 18.9187(URFW_t) - 1.2086(WWP_{t-1}) + 0.0086(URTS_t)$	0.990810
		(0.0000) (0.0000) (0.4198) (0.0000)	
UKW_t	=	$-140.7867 + 19.4553(UKFW_t) + 0.355(WWP_{t-1}) + 0.0072(UKTS_t)$	0.999244
		(0.0000) (0.0000) (0.0139) (0.0000)	

Table 4.2. continued

			Adjusted R^2
SAW_t	=	$-173.5938 + 20.3105(SAFW_t) - 1.3384(WWP_{t-1}) + 0.0086(SATS_t) + 0.7826(SAXR_t)$	0.998695
		(0.0000) (0.0000) (0.0873) (0.0000) (0.0146)	
$AUSMIL_t$	=	$2152.603 + 4.3502(AUSGDP_t) + 364.1448(AUSXR_t) - 5.2708(AUSLP_t) - 211.8039(WWP_t) - 176.9914(AUSPOP_t)$	0.602816
		(0.0132) (0.0275) (0.3816) (0.0001) (0.0101) (0.1304)	
$NZMIL_t$	=	$896.2285 + 1.9128(NZGDP_t) - 0.745(NZLP_t) - 5.5875(WWP_t) - 133.7993(NZPOP_t)$	0.436373
		(0.0000) (0.0182) (0.0567) (0.7049) (0.0166)	
$ARMIL_t$	=	$0.9596(ARGPOP_t) + 61.9118(WWP_t)$	0.590515
		(0.0535) (0.0000)	
$URMIL_t$	=	$-1133.539 - 6.3963(URXR_t) + 409.5751(URPOP_t) + 3.7829(WWP_t)$	0.529464
		(0.0000) (0.0002) (0.0000) (0.6820)	
$UKMIL_t$	=	$3298.267 + 0.1733(UKGDP_t) + 274.8001(UKXR_t) - 59.5911(UKPOP_t) + 5.7611(WWP_t)$	0.428481
		(0.0425) (0.1672) (0.2312) (0.0687) (0.7074)	
$SAMIL_t$	=	$85.0494 - 3.7254(SAXR_t) + 4.3516(WWP_t)$	0.419931
		(0.0000) (0.0160) (0.3985)	
$AUSSTK_t$	=	$-653.557 + 4.481(WSTK_t) + 180.3406(WWP_t) + 0.8685(AUSSTK_{t-1})$	0.826595
		(0.0046) (0.0697) (0.0312) (0.0000)	

Variables are defined in Table 3.1
Values in parenthesis are p-values

significance and the adjusted R^2s from the models varied to some extent, however, overall they were very close to each other. Lamb, wool and wool incentive prices were still not significant most of the time, but with the expected signs. World lamb and wool prices were also not significant most of the time and in some cases their signs did not comply with economic theory. Given the results, we cannot choose one estimation procedure over the other.

3SLS Model

A main advantage of the 3SLS is that it uses seemingly unrelated regression (SUR), also know as the multivariate regression, with instrumental variables (Greene, 2000). Therefore, it accounts for heteroskedasticity and continuous correlation in the errors across equations. However, in order to use this procedure, which consists of estimating the cross-equation covariance matrix, we needed to have enough degrees of freedom.

As shown in Table 4.3 some changes were made to the original model for the 3SLS model. Due to the large number of equations in the system and not enough observations, the model encountered a problem of matrix singularity. Therefore, some of the equations in the system were eliminated, starting from the least important ones. The whole model was estimated every time an equation was eliminated to test if the matrix singularity problem was fixed. After carefully eliminating and re-specifying the remaining equations we ended up with the equations for the supply and demand for lamb and wool for the U.S., Australia and New Zealand in Table 4.3. Both, Australia and New Zealand, are the major producers of wool and lamb in the world.

Table 4.3. Regression Equations for Sheep Industry Model Estimated Using 3SLS Over the 1980-2003 Time Period

			Adjusted R^2
$SDIE_t$	=	$0.0432(SEWE_{t-1}) – 3.3953(EWEP_{t-1}) – 0.9916(WINCP_t) + 715.5574(1/TIME) – 453.645(1/TIME^2)$	0.936153
		(0.0000) (0.0000) (0.9010) (0.0000) (0.0000)	
$SSLT_t$	=	$349.4483 + 0.0291(SEWE_t) – 4.3288(EWEP_{t-1}) + 54.8058(D1998) – 6.3168(TIME)$	0.932860
		(0.0000) (0.0000) (0.0000) (0.0002) (0.0002)	
$SEXP_t$	=	$– 2.4044(EWEP_{t-1}) + 5.6272(MXCON_t) + 326.6899(D1998) + 475.8938(D92\_94) – 26.4044(WINCP)$	0.785983
		(0.0013) (0.0000) (0.0000) (0.0000) (0.0080)	
$EWEL_t$	=	$– 1743.925 + 0.2932(SEWE_t) + 8.00985(EWEP_{t-1}) + 1.0961(LAMBP_t) + 1.2635(TIME^2)$	0.988438
		(0.0000) (0.0000) (0.0000) (0.0000) (0.0080)	
$SIMP_t$	=	$– 1.3097(CANL_t) + 0.3028(LAMBP_t) + 0.2604(TIME^2) – 28.3024(D96\_98)$	0.880113
		(0.0000) (0.0000) (0.0000) (0.0000)	
$LCRP_t$	=	$2185.399 + 0.5808(SEWE_t) – 1.4546(TIME^2)$	0.987656
		(0.0000) (0.0000) (0.0000)	
$LDIE_t$	=	$333.1613 + 0.083(LCRP_t) – 12.0939(TIME) – 21.4505(WINCP_t)$	0.943384
		(0.0005) (0.0000) (0.0000) (0.0011)	
$LSLT_t$	=	$4084.522 – 19.6015(EWEP_{t-1}) – 62.2478(TIME) + 0.2335(SEWE_t) + 133.3779(WINCP)$	0.954041
		(0.0000) (0.0000) (0.0000) (0.0000) (0.0001)	
$CWGT_t$	=	$46.6002 + 1.4234(TIME) – 0.0327(TIME^2) + 0.0506(LAMBP_{t-1})$	0.932788
		(0.0000) (0.0000) (0.0000) (0.0000)	
$FLEC_t$	=	$1.2118 – 0.0443(PDI_t) + 0.8298(FLEC_{t-1}) + 0.1008(WOOLP_{t-1}) + 0.0012(LAMBP_{t-1})$	0.754728
		(0.0874) (0.0000) (0.0000) (0.0000) (0.9094)	
$LCON_t$	=	$– 0.2062(LAMBP_t) + 0.0084(INC_t) – 3.0653(TIME) + 0.6519(LCON_{t-1})$	0.550155
		(0.1962) (0.0004) (0.0020) (0.0000)	
$LEXP_t$	=	$– 0.0582(LAMBP_t) + 0.1289(MXCON_t) + 0.4129(WINCP_t)$	0.843484
		(0.0000) (0.0000) (0.0004)	
$MILL_t$	=	$– 217.2775(POLP_t) + 246.9486(RAYP_t) + 122.511(ACRP_t) – 64.6289(D98\_03)$	0.813082
		(0.0000) (0.0000) (0.0000) (0.0000)	
$WEXP_t$	=	$0.2858(WINCP_t) – 8.0759(D1998) – 0.0019(AUSWX) + 0.6933(TIME)$	0.806982
		(0.4216) (0.0000) (0.0492) (0.0000)	

Table 4.3. continued

			Adjusted R^2
$WSTK_t$	=	$0.0026(INC_t) + 1.9206(WINCP_t) + 0.2857(WSTK_{t-1}) - 1.3599(EWEP_t) + 0.0477(AUSW_t)$	0.502374
		(0.0000) (0.3936) (0.0000) (0.0000) (0.0000)	
$AUSL_t$	=	$24.9(AUSCW_t) + 4.92(AUSTS_t) + 0.79(WLP_{t-1}) - 73.14(AUSW_t) - 5.59(AUSCHP_t) + 5.56(AUSPP_t) - 126.2(D1996)$	0.766364
		(0.0000) (0.0000) (0.0622) (0.0000) (0.0000) (0.0000) (0.0000)	
NZL_t	=	$-1185.686 + 42.9544(NZCW_t) + 22.4397(NZEW_t) + 1.5304(WLP_{t-1}) - 1.1023(NZBP_t)$	0.796776
		(0.0000) (0.0000) (0.0000) (0.0000) (0.0146)	
$AUSCON_t$	=	$729.0 + 154.83(AUSXR_t) + 0.282(AUDGDP_t) + 0.335(WLP_t) - 4.358(AUSEP_t) + 2.39(AUSBP_t) - 25.46(AUSPOP_t)$	0.784718
		(0.0000) (0.0050) (0.1984) (0.2620) (0.0000) (0.0000) (0.0731)	
$NZCON_t$	=	$665.0182 - 0.0179(WLP_t) - 161.2704(NZPOP_t)$	0.782492
		(0.0000) (0.8129) (0.0000)	
$AUSW_t$	=	$-1815.972 + 63.8553(AUSFW_t) + 5.1898(WWP_{t-1}) + 12.8789(AUSTS_t) + 26.8074(D89\_90)$	0.999010
		(0.0000) (0.0000) (0.0020) (0.0000) (0.0000)	
NZW_t	=	$-481.5583 + 20.758(NZFW_t) + 4.5454(WWP_{t-1}) - 0.3234(NZLP_{t-1}) - 33.456(NZXR_t)$	0.996292
		(0.0000) (0.0000) (0.0000) (0.0000) (0.0000)	
$AUSMIL_t$	=	$2728.866 + 5.6093(AUSGDP_t) + 683.8354(AUSXR_t) - 4.4023(AUSLP_t) - 273.1848(WWP_t) - 263.4671(AUSPOP_t)$	0.586799
		(0.0000) (0.0000) (0.0000) (0.0000) (0.0000) (0.0000)	
$NZMIL_t$	=	$980.1897 + 2.0167(NZGDP_t) - 0.5643(NZLP_t) - 8.9903(WWP_t) - 161.8842(NZPOP_t)$	0.418599
		(0.0000) (0.0000) (0.0000) (0.0292) (0.0000)	
$AUSSTK_t$	=	$-644.6326 + 4.7196(WSTK_t) + 170.972(WWP_t) + 0.8446(AUSSTK_{t-1})$	0.826124
		(0.0000) (0.0002) (0.0004) (0.0000)	

Variables are defined in Table 3.1
Values in parenthesis are p-values

The results of the 3SLS procedure were relatively better than the other two models. All signs were identical to the other two procedures, and the adjusted R^2s were also very close to the other two models. However, the 3SLS model yielded more significant variables than the other two models, especially for key variables such as U.S. lamb and wool prices, wool incentive price, and world lamb and wool price.

Ex-Post Simulation

The model was simulated in EViews© using the "model solver" routine for the 1997-2003 time period. Figure 4.1A contained the actual and simulated stock ewe numbers generated by the OLS, 2SLS, and 3SLS models. All three models simulated the data fairly well, following the trend, but overestimated the ewe numbers in all periods except in 2002 and 2003 where actual and simulated values were almost identical for all three models. The Theil's U_2 statistics for stock ewe numbers were 0.022, 0.025, and 0.023 for the OLS, 2SLS, and 3SLS models, respectively (Table 4.3).

All three models simulated lamb and mutton imports very well (Figure 4.1B). The OLS models seemed to follow the actual values better than the other two models, overestimating lamb and mutton imports from 1997 to 1999 and from 2001 to 2002, and underestimating imports very slightly in 2000 and 2003. The three models "goodness-of-fit" qualities were measured by the Theil's U_2 statistic in Table 4.4. As expected, the OLS model had the lowest U_2 statistic, 0.0361, followed by the 3SLS and 2SLS models with 0.0760 and 0.0762, respectively.

Figure 4.1C showed the actual and ex-post simulation of wool exports for all three models. Again, the OLS model seemed to follow the actual values closely than the

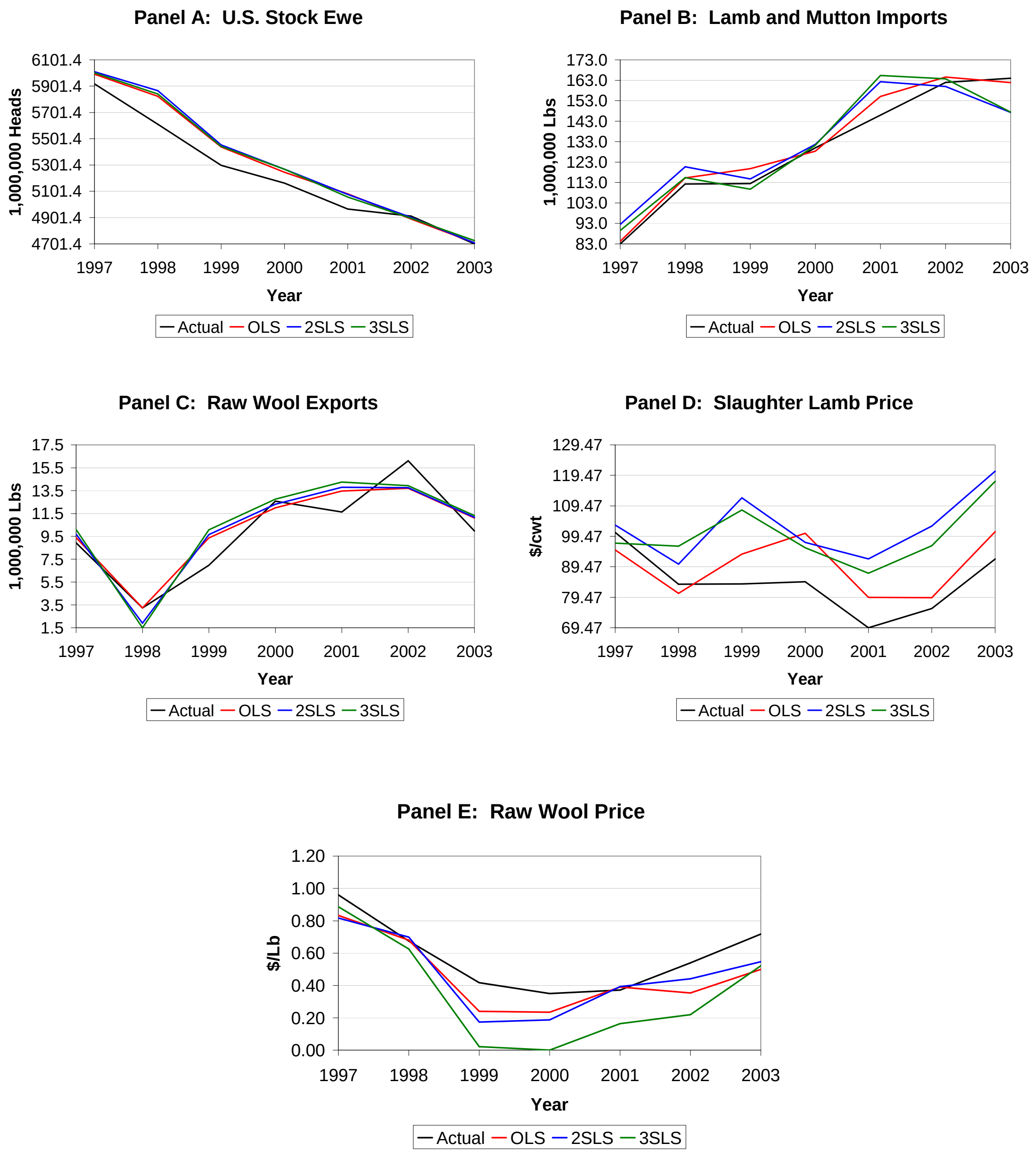

Figure 4.1. **Ex-post simulations for OLS, 2SLS, and 3SLS models for the sheep industry, 1997-2003**

Table 4.4. Ex-Post Simulation Results Theil's U_2 Statistic for the OLS, 2SLS, and 3SLS Sheep Industry Models, 1997-2003

	OLS	2SLS	3SLS	Best
Stock Ewes	0.021651	0.025124	0.022983	OLS
Replacements	0.062216	0.077027	0.069543	OLS
Lamb Slaughter	0.054941	0.055055	0.053513	3SLS
Lamb and Mutton Imports	0.036092	0.076228	0.075956	OLS
Lamb and Mutton Exports	0.116974	0.147051	0.132555	OLS
Wool Production	0.026539	0.026953	0.030150	OLS
Lamb Price	0.107621	0.247662	0.212711	OLS
Wool Price	0.232781	0.217606	0.249332	2SLS

other two models, overestimating wool exports in 4 of the 7 years. The Theil's U_2 statistic agreed with what was seen in Figure 4.1C, indicating that the OLS model had a better fit than the other two models (Table 4.4).

Ex-post simulated lamb prices were summarized in Figure 4.1D. Neither model did a good job of tracking the turns in prices from 1998 to 2000. All three models followed the down and up turns from 2001 to 2003, but overestimated the prices in all cases. The Theil's U_2 statistic indicated that the OLS model had a better fit (Table 4.4).

Finally, simulated and actual wool prices are shown in Figure 4.1E. All three models underestimated wool price, with the exception of the OLS and 2SLS models in 1998 and 2001. From Figure 4.1C, the 2SLS model had a better fit than the other two models. As expected, the Theil's U_2 statistic for the 2SLS model was the lowest of the three models.

Table 4.4 contained the Theil's U_2 statistics for several other variables not reported in the figures. Neither model did a good job of simulating lamb price, wool price, and lamb and mutton exports, as indicated by the Theil's U_2 values. However, stock ewes and wool production had U_2 statistics lower than the generally accepted "good" U_2 value of 0.05 or less.

Based on the ex-post results the OLS model outperformed the other two models for six out of the eight variables reported in Table 4.4, as it had the lowest U_2 statistic among the three models. The only exceptions were lamb slaughter and wool price, where the 3SLS and 2SLS models outperformed the OLS model, respectively. Therefore, the OLS model was used in the remainder of the chapter to analyze policy impacts on the industry.

Elasticity Estimates

Elasticities for stock ewes, wool and lamb production, and lamb consumption generated from the OLS model for one, two, and four year response horizon were summarized in Table 4.5. Responses for stock ewes and wool production were calculated given a one time 10 percent increase in wool and lamb prices in 2004, while responses for lamb production and consumption were calculated given a one time 10 percent increase in the 2004 lamb price only.

Increases in wool and lamb prices increased stock ewe numbers. The 10 percent increase in wool price increased ewe numbers slightly, 0.13 percent by 2006 and then goes to zero by 2008. The increase in lamb price had a much larger and longer term impact than the wool price increase for stock ewes. By 2005 ewe numbers would have increased by 0.52 percent, decreasing the impact to 0.23 percent by 2006, and increasing again by 0.34 by 2008.

Table 4.5. Elasticities Developed from OLS Sheep Industry Model for 1, 2, and 4 Year Responses for a One Time Shock in Selected Variables, Percent Change

	-----------	Years	-------------
	1	**2**	**4**
Stock Ewes			
10% increase in Wool Price	0.00	0.13	0.00
10% increase in Lamb Price	0.52	0.23	0.34
Wool Production			
10% increase in Wool Price	0.10	0.06	0.02
10% increase in Lamb Price	0.00	0.20	0.30
Lamb Production			
10% increase in Lamb Price	0.71	0.08	0.13
Lamb Consumption			
10% increase in Lamb Price	-1.43	-0.59	-0.24

A one time 10 percent increase in wool price would cause a 0.1 percent increase in wool production in 2005. By 2006, the increase was 0.06, and by 2008 the increase was only 0.02 percent. The increase in lamb prices had no affect on wool production in2005. However, in 2006 and 2008 wool production will increase by 0.2 and 0.3 percent, respectively.

Moreover, a 10 percent increase in lamb price would have a 0.71 percent increase in lamb production in 2005, a 0.08 increase in 2006, and a 0.13 increase in 2008. On the other hand, the 10 percent increase in lamb price would have a decrease in lamb consumption by 1.43 percent in 2005. By 2006 the decrease in lamb consumption was 0.59 percent, and a 0.24 percent decrease by 2008.

Baseline Analysis

An ex-ante simulation was performed to develop a baseline projection for the 2004-2008 time horizon. The baseline assumptions included:

- No change in wool loan rate set at $1 per pound of raw wool
- Exogenous variable projections were available from the FAPRI January 2004 Baseline, and also forecasted using ARIMA and VAR models.

The baseline simulation projected stock ewe numbers to continue to decline to about 4.17 million head (about 10 percent) by 2007 (Figure 4.2A). However, stock ewes increased by about 90,000 head in 2008 to 4.26 million head.

Imports of lamb and mutton were projected to slightly decrease in 2004 to 147 million pounds, and then increase constantly to about 200 million pounds in 2008 (Figure 4.2B). Wool export was projected to increase sharply from 10 to about 14 million pounds by 2004 and keep increasing at a lower rate to reach 16 million pounds by 2008 (Figure 4.2C).

Slaughter lamb price increased to $98.07/cwt. in 2004, declined the next two years to $84.15/cwt., and increased in 2007 and 2008 to $92.63/cwt (Figure 4.2.D). Finally, wool price is projected to increase from 2004 to 2007 reaching $1.23 per pound in 2007, then, sharply decrease to $0.97 per pound by 2008.

Policy Alternatives

The policy alternatives analyzed in this study are three different levels of wool marketing loan rate: scenario 1 has a zero loan rate, scenario 2 has a loan rate of $0.50 per pound of wool, and scenario 3 has a $2.00 loan rate per pound of wool. The effects of each scenario on sheep numbers, lamb and mutton imports, wool exports, and lamb and wool prices are discussed in detail.

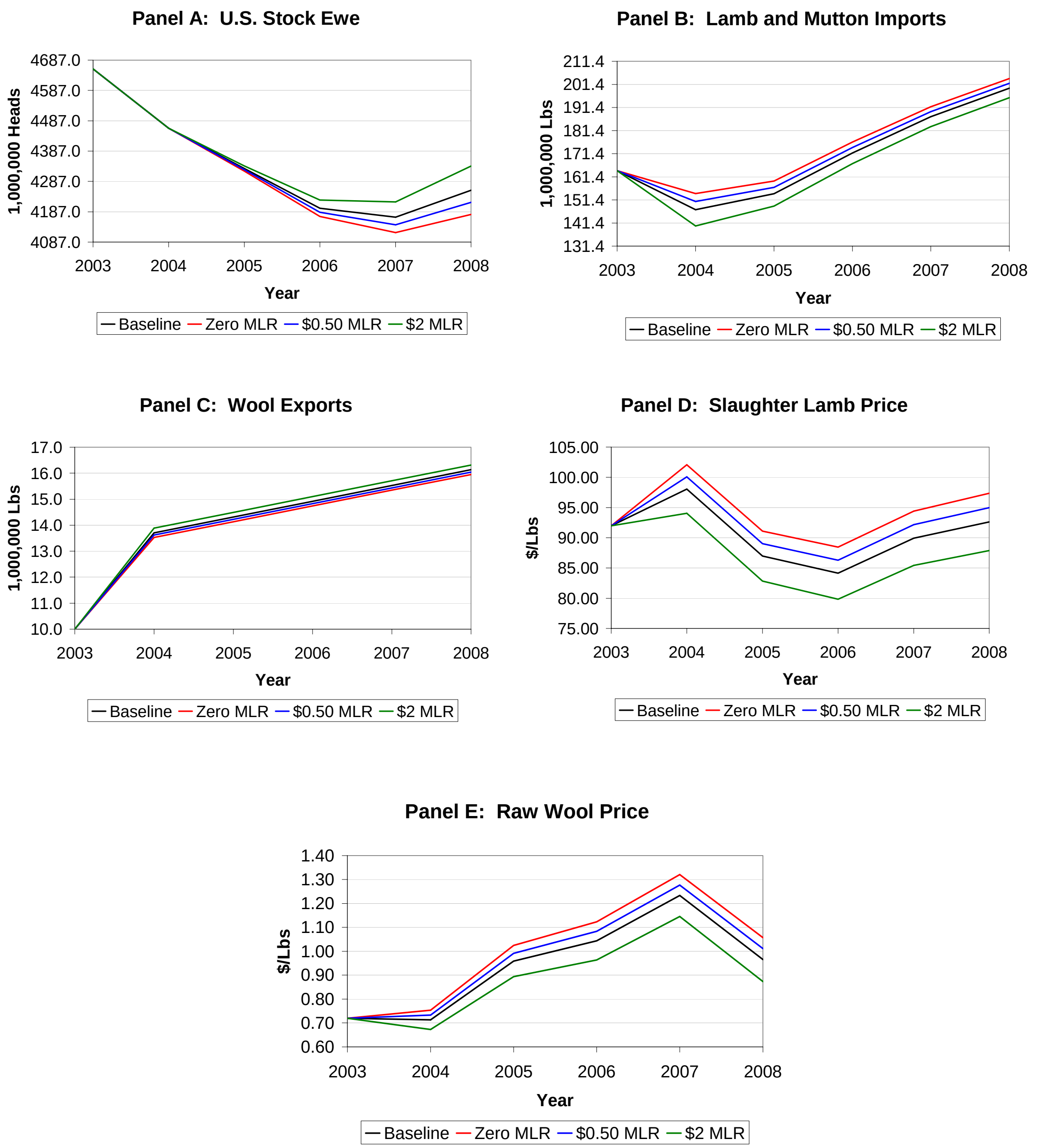

Figure 4.2. Ex-ante simulations of baseline and three policy scenarios for the sheep industry, 2004-2008

Stock ewes continue its negative trend under all three scenarios, except for 2008 where all scenarios show an increase in ewe numbers (Figure 4.2A). The magnitude of the negative trend was smaller for scenario 3 compared to the baseline, and also compared to scenarios 2 and 1. Under scenario 1, stock ewe number reached about 4.18 million head in 2008 compared to 4.22 and 4.33 million under scenarios 1 and 2, respectively.

Lamb and mutton imports were also affected under the three scenarios (Figure 4.2B). The loan rate was hypothesized to have a positive affect in the short run and a negative effect in the long run on lamb and mutton imports, as a higher loan rate will make producers increase the replacement number to build the herd. However, the model did not complied with prior expectations for the short run affect. Throughout the time horizon, a higher loan rate (scenario 3) lowered the amount of lamb and mutton imports, as higher loan prices increased sheep numbers and also lamb production. Under scenario 3, lamb and mutton imports reached 195 million pounds by 2008, while under scenarios 1 and 2 they reached 204 and 202 million pounds, respectively, by 2008.

Figure 4.2C showed the effect that the three levels of loan rate have on wool exports. As expected, a higher loan rate increased wool production, which it is likely to lead to an increase in wool exports. The converse was true for a decrease in loan rate. However, loan rates seemed to have very little affect on wool exports as seen by the small differences of the projections. By 2008, wool exports were projected to be 15.95, 16.04 and 16.31 million pounds under scenarios 1, 2 and 3, respectively.

Figure 4.2.D contained the baseline and three loan rate levels for slaughter lamb price. A higher loan rate was expected to increase lamb slaughtering, which will lead to a decrease in lamb prices, while a lower loan rate will have the opposite effect. Figure 4.2.D showed that lamb prices under scenario 1 were higher than under scenarios 2 and 3.

Finally, Figure 4.2E showed the effects that different levels of loan rate have on wool price. As expected, a lower loan rate will decrease wool production, which will lead to an increase in wool price, and vice versa. By 2008, it was predicted that wool price will be \$1.06, under scenario 1, and \$1.01 and \$0.87, under scenarios 2 and 3, respectively.

Mohair Industry

The estimated equations for the mohair model were summarized in Table 4.6. All equations in the system were estimated using OLS estimation procedures.

The number of goats clipped (SHORN) was estimated as a function of mohair incentive price, and lagged mohair price, production cost and goats clipped. All variables were significant at least at the 95 percent confidence level, and the equation yielded a high adjusted R^2, 0.9407. Lagged mohair price, and mohair incentive price had a positive affect on goats clipped, as expected. Moreover, lagged production cost (MOCST) complied with economic theory having a negative affect on number of goats clipped.

The adjusted R^2 on mohair yield per goat (MOFW) was very low, 0.1745. This low R^2 reflected a large amount of unexplainable variability in the data. A weather

Table 4.6. Regression Equations for Mohair Industry Model Estimated Over the 1980-2003 Time Period

			Adjusted R^2
$SHORN_t$	=	$78.3321(MOP_{t-1}) + 59.1789(MOINCP_t) – 51.1507(MOCST_{t-1}) + 0.9430(SHORN_{t-1})$	0.940658
		(0.0179) (0.0136) (0.0012) (0.0000)	
$MOFW_t$	=	$6.9879 + 0.0239(MOP_{t-1}) + 0.1196(MOINCP_t)$	0.174506
		(0.0000) (0.7637) (0.0112)	
$MOEXP_t$	=	$246.5041(MOP_t) + 746.6211(MOINCP_t) + 0.6664(MOEXP_{t-1})$	0.765152
		(0.4753) (0.0483) (0.0000)	
$MOMIL_t$	=	$– 144.7832(MOP_t) + 200.6375(MOINCP_t) + 0.7540(MOMIL_{t-1})$	0.645441
		(0.2131) (0.0180) (0.0000)	
$MOSTK_t$	=	$– 201.6716(MOP_t) + 106.8698(MOINCP_t) + 1.0423(MOSTK_{t-1})$	0.834040
		(0.0418) (0.0402) (0.0000)	
$MOIMP_t$	=	$171.9733 – 0.8320(MOINCP_t) – 0.0073(INC_t) – 0.1052(MOIMP_{t-1}) + 232.5669(D81) + 221.5243(D94\_95)$	0.943230
		(0.0151) (0.7874) (0.0151) (0.0435) (0.0000) (0.0000)	

Variables are defined in Table 3.1
Values in parenthesis are p-values

variable, the Palmer Drought Index for Texas, was examined, but it failed to add anything to the model and was eliminated. Both variables, lagged mohair price and incentive price, had their expected sign, but only the incentive price (MOINC) was significant at the 0.05 level.

Mohair exports (MOEXP) were modeled as a function of mohair price, incentive price, and mohair exports lagged one period. Both variables had the expected signs, but only mohair incentive price was significant at the 95 percent level. Mohair stock (MOSTK) estimated parameters agreed with economic theory, except for mohair price, and it had a fairly good adjusted R^2, 0.8340.

Domestic mill demand (MOMIL) was estimated as a function of mohair price, mohair incentive price and domestic mill demand lagged one period. Both variables complied with economic theory, but only the incentive price variable was significant at the 0.05 level. The negative relationship between domestic mill demand and mohair price was expected based on the law of demand.

Finally, mohair imports (MOIMP) were modeled as a function of mohair incentive price, income, two dummy variables, and mohair imports lagged one period. All variables were significant at the 0.05 level except for the incentive price and lagged mohair imports, and the equation yielded a high adjusted R^2, 0.9432. Mohair incentive price had a negative relationship with imports, which complies with prior expectations. However, income had a negative relationship to imports, which lead us to believe that mohair is an inferior good.

Ex-Post Simulation

The model was simulated in EViews© using the “model solver” routine for the 1997-2003 time period and results were presented in Figure 4.3. Figure 4.3A contained the actual and simulated number of goats clipped for the model. The model simulated the historical data fairly well, following the trend, but underestimating the numbers of goats clipped in 1997, 1998, and 2003, while slightly overestimating from 1999 to 2002. The Theil’s U_2 statistic for the number of goats clipped was 0.141.

The model did not simulate mohair exports well, as the model over estimated historical values in 1998 and 2000 to 2003 and underestimated in 1999 (Figure 4.3B). However, the model followed the turns the last three years of the simulation period. The Theil’s U_2 statistic for mohair exports was very high, 0.432. Figure 4.3C showed the actual and simulated mohair stocks. The simulated model followed the actual trend, but overestimated actual values in 1997-1998 and 2002-2003, and underestimated the model from 1999 to 2001. The Theil’s U_2 statistic for this model was fairly good, 0.054.

Simulated and actual mohair price values were shown in Figure 4.3D. The model did not simulate mohair price well, moving in opposite directions from 1997 to 1999, and overestimating the actual values the last four years of the simulation period. The Theil’s U_2 statistic was 0.474, which showed that the model did not simulated well.

Baseline Analysis

A baseline scenario was developed to simulate the mohair industry for the 2004-2008 time horizon (Figure 4.3). The only assumption made was no change in the loan rate set at $4.20 per pound of mohair.

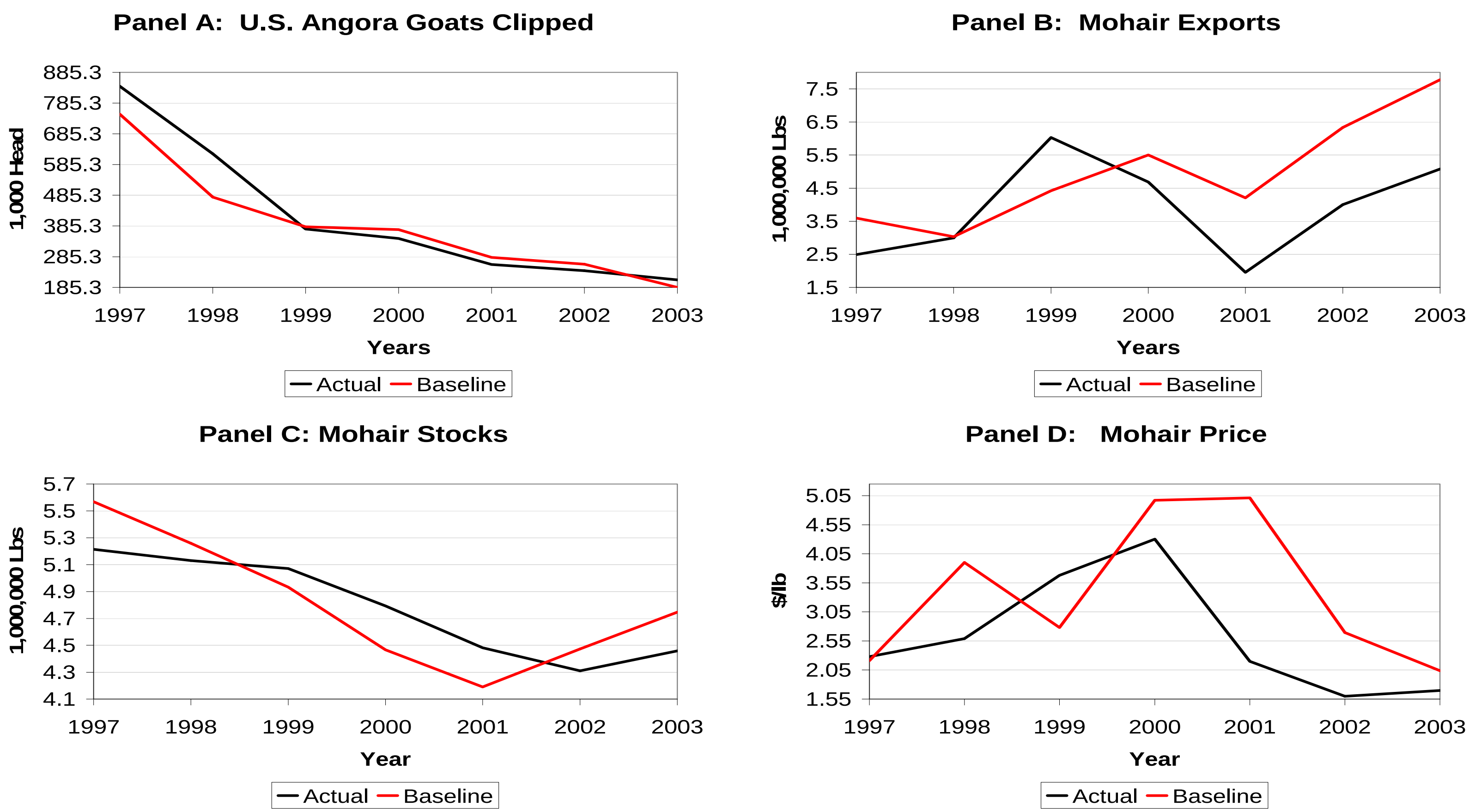

Figure 4.3. Ex-post simulations for the mohair industry, 1997-2003

The baseline projections for goats clipped over the time horizon were presented in Figure 4.4A. Goats clipped showed a constant negative trend, declining to about 56,000 head by 2008. Mohair exports were projected to increase constantly to about 10 million pounds by 2008 (Figure 4.4B). This increase was due to a constant decrease in mohair stocks and domestic mohair mill use.

Mohair stocks were projected to constantly decline throughout the time horizon reaching 1.2 million pounds by 2008 (Figure 4.4C). Finally, Figure 4.4D showed the baseline for mohair price. The projected values showed a slight, but constant increase in mohair prices from $1.75 per pound in 2004 to $1.85 per pound in 2008.

Policy Alternatives

The policy alternatives analyzed in this study are three different levels of mohair marketing loan rate: scenario 1 has a zero loan rate, scenario 2 has a loan rate of $2.10 per pound of mohair, and scenario 3 has a $6.20 loan rate per pound of mohair. The effects of each scenario on number of Angora goats clipped, mohair exports, mohair stocks, and mohair price are presented in Figure 4.4.

A minimum number of goats clipped was set at 10,000 head, based on an assumption that the number of goats clipped does not go to zero in the next five years. The number of goats clipped continued to decrease under scenarios 1 and 2, reaching the 10,000 head floor by 2005 and 2006, respectively (Figure 4.4A). However, under scenario 3, the number of goats clipped increased steadily from 247,200 head in 2004 to 357,300 in 2008.

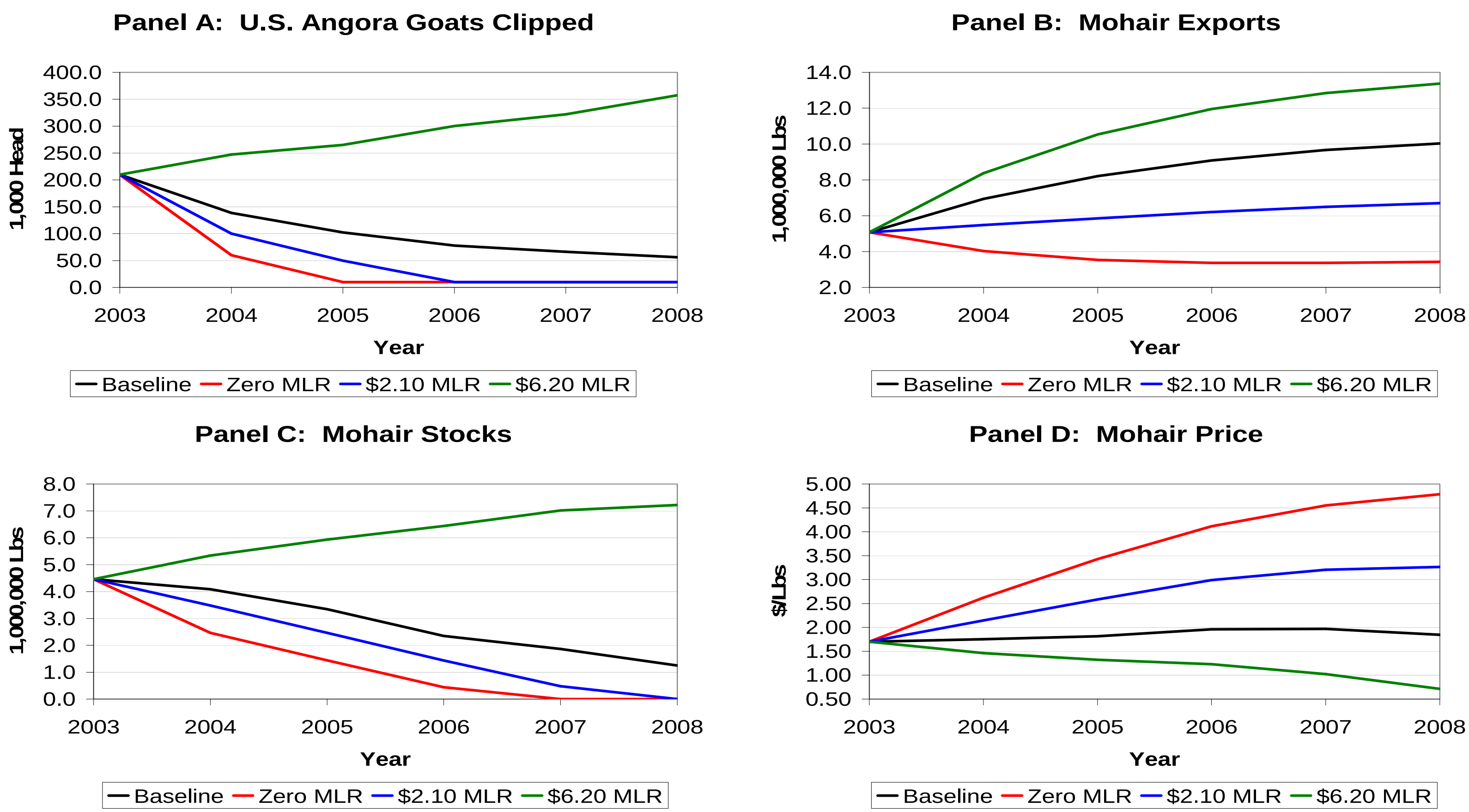

Figure 4.4. Ex-ante simulations of baseline and three policy scenarios for the mohair industry, 2004-2008

Mohair exports increased under scenario 3, as expected, due to an increase in mohair production, reaching 13.4 million pounds in 2008. On the other hand, mohair exports decreased under scenarios 1 and 2 to about 3.4 and 6.7 million pounds, respectively, by 2008. The baseline and the three loan rate levels for mohair stocks were included in Table 4.4C. As expected, a higher loan rate (scenario 3) lead to an increase in mohair stock due to an increase in production. The converse was true for a decrease in loan rate.

Finally, Figure 4.4D showed the effect that different loan rate levels had on mohair price. The increase in production under scenario 3, due to an increase in the number of goats clipped led to a decrease in mohair price from $1.70 per pound in 2003 to $0.71 per pound in 2008. Under scenarios 1 and 2 the opposite affects were observed due to a reduction in mohair production.

CHAPTER V

SUMMARY AND CONCLUSIONS

The United States sheep industry has been declining steadily since 1960. Per capita consumption of lamb and mutton has fallen from 2.9 pounds in 1970 to 1.2 pounds in 2003. Wool use has also declined since the popularity and quality of manmade fibers have increased, specially by the introduction of polartec fleece. Two other major factors contributing to the reduction in the U.S. sheep industry are: scarcity of labor and predator losses.

The sheep industry has been supported by wool incentive payments under the National Wool Act since 1954. These payments have not been able to halt the decline in sheep numbers. In 1993, the U.S. Congress passed a three-year phase out of Wool Act incentive payments with the last payments occurring in 1996. The 2002 Farm Bill reinstated support for the industry by implementing a loan program, similar to other commodities, with loan rates of $0.40 and 41.00 per pound for un-graded and graded wool, respectively.

The U.S. is the second largest producer of mohair with 15 percent of total world production, only exceeded by South Africa with 63 percent of the total world mohair production. Texas accounts for over 85 percent of the U.S. mohair production. The number of goats clipped in the U.S. fell from 4.6 million head in 1965 to about 285,000 in 2003. Most U.S. production has been exported to Europe and more recently to South

Africa. The mohair market has been highly volatile due to fashion changes and world economic events.

Mohair also received incentive payments through the Wool Act. Mohair payments were also phased out along with the wool incentive payments. Moreover, the 2002 Farm Bill reinstated support for the industry by implementing a marketing loan program with loan rates of $4.20 per pound of mohair.

Objectives

The objective of this research is to analyze the impacts of different levels of loan rates on the U.S. sheep and mohair industries. Three different levels of loan rates will be analyzed for wool and mohair: $0, $0.50 and $2.00, and $0, $2.10 and $6.20 per pound for wool and mohair, respectively. The results of this research will be useful to sheep and mohair producers, as well as other stakeholders in the U.S. industry. By analyzing and providing information on the impacts of alternative policies, the industries will be better able to address the impacts of policy alternatives and craft policies to address emerging issues.

Procedures

Annual data was used to estimate parameters for the models of the U.S. sheep and mohair industries. The models used econometric equations and biological identities. Eight different regions or countries were modeled to provide estimates of the impacts of exchange rates on imports and exports for the sheep industry. The eight different regions or countries were Australia, United Kingdom, South Africa, New Zealand, Argentina, Uruguay, Canada, and Mexico.

Supply and demand models for each one of these regions or countries were estimated. The sheep industry model was estimated using OLS, 2SLS, and 3SLS procedures. The models estimated with these three estimation procedures were validated through historical simulation.

On the demand side for lamb, a complete demand system approach was used to capture the interdependence relationships among demands and make a formal attempt to incorporate the restrictions of modern consumer behavior theory. The demand system models that were tested in this study are the Rotterdam and Linear Approximation Almost Ideal Demand System (LA/AIDS). Due to the low per capita consumption of lamb meat compared to the other meats in the system, i.e. beef, pork, and chicken, a weak separability test was performed to find out if lamb meat should be included in the meat system. The result was that a complete demand system could not be used. As the complete demand system approach was disregarded, statistical testing was done to test which single equation model, OLS, 2SLS, and 3SLS was a better predictor of the industry. Theil's U_2 statistic was used to measure the performance of the simulation model and the OLS model was selected.

Supply and demand equations were estimated for the mohair model. Only an OLS model was estimated due to a lack of available data. As with the sheep model Theil's U_2 statistic was used to measure the performance of the simulated model.
The supply and demand sides of the sheep and mohair models were solved simultaneously to determine market-clearing prices. The EViews© "Solver" routine was

used to equate supply and demand. The completed systems were then used to analyze the effects of various policy changes on the industries.

Results

The weak separability test failed to reject the null hypothesis that lamb meat should not be part of the meat group at the 0.05 significance level. This outcome suggested that lamb meat demand could be separated from other meats demand for analytical purposes. This implied that a complete demand system approach would not be useful to capture the interdependence relationship among lamb meat and the other meats. Therefore, the demand system approach was not used it this study.

The OLS, 2SLS, and 3SLS models performed fairly well in ex-post simulation. The Theil's U_2 statistics were reasonable for all variables except for lamb and mutton exports, and lamb and wool prices. The OLS model did a better job simulating most of the variables except for lamb slaughter and wool price. Based on these results the OLS model was chosen for further use in policy analysis for the 2004-2008 time horizon.

The policy alternatives analyzed in this study for the sheep industry were three different levels of wool marketing loan rate: scenario 1 had a zero loan rate, scenario 2 had a loan rate of $0.50 per pound of wool, and scenario 3 had a $2.00 loan rate per pound of wool. Results from the ex-ante simulation showed that stock ewe numbers would continue their decrease under all three scenarios, except in the last period, 2008, where stock ewe number increases. However, the rate of decrease from 2005 to 2007 was lower under scenario 3. Under all scenarios, lamb and mutton imports decreased the first year and then increased in subsequent years, but the rate of increase was higher under scenario 1. Wool exports would increase under scenario 3 and decrease under scenarios 1 and 2 compared to the baseline. Under scenario 1, slaughter lamb and wool prices would increase compared to the other scenarios.

The mohair model did not perform well in ex-post simulation. Theil's U_2 statistics were high in all cases except for mohair stocks. Ex-ante simulation showed that goats clipped and mohair stocks will continue to decline through the 2004-2008 time horizon, while mohair exports and prices are expected to increase.

The policy alternatives analyzed for the mohair industry were three different levels of mohair marketing loan rate: scenario 1 had a zero loan rate, scenario 2 had a loan rate of $2.10 per pound of mohair, and scenario 3 had a $6.20 loan rate per pound of mohair. Under scenario 3, goats clipped increased through the whole time horizon, while under scenarios 1 and 2 they decreased. Mohair exports increased under scenarios 2 and 3, but decreased under scenario 1. Under scenario 1, mohair stocks decreased while mohair prices increased compared to scenarios 2 and 3.

Conclusions

The sheep and mohair industries will continue their downsizing trend. Marketing loan payments for wool in the 2002 Farm Bill resulted decline in ewe numbers, except for the last forecasted period, 2008. Moreover, an increase in the marketing loan rate (scenario 3) resulted in reduced decline in ewe numbers compared to the baseline, but will not reverse their downward trend until 2008. Raising the marketing loan rate, form the current level would likely increase the U.S. wool exports. On the other hand, removing or lowering the current loan rate will have a minimal impact on ewe numbers, but will raise lamb imports, and lamb and wool prices. However, eliminating the loan rate would reduce wool exports slightly.

Marketing loan payments for mohair in the 2002 Farm Bill showed a constant negative trend in the number of goats clipped and mohair stocks, while it showed a slight increase in mohair exports and price. Increasing the mohair marketing loan rate will result in an increase in the number of goats clipped and would likely increase mohair exports and mohair stocks. On the other hand, removing the current marketing loan will decrease the number of goats clipped and mohair exports, but will raise mohair prices.

Overall, implementing a marketing loan for wool and mohair in the 2002 Farm Bill had significant effects in the sheep and mohair industry. Even though the marketing loan rate program will not alter the long-term reduction in U.S. sheep and Angora goat numbers, the loan program helps to reduce their negative trend.

Limitations and Additional Research

The biggest limitation of this study was the lack of data to adequately develop the supply and demand for the trading partners, and the mohair industry. Also data limitations contributed to the estimation of the complete 3SLS model, as some equations were deleted from the original model.

Some potential question marks also remain about the baseline projections. Wool exports continue to increase, even though wool production is decreasing. Some of this inconsistency could be explained by the reduction of wool stocks, but the wool export equation had a very strong trend component that increases exports. Moreover, wool price may be too high, as indicated by a 2007 wool price of $1.23 per pound, given a

2004 price of $0.71 per pound. Even though, this increase in wool price is explained by projections of a reduction in domestic and world wool production, wool demand has reached a historic low and no sign of recovery is expected in the horizon.

For modeling the mohair industry, the major limitation was the lack of data for the industry. Moreover, among the limited amount of data, there were some problems with the data, i.e. a large amount of unaccounted mohair, which made it difficult to close the model.

Several future research projects can be identified from this research. One is that lamb production and consumptions are highly seasonable. Lamb production has historically peaked in the spring of each year, due to biological constraints and demand for the Easter holiday. Therefore, a monthly or quarterly model may be more suitable for analyzing the sheep industry.

Second, most of the returns from the industry come from lamb production. Hence, additional research on lamb demand at the retail level should be done to quantify the changes in per capita consumption. Complete demand systems have shown to be more useful at the retail level to measure the interdependence of demand.

Lamb imports are a continuing source of concern for the sheep industry. This analysis indicates an increase of close to 25 percent over the next few years. Further research on lamb imports will be needed to stay abreast of the rapidly changing market place and its impacts on the industry.

Moreover, this study only addressed one policy alternative, three levels of marketing loan rates. Other policy alternatives need to be evaluated such as lamb import restrictions to measure the effects on the sheep industry.

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