An hedonic price model for the national apple market: Implications for Arizona apple growers

Order Number 1342678

An hedonic price model for the national apple market: Implications for Arizona apple growers

Stephens, Virginia Lorraine, M.S.

The University of Arizona, 1990

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

AN HEDONIC PRICE MODEL FOR THE NATIONAL APPLE MARKET: IMPLICATIONS FOR ARIZONA APPLE GROWERS

by

Virginia Lorraine Stephens

A Thesis Submitted to the Faculty of the
DEPARTMENT OF AGRICULTURAL ECONOMICS
In Partial Fulfillment of the Requirements
For the Degree of
MASTERS OF SCIENCE
In the Graduate College
THE UNIVERSITY OF ARIZONA

1990

STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: Virginia Lorraine Stephens

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Eric Monke
Eric Monke
Professor of Agricultural Economics

13 Dec 1990
Date

ACKNOWLEDGMENTS

I would like to thank Shawn, Linda, Connie, Julie, Anne, Dr. Trondstadt, and Pat Jones of the Computer Center. Special thanks is deserved by Dr. Eric Monke who endured the writing of the thesis from beginning to end. His continual encouragement is deeply appreciated.

I would also like to express thanks to Cathy, Mike, my cats (Taz, Priss Ann, and Pooky), Julie, Bobbie, and my parents. But most of all, I would like to thank my husband, Jerry Huthoefer, for trying to understand what it was all about, even when he wasn't quite sure.

TABLE OF CONTENTS

Page

LIST OF ILLUSTRATIONS

LIST OF TABLES

ABSTRACT

An hedonic model of apple prices was developed using data from the three largest producing regions of the United States. Results were used to determine the relative values of selected quality attributes. Specifically, coefficients on the variables produced by the regression represented price premia and discounts for the quality attributes. The variables included in the model were crop year, seasonality, region, variety, size, grade, storage, and a variable designed to measure the impact of the Alar scare on the 1988 crop of Red Delicious apples.

Three models were developed. Model I utilized a linear functional form; Model II utilized a log-linear functional form; and Model III utilized a linear functional form with real price as the dependent variable. The results of Model I were used in the final analysis. It was found that size, grade, storage, and seasonality had consistent relationships to the price of an apple. The findings are applied to the Arizona apple industry.

CHAPTER ONE

INTRODUCTION

This thesis presents an hedonic price analysis of the national apple market. The objective of the study is to provide information useful to the apple growers of Arizona, who are currently struggling to establish themselves as a viable local industry. A time series of apple prices is used to estimate price differentials for selected quality attributes. The analysis is primarily concerned with demand-related factors. Supply of quality attributes is assumed to be inelastic. The results show that several quality factors may be incorporated into long-term plans by apple farmers to gain a price advantage.

A. Highlights of the Apple Industry

The apple is grown in about 35 of the 50 states. Nearly two-thirds of production comes from Washington, New York, and Michigan; Washington alone produces almost half. Between 1965 and 1988, domestic production increased from 6.1 billion pounds to 9.2 billion pounds, an increase of nearly 50 percent. Growth in exports has expanded market opportunities for domestic apple growers; total exports of fresh apples exhibited a 130 percent increase over this same period. The United States remains a large net exporter. Imports of fresh and dried apple products averaged 70 percent of total exports during the period 1965 to 1969; 53.1 percent during the period

1970 to 1979; and 55.6 percent during the period 1980 to 1987 (Agricultural Statistics, 1982, 1989).

The apple has always been widely consumed, but production methods and characteristics of demand have changed greatly over time. Efficient management and technological advances in growing, packing, and marketing, have created economies of scale in an industry formerly dominated by small farmers.

Large-scale production of apples, perfected in the 20th century, has overcome many obstacles. Problems have included grading and standardization, transport of a fragile and perishable product to distant markets, marketing of a consistent-quality product to increasingly aware consumers, large scale assembly, long-term storage for a product harvested within a period of sixty days but marketed throughout the year, and financing of growers producing a single crop at relatively high cost. The number of growers has diminished steadily giving way to larger operations and highly organized cooperatives.

Production patterns are ultimately constrained by consumer demand. The characteristics of demand for apples have changed through time. Today, color, size, and shape are qualities valued by consumers. Before the commercialization of the apple industry, people were more desirous of good tasting and good cooking apples, primarily due to the popularity of cider and the relatively small selection of apples available in any one region. Consequently, appearance was of secondary importance.

B. The Hedonic Method

The method of analysis selected for the study of apple prices has been established as a useful tool for deriving relative values of a commodity's attributes. The hedonic method originated in studies of durable commodities. The first was a study of automobiles by Andrew Court (1929). The technique has been used since then in a wide variety of applications, including automobiles, real estate, employee wages, amenities, price indexing, and agricultural commodities. The principle underlying an hedonic approach is that prices can be analyzed as an aggregate of demands for individual characteristics. A demand exists not only for the product but for the individual quality attributes of the product. The price of a product becomes the sum of the implicit prices associated with each quality attribute.

Court, Griliches, Rosen, and Lancaster are among the prominent contributors to the development of hedonic estimation methods. After Court's early article, hedonic methods were ignored for nearly 30 years. Griliches (1961) and Adelman and Griliches (1961) revived hedonic studies in the 1960's and prompted renewed interest by a number of other authors. In the early stages of the revival, the theory was further developed and its application broadened for use on commodities other than durables. Critics have focused on the choice of proper functional forms, selection of appropriate parameters, and feasibility of the method to explain quality changes under exceptional conditions, such as when qualities are known to change. Nevertheless, the method continues to be used and the theory refined as a practical tool for the study of prices.

Hedonic estimation generally uses linear regression to estimate price premia and discounts associated with a commodity's quality characteristics. If these differentials are stable, they inform growers about the potential advantages of particular production strategies. For example, if a particular quality characteristic of the apple earns a consistent premium above other characteristics, growers could alter production methods to increase the quantity of this quality in the final product. Of course, changes in strategy based on such a result would also depend on the cost of producing more of the quality characteristic.

Hedonic indexes have served various objectives in studies of agricultural commodities. For example, in a study of tomatoes by Jordan, et. al., the results were intended to aid tomato packers in minimizing damage to the tomatoes during transportation. Implicit prices were derived for various handling techniques used in the packing process to determine which methods were the most cost efficient given damage levels and cost of the technique. In another study of wheat, protein levels and their relation to price was analyzed in an attempt to determine optimal protein levels. Other agricultural commodities studied include cotton, rice, malt barley, and lamb carcasses.

C. Purpose of the Thesis

The value of hedonic information for Arizona apple growers arises because the modern industry is highly competitive. Arizona is struggling with the problems of competing with larger and more established regions.

For example, standards for shape and color are currently set by Washington. Washington producers pride themselves on being able to grow an apple that is deep red in color and has a tapered shape with lobes on the bottom. Consumers have associated these characteristics with a good quality apple. Apples grown in Arizona tend to be rounder in shape, less intense in color, and do not have the lobes on the bottom.

Arizona growers need a strategy which would give them an edge in such a competitive environment. Otherwise, prospects for the future do not look bright. Several suggestions have been offered. One involved the establishment of a market niche for Arizona apples. Due to the climate in Arizona, apples test 10 to 15 percent higher in sugar content than apples grown in cooler regions. Arizona is hoping to capitalize on the sweetness factor--something that has not been previously attempted. Hopes are high that the increasingly consumer-aware market will accept it. If they do, the next step is to determine how much consumers would be willing to pay for a sweeter apple, to be sure that the premium can justify the cost of implementing and marketing this strategy.

An hedonic analysis of apple prices may bring to light part of the information required to make such a decision. Eight variables were selected for the hedonic model: crop year, seasonality, region, variety, size, grade, storage method, and a variable designed to measure the effects of the Alar scare on the 1988 crop. Not all variables are related to the physical quality of the apple, but all are influential in determining the price of the apple.

The objective of the study is to determine which quality-related characteristics of the apple, if any, are bringing a premium and which characteristics are bringing a discount. Is there any price differentiation among quality attributes for the apple? Specifically, does one variety possess a significant price advantage over another; or, do consumers place a higher value on an apple grown in a particular region of the country? It is the intention of this thesis to provide an insight into these types of questions.

Chapter Two presents a profile of the U.S. apple industry beginning with a historical sketch and progressing through modern day. Chapter Three presents a review of literature on the hedonic method emphasizing theoretical development and empirical applications. Chapter Four presents the hedonic model of apple prices and the results from the regressions of three versions of the model. Model I utilizes a linear functional form; Model II utilizes a log-linear functional form; and Model III utilizes a linear functional form with real price as the dependent variable. Chapter Five attempts to apply the results from the analysis to the Arizona apple industry.

CHAPTER TWO

PROFILE OF THE APPLE INDUSTRY

> The most important and probably the most widely grown tree fruit in the world is the apple (Smock and Neubert, p. 5).

Prior to the 20th century, apple growing and processing were common activities in the American household. Today, both production and processing are dominated by a small number of large farmers and well-organized cooperatives. The path that the apple has taken in America was greatly influenced by technologies and consumption patterns in Europe, particularly Great Britain. A wild crab apple existed in America long before the colonists first appeared with apple seeds and stocks from Great Britain. The native variety was largely ignored, however, as the colonists gradually developed new and more palatable strains. Unlike many other fruits, the apple was grown widely throughout the colonies and subsequently throughout the United States as population grew and ventured westward.

Development of the apple as an industry began in the 20th century. Although the apple continued to be developed in most of the states, certain areas began to dominate. Technological advances in growing, packing, harvesting, and marketing methods changed a small farm operation into a respected industry. Today, the United States produces over 230 million bushels of apples per year, ranking them the largest producer of apples in the world.

This chapter presents a profile of the U.S. apple industry. The history of the apple, its arrival in America, the development of the modern industry, as well as highlights of the trade and processing sectors, will be discussed.

I. HISTORY OF THE APPLE

Today, the United States produces over 230 million bushels of apples per year. Most of the fruit comes from 35 or more of the 50 states--states which offer a temperate climate, ample moisture and sunlight, well-drained soil, and a winter season during which the trees can rest. The history of the apple is long and colorful. This section begins with its earliest known origin and proceeds through present day.

A. The Ancient Apple

The origin of the apple has been traced back to prehistoric times. Fossil evidence indicates that the first apple was very similar to the European crab apple. Weighing only half an ounce, it has been speculated that the early crab apple increased in size either through multiple cross-pollinations or by cultivation.

The first cultivated apples were grown in the region south of the Caucasus, encompassing the area from the Persian province of Ghilan on the Caspian Sea to the Trebizond on the Black Sea. These early apples were the product of cross-breeding between Asiatic and European crab apples. Carbonized apples of a different species have also been found among the remains of non-Aryan peoples living in Switzerland. This species has been linked to the *Malus sylvestris* species whereas the former is linked to the *Pyrus malus* species. Inhabitants of the Caucasus region--Caucasians, Aryans, and Indo-Europeans--helped to spread the apple as they traveled the world. Dissemination of the apple moved westward; apples did not reach the Far East until after the Middle Ages, when contacts were made with Europe.

> From its early sources it spread wherever man spread; for the apple . . . is a readily adaptable form of life. Its gene pool is rich. It yields to infinite variation, both in fruit and in the adaptability of the plant to climatic conditions (Lape, p. 9).

The Greeks and Romans were instrumental in establishing the techniques of growing apples throughout Europe and Asia. Homer, who lived sometime between the twelfth and seventh centuries B.C., wrote of the apple. Later Greek writers would help to date the apple by including the fruit in biblical songs. The Greeks and Romans regarded the apple as a luxury item because of its smooth texture, sweet aroma and taste, and pleasing effect on the eyes and nose. Because of its appeal to the senses, the Greeks called the apple tree the "bearer of splendid fruit."

Cato made a technical contribution by publishing *De Agricultura*. Written in the second century B.C., the book offered advice on the care of plants, including the apple tree. Many of the procedures described in the book are still used today. Cato described a grafting technique and several methods of propagation. One involved taking cut branches and placing them in the soil so they could grow roots; a second method involved bending the attached branches and burying the ends in the soil (a technique known as layering); and third, a more sophisticated method call air layering.

Pliny also wrote of the apple in *Historia Naturalis,* completed in A.D. 77. One of Pliny's main contributions to the apple cause was his advice on the picking and storage of apples. According to Pliny, the optimal harvest period began after the autumnal equinox, sometime between the sixteenth and the twenty-eighth day of the last moon--or between the last week of September and the first week of October. To avoid decay caused by moisture, Pliny cautioned against picking on rainy days or too early in the morning when dew was present on the trees. For storage of apples, Pliny recommended a cool, dry room with windows on the north side to be opened on sunny days. The floor would be "planked and covered with a layer of close-packed straw or with the chaff from grain. The apples should be laid out in rows, with spaces in-between to allow for air circulation" (Wynne, p. 10). This method of storage was practiced until the advent of cold storage in the 20th century. An additional storage method where the apples were buried in a hole approximately two feet deep with sand in the bottom and covered with an earthenware lid is also in use on a small scale today.

B. The Apple in Europe

The Romans are believed responsible for introducing the apple into England and France (Bultitude, p. 5). However, much of the ancient technology described by Cato and Pliny was ignored by the British. Crop rotation, fertilization, and propagation methods were practiced on a much smaller scale, if at all. Instead, seed-grown trees were the rule. The primary reason for these production practices was the popularity of cider. Apples used for cider do not require as high a quality as dessert apples. In contrast, good eating and cooking apple varieties are propagated by grafting live buds from the original tree to a new seedling or another tree. The fruit from a tree grown from the seed of an apple will produce a fruit different than the apple from which the seed came with no guarantee of like quality.

In Europe, more emphasis was placed on improving varieties. One important technological improvement involved the training of apple trees to trellises, called espaliers. This method required heavy pruning of the tree's branches and then supporting the tree by artificial means. The result was a tree that produced larger apples of a better quality (Wynne, p. 18).

The French also developed a grafting method where apple branches were grafted to the trunk of a wild native variety tree. The result was a smaller tree which bore larger fruit. Less than half the size of a standard apple tree, the tree bore a good crop of full-sized apples, often of better quality than the larger parent. Trellis and dwarf tree technology spread throughout Europe. For England, however, emphasis on quality would not come until the emigration of the Huguenots from France. The Huguenots also have been given credit for helping the spread of apple growing technology in Holland, Switzerland, and America (Wynne, p. 18).

C. The Apple in America

The apple had been in cultivation in Europe for nearly 2,000 years before the colonists arrived in America. Seeds of various European varieties and grafted trees were brought by the colonists. As in England, progress with technological improvements was slow. Until the early 1800's, the majority of all apple trees were seed-grown. As a crop, however, the apple was more important to America than England, particularly in the North.

Initially, apples were primarily used for cider. Part of the reason for the popularity of cider, both in England and later in America, was people's reluctance toward drinking water. Water was associated with disease. Colonists maintained this attitude in the New World, even though the drinking water in America was safe. The colonists focused their efforts on brewing beer and wine (cider is a form of wine), thereby slowing their progress in improving apple farming techniques. Cider was also an important ingredient in many other products, such as cider vinegar, applejack brandy, and various types of crude medicines. The apple was also used to feed livestock and a popular ingredient in many recipes.

The first apple orchard was planted in America around 1625 on Boston's Beacon Hill with imported seeds. Little attention was paid to the native crab apple trees at that time. One of the farmers credited with the first plantings was William Blaxton. In addition to the Beacon Hill orchard, Blaxton also planted the first orchards in Rhode Island. One of Blaxton's legacies is the Blaxton Yellow Sweeting.

Eventually, new high-quality varieties developed from seed. Some early examples were the Roxbury Russet, the Newtown Pippin, and the Rhode Island Greening. The varieties were all in cultivation by the early

1700's. From this time, more advanced methods were practiced. By the end of the 1700's, grafted trees had overtaken the planting of seed trees.

Orchards also reached considerable sizes as the importance of the apple, and population, increased. One particular orchard in Virginia was reported to have some 2,500 trees in cultivation, mainly imported English varieties grafted onto seedling stocks. English imports were the most prevalent at this time as the seeds were easily imported from the motherland. The shipment of live trees and scions was more complicated and expensive. Eventually, the seed trees produced new varieties that were better suited to the climate than any of the English imports. By the early 1800's, the majority of the estimated 100 varieties offered by the professional nurseries were native American trees.

Transport of apples in the early days was very limited and shipment to distant markets was impractical. The exception to this pattern was the use of the Hudson River to transport apples from the upper Hudson Valley to New York City. Otherwise, consumers depended upon local farmers to supply their needs. Consequently, the apple was grown widely throughout the colonies.

During the 1800's, population expanded westward. Because of the colder weather encountered in the northern areas, a search was undertaken for varieties that could withstand a harsher climate. In one effort, imported trees from Russia, northern Germany, and Scandinavia were crossbred with selected American varieties. By the middle of the century, the number of varieties in cultivation in the United States exceeded 500.

From the northeastern districts, apple farming gradually moved westward to Iowa and Ohio. By the middle of the 1800's, Iowa had become an important center for apple research and development. From Iowa, the apple moved further west into Oregon and finally into the northwestern regions of Washington and Idaho. This final push marked the completion of the spread of the apple across America.

During the 1800's, new cities were forming and older cities growing at a very rapid pace. Incomes were also increasing and as a result, demand for all types of fruit increased, creating a lucrative market for the apple industry. One prominent apple farmer at this time was William Coxe of Burlington County, New Jersey. In 1817, Coxe published a book on his achievements in apple farming. His orchard contained nearly every variety grown in America at that time. Along with other serious apple farmers, Coxe was instrumental in making apple production a science (Wynne, p. 27).

The growth and establishment of nurseries was instrumental in shaping the modern apple industry. As one historian states,

> The importance of the early nurseries in the colonies and subsequently in the whole United States cannot be ignored. Not only did they disseminate new varieties of fruits, but they were also the botanical gardens of their day (Lape, p. 18).

The most prominent of these early nurseries was started in 1730. By 1845, the Prince nursery had catalogued 350 varieties. Many commercial orchards were prospering at this time using grafted trees and sorting out higher quality varieties. Through this process, the nurseries asserted a significant influence over production.

Despite the advances made during this century, apple growing remained largely a farm operation. The average farm ranged from a few trees to a few acres,

> with trees being given no intensive care. Spraying was an unknown practice and few trees were fertilized unless it was with barnyard manure. Many if not most of the orchards had livestock grazing in them (Smock and Neubert, p. 3).

Some trade developed during this period, principally with the East and West Indies. Trade with the East Indies probably began early in the 18th century. Transatlantic shipments were not confirmed until 1758 when Ben Franklin received a package of Newtown Pippin apples while in London. By 1773, however, American apples were being shipped to London markets, and by 1821 total exports had reached 68,443 bushels of apples with a value of 39,966 dollars (Smock and Neubert, p. 2).

By the end of the 1800's certain regions had begun to dominate production, although small operations were still prevalent across the United States. A 1900 census reported over 2 million bearing apple trees--nearly 2-1/2 times the number reported in 1935 (Smock and Neubert, p. 3).

II. THE APPLE IN THE 20TH CENTURY

> The development of the apple by man in the twentieth century has been partially a retrogression. This is a strange paradox, for exactly in this time the breeding of new varieties of apples has been taken over from chance to scientific planning. The trouble is that the breeding programs have been geared almost completely to commercial interests (Lape, p. 25).

The 20th century witnessed the growth and development of fruit farming as an industry. As cities grew larger, farmers were forced further away from the urban areas. Transportation became an important factor. Gradually, smaller farms disappeared. Larger operations were better suited to new technologies, such as cold storage and modern trucking. These two innovations narrowed the number of varieties grown commercially to a select few. Better storage and more efficient transportation allowed farmers to choose varieties which produced consistent quality and the greatest and most reliable yields.

Innovations in production and marketing led to further changes on the supply side. Nurseries began to organize and consolidate. As these large regional nursery firms evolved, they asserted an increasing influence over the types of trees grown. Nurseries promoted those varieties which they favored and whose propagation they controlled.

A natural progression in the narrowing of varieties grown was taking place. First, farmers were interested in specialization, a tendency that was further encouraged by the consolidation of nurseries. On the demand side, canneries and later, supermarket chains, narrowed the market further by restricting their purchases to varieties popular with consumers. From a high of nearly 1,000 varieties cultivated in the 1870's, there existed only about 100 a century later.

The qualities desirable in the selection and improvement of a variety are tolerance to refrigeration, shipping qualities (the bruising factor), color or appearance, and yield. Taste has been less emphasized as a marketable quality. As a result, current varieties are considered inferior in sharpness of taste and varietal selection when compared to their ancestors.

The justification given by producers is that current production costs allow production only of guaranteed sellers. Technological change has become conservative, focusing on improving currently existing and popular apple varieties rather than the development of new strains. One example is the extensive time and research that has been undertaken to deepen the color of the Red Delicious apple.

Before apple processing became a commercialized operation, canning, freezing, drying, and other processing activities were practiced initially on farms and in households. Growth of the commercialized processing industry was a natural outcome of the localization and concentration of the apple growing areas, that took place during the turn of the century. This situation created the perfect conditions for the development of large scale processing centers. Increased production of apples and an increasing percentage of low-quality apples provided a concentrated source of low-cost fruit.

Processing provided ways to dispose of large quantities of low grade fruit and to absorb surpluses during years of high production. Products differ from region to region, including canned, dried, and frozen apple products, juice and cider, vinegar, applesauce, jelly and jam, apple butter, mincemeat, and fresh fruit slices. Cider is the most popular product produced by processors on a national level [See Table 2.2]. Table 2.1 shows total production, total quantities processed, and quantities processed as a percentage of total production for crop years 1982 through 1988:

(Table 2.1)

U.S. APPLE PRODUCTION AND QUANTITIES PROCESSED
1982 - 1988
(Million lbs.)

Year	Total Production	Total Processed	Percent of Total Production
1982	8,110.0	3,549.6	.42
1983	8,314.5	3,682.4	.45
1984	8,285.5	3,593.7	.43
1985	7,949.0	3,627.6	.46
1986	7,891.0	3,302.7	.42
1987	10,542.6	4,620.2	.46
1988	9,157.5	3,844.6	.42

Source: Agricultural Statistics, 1982-1988

From these figures, it is clear that processing plays an important role in the apple industry. For the period 1982 through 1988, nearly half of all apples produced were sold to the processing sector.

Table 2.2 describes the pattern in processed utilization for the United States for years 1982 through 1988.

(Table 2.2)

PROCESSED UTILIZATION FOR THE UNITED STATES
1982 - 1988
(Million lbs.)

Year	Frozen	Dried	Other*	Canned	Juice/ Cider
1982	190.8	223.9	116.3	1,245.5	1,773.1
1983	169.6	258.3	93.4	1,209.8	1,951.3
1984	198.1	303.6	95.8	1,179.8	1,816.4
1985	194.3	24.24	73.9	1,255.4	1,842.1
1986	257.3	199.4	90.9	1,179.0	1,648.9
1987	248.8	283.8	73.2	1,289.6	2,924.8
1988	275.7	285.0	66.7	1,399.1	1,818.1

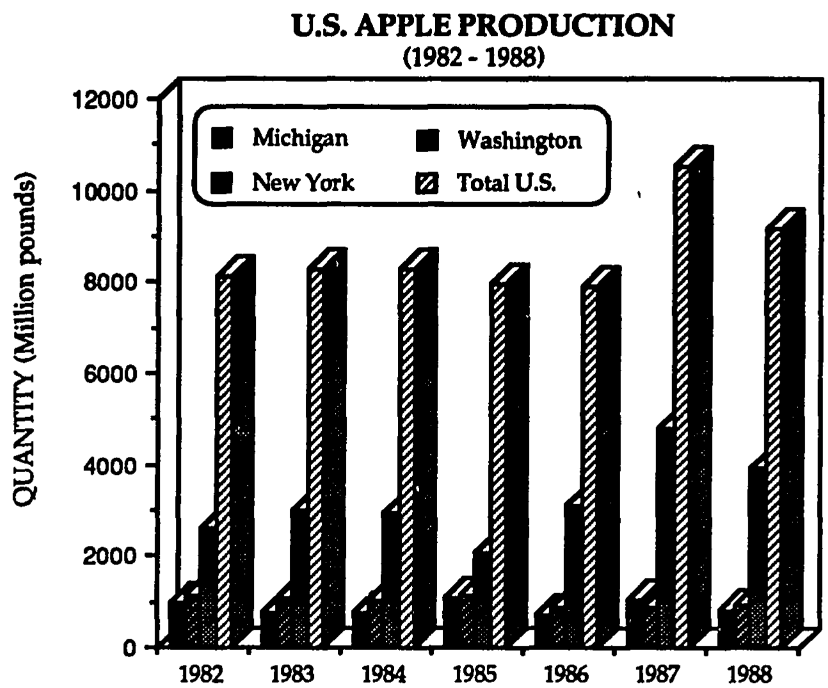
*Other includes jam, vinegar, fresh slices, wine
Source: Agricultural Statistics, 1982-1988

The major processing categories are frozen, dried, canned, juice and cider, and a miscellaneous category which includes jam, vinegar, fresh slices, and wine. For the sample period, juice and cider products have consistently led the production of other processed products by a large margin.

III. U.S. PRODUCTION AND FOREIGN TRADE STATISTICS

Figure 2.1 contrasts the growth and production levels of the top three apple producing regions against total U.S. production for crop years 1982 through 1988:

(Figure 2.1)



Source: Agricultural Statistics, 1988

The 1988 crop year shows production at 9,157.5 million pounds, an increase of 13 percent over the beginning of the period. Average U.S. production for the period is 8,607 million pounds. Michigan, the third largest producer of apples in the United States, averaged 883 million pounds for crop years 1982 through 1988, and New York, the second largest producer, averaged 1,008 during this period. Washington, the largest producer, averaged 3,200 million pounds, which represents approximately 40 percent of total U.S. production over this period. Together, these three regions account for 60 percent of total domestic production.

In the international arena, the United States ranks fifth in the export of apples, sixth in imports, and eleventh in per capita consumption. The top apple exporter is France, followed by Hungary and Italy; the top importers are West Germany and Great Britain; and Austria leads the world in per capita consumption with 50 kilograms per capita. The United States averages 17.9 kilograms per capita (Apple News, p. 8).

Table 2.3 shows trade statistics of the United States for crop years 1980 through 1987:

(Table 2.3)

U.S. APPLE TRADE: 1980 - 1987
(Year beginning October)
(Million pounds)

Year	Imports	Exports	Net Trade
1980	169	703	+534
1981	283	612	+329
1982	218	613	+395
1983	278	530	+252
1984	292	473	+181
1985	336	337	+1
1986	329	409	+80
1987	292	670	+378
Average:	275	543	+268

Source: Agricultural Statistics, 1988

U.S. trade in fresh and dried apples over the 1980 through 1987 period has established the United States as a large net exporter. The trade year 1985 is the only year in which imports neared the export total; otherwise, exports have exceeded imports by an average of 268 million pounds or 97 percent.

IV. PROFILE OF THE LARGEST PRODUCING REGIONS

Although the apple is grown widely throughout the United States, certain regions have come to dominate. The top three producing regions in the United States are Washington, New York, and Michigan. Climatic and geographical conditions have been the most important factors in starting the industry. Efficient organization and management by apple cooperatives and growers have helped to create economies of scale, solidifying their market position. Growing, harvesting, and packing methods in these areas represent the leading edge of technology in this dynamic industry.

A. Michigan

Apple cultivation began in Michigan over 150 years ago. In a manner very similar to the growth of the apple industry in most of the United States, the apple initially was grown throughout the state. However, the area bordering the east side of Lake Michigan eventually developed into the state's primary producing region. This area has come to be known as the "Fruit Belt of Michigan."

One of the most attractive features offered by Michigan is its climate. Apples need a cold winter dormant period, late frosts to allow the apple blossoms to properly grow and pollinate, and protection against early freezes to permit late varieties to mature. The lakes of Michigan help provide these conditions.

Well-developed transportation systems have also contributed to the industry's growth. Initially, waterways provided sufficient access to nearby markets. Later, the construction of superhighways and advances in both trucking and rail transportation replaced water transport as the primary mode of transportation. This also created access to otherwise unreachable markets. These advances contributed tremendously to the ultimate growth of the apple industry in Michigan.

The major varieties grown are the Red Delicious, Golden Delicious, McIntosh, Jonathon, Rome Beauty, Cortland, Empire, and IdaRed. Jonathon is the specialty apple; Michigan leads the country in production of this variety. A large percentage of Michigan's apple crop goes to processing. Recent estimates place this figure at over 50 percent; further increases are expected if the industry continues to grow. The major processed products include applesauce, canned and bottled juices, and frozen apple slices.

B. New York

The oldest apple producing region, New York's industry contains two major producing regions: Western and Eastern New York. The Western region is responsible for approximately 70 percent of the state's total production (Anderson, p. 9). Whereas apple production has remained relatively constant, both area and the number of growers has declined considerably. McIntosh is the dominant variety grown in the state and is most important for the Eastern region. McIntosh is followed by Red Delicious, and other important varieties include the Rhode Island Greening, Rome, and IdaRed. New York has responded to the renewed interest in the fresh market by increasing the state's cold and controlled atmosphere storage capacity.

Processing also plays an important role in the state's apple industry, particularly in the Western region. Major processed products include apple sauce, apples for freezing, pie filling, and apple cider and juice. The processing sector in New York is characterized by economies of scale and industry consolidation except for the juice and cider processors which are relatively small in size. During the period 1970 to 1987, the number of plants engaged in the production of apple cider and juice fluctuated significantly. Apple sauce has shown the most consistent production over the period (Anderson, p. 14).

C. Washington

> The boxed apple of the states of the northwest is recognized by experts to be one of the most efficiently marketed of all crops (Maynard, p. v.).

Since the commercialization of apples on a national scale, the Washington area has led the country in total production. As early as 1921, Washington was producing over half of all commercially sold apples. The development of the northwest states as a leading apple growing region began in the early 1900's. In 1910, the Hood River Valley of Oregon became the first successful apple growing operation in the West. The Washington districts of Wenatchee and Yakima Valley began extensive planting shortly thereafter. The three main apple producing areas in Washington are the Wenatchee district, the Yakima region, and the Columbia Basin region located in the southeastern portion of the state. Red Delicious, Golden Delicious, and Granny Smith are the most widely grown varieties in the state with Red Romes and Winesaps rounding out the major varieties. Together, these regions produce between one-third and half of the nation's total crop.

Production, packing, and marketing technologies are unequaled. Apples are the state's most important agricultural economic activity, and the large cooperatives are a powerful force in both industry and the political arena. In retail markets, prices of Washington apples are often considered the standard for all others. In politics, the Washington apple growers influence key decisions on issues affecting the apple industry.

Because of the organization of Washington growers, concentrated efforts have been made to promote and advertise their product. Other regions are not able to do this as successfully because growers are less well-organized. One recent example is the approach Washington has taken to remedy the situation caused by the Alar scare. In an aggressive public relations effort, the Washington Apple Commission held press conferences in Los Angeles, San Francisco, Chicago, New York, Washington, D.C., and Seattle as well as making radio and television appearances to deliver the message that the Washington apple industry responsibly uses chemicals. In meeting with the press, the Washington Apple Commission emphasized that Alar was no longer used and that Washington growers had been limiting usage for the past twenty years. An additional topic concerned the promotion of quality in an attempt to create "brand awareness" of Washington apples versus apples from other regions (Washington Apples, p. 6C-8C).

V. CURRENT TRENDS

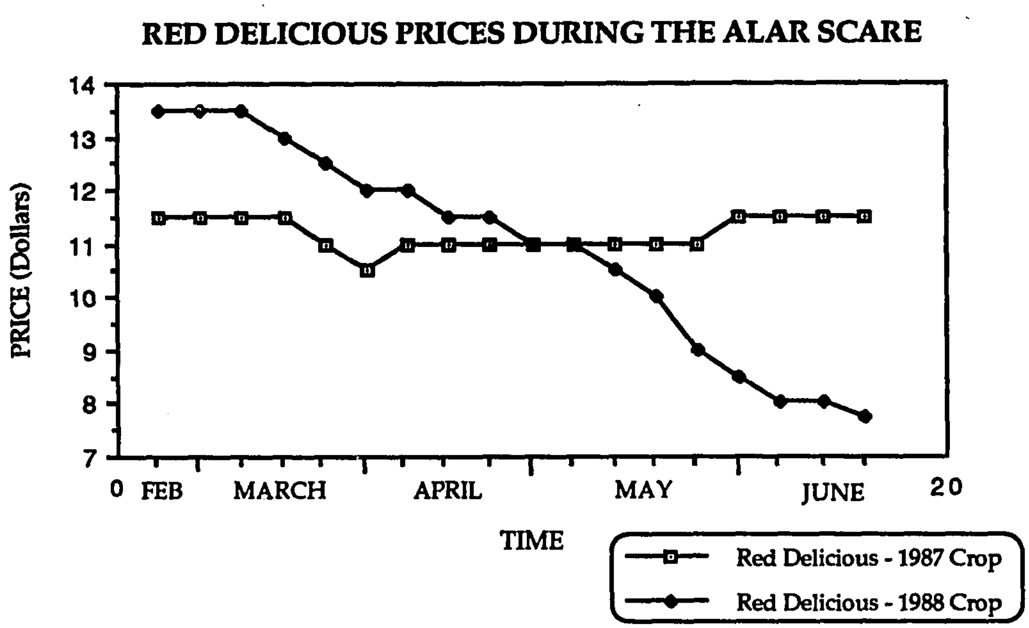
The future of the country's apple industry will reflect efforts to keep abreast of changing consumer tastes and regulations. Potential areas of activity include pesticide and chemical use, refinements in grading standards to reflect renewed interest in quality over appearance, increasing demand for processed products and pick-your-own operations, and the possibility of labor shortages, because apple harvesting is a labor-intensive activity.

A. Chemical Use

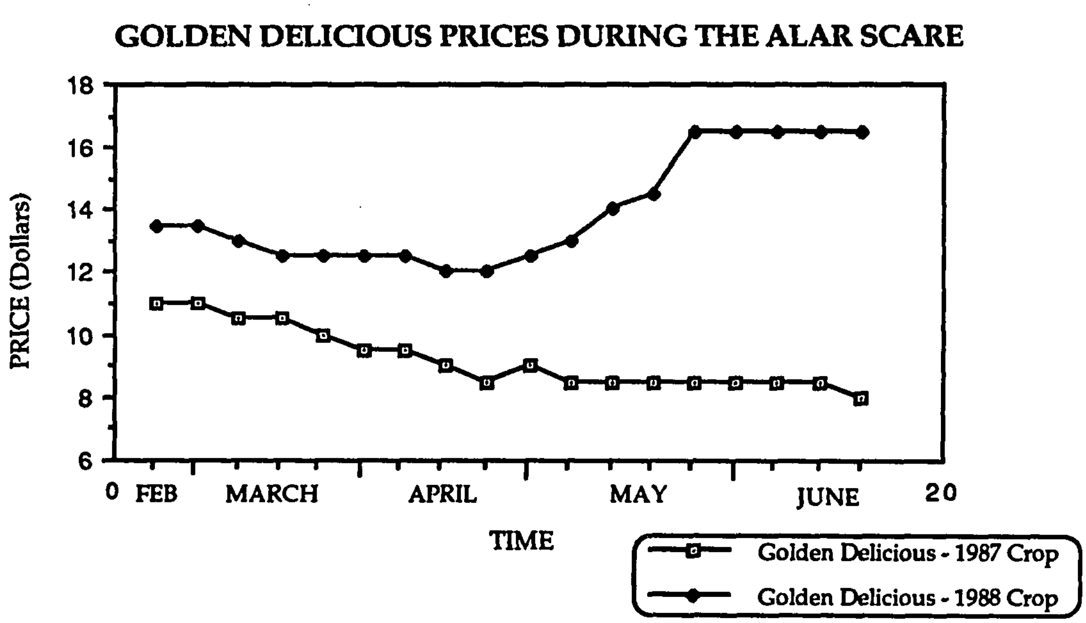
The 1989 Alar scare--a consumer scare prompted by the discovery and media hype that potentially dangerous chemicals were being used on apples--caused increased awareness by consumers of the use of pesticides on fresh fruit.

To illustrate the effects of the Alar scare on the U.S. apple industry, Figures 2.2, 2.3, and 2.4 contrast the prices of two consecutive crop years for Red Delicious, Golden Delicious, and Granny Smith apples:

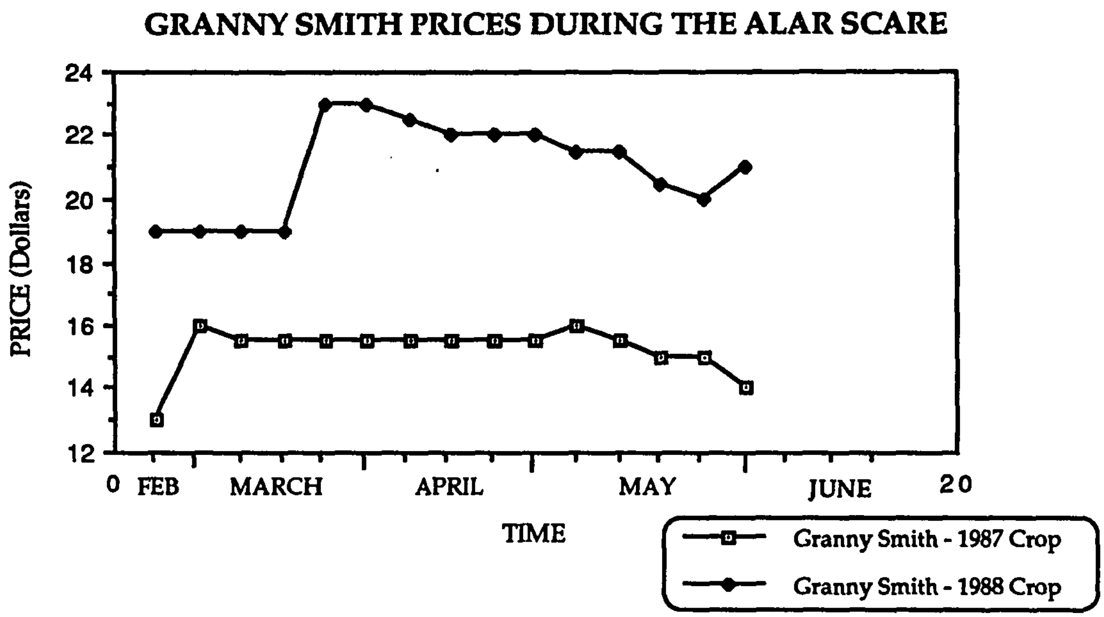
(Figure 2.2)



(Figure 2.3)



(Figure 2.4)



Source: USDA Agricultural Marketing Service, Fruit and Vegetable Division. "Apple Prices and Shipments," June 20, 1989

The first year, 1987, represented a typical marketing season for the apple industry and extraordinary external events were absent. Concerns over Alar use on apples surfaced in early 1989. By this time, the 1988 crop was mid-way through its marketing season. Figure 2.2 contrasts the 1987 and 1988 weekly crop prices for Red Delicious. 1988 crop prices began strong, bringing two dollars more per box over the previous year. In March, the Alar scare began to influence the apple market and Red Delicious prices began to drop. From March to the end of the season in June, Red Delicious prices dropped by six dollars--almost 50 percent. Normally, Red Delicious prices remain relatively constant over this period as shown by the 1987 price line.

Figure 2.3 shows the movement of Golden Delicious prices during this same time period. As with Red Delicious, Golden Delicious prices were higher in the marketing season of 1989 than in 1988. However, unlike Red Delicious, Golden Delicious prices increased over the rest of the season. Figure 2.4 shows Granny Smith apple prices. Like Golden Delicious, Granny Smith also experienced an increase in prices over this period. In the weeks that Red Delicious began its decline, Granny Smith prices jumped by four dollars, maintaining a relatively steady price over the rest of the season.

Clearly, the Alar scare most affected Red Delicious prices. Demand shifted from the most widely consumed variety, which consumers associated with Alar use, to the secondary varieties. As this occurred, prices for these other varieties increased.

In a reversal of research direction, the industry is now trying to curb the use of synthetic chemicals and pesticides. Large scale operations are highly dependent on chemicals to help modify vegetative growth, fruit firmness, fruit color, flower bud initiation, fruit thinning, fruit drop, and scald development (Carlson, et. al., p. 188). In Washington, some of the changes include the growing of organic produce, computer monitoring and analysis of insect populations to determine optimum times to apply chemicals, stricter quality-control programs that test incoming apples for chemicals, a reduction in the use of post-harvest chemicals, and increased emphasis on the search for biological means of restricting insect damage.

Ironically, the situation may present an opportunity for farmers to reduce their costs and increase profits, as chemicals are a major cost in the production process. Reduction of chemical use was not attractive for growers in the past because certain levels of application were required to produce qualities that consumers desired. Since tastes are now changing, indications are that consumers may be more willing to purchase an apple that is not deep red in color in exchange for the assurance that the fruit is pesticide-free.

B. Grading Standards

Another trend in consumer taste has been the resurgence in demand for a better-tasting apple instead of a better-looking apple. Although retailers continue to desire an apple that is 90 percent to full color, expectations are that the consumer will seek out quality over appearance in the future. The Washington apple industry has introduced "minimum firmness standards for all apples shipped out of the state" (Warner, p. 4c). Effective for the 1989/90 crop, this standard is intended to prevent over-mature apples from reaching consumers. Prior to this, requirements for firmness applied only to Fancy and Extra Fancy grades and softer apples were shipped under the U.S. No. One grade, also known throughout the industry as the "escape grade."

Historically, apple grades were based solely on the color of the apple. Consequently, apples were harvested later than required, resulting in a softer product. With the new standard and the ban on Alar, which helps deepen the color of the apple by regulating its growth, growers may have to sacrifice color for firmness. Under ideal climatic conditions (cool evening temperatures before harvest), growers obtain firmness and good color naturally.

C. Labor

One major problem in production is the availability of qualified harvest workers. Labor costs will increase as growers compete with similar industries for competent help. As a result, continued emphasis will be placed on the development of techniques that reduce harvest labor requirements and increase mechanization. Current research is focusing on shake and catch systems for the processed apple market, modification of tree form and more attention to pruning methods to minimize bruising of apples harvested in shake and catch operations, platform and conveyor harvesting, the addition of lights at night so that workers can pick around the clock, and the development of mechanical pruners (Carlson, et. al., pp. 195-196).

Aside from choosing the varieties to plant, three options are available to growers: fresh, processed, or pick-your-own operations. The fresh fruit market will probably remain stable in the future, however, opportunities in both the processed market and pick-your-own operations are expected to show added strength.

VI. CONCLUSION

From a modest beginning, the American apple industry has developed into a respected industry on both the domestic and international level. This chapter has provided some insights into the history and growth of the industry in the 20th century. In addition, highlights of the trade and processing sectors, the 1989 Alar scare, and current trends were discussed.

Three states have emerged to dominate the others in apple production--Washington, New York, and Michigan. Together, these states account for about two-thirds of total U.S. production, with Washington producing almost half. Processing remains an important market for apples, utilizing about 40 percent of all apples grown. The foreign sector has also been an important outlet for U.S. apples with the United States consistently recording a positive balance of trade.

The Alar scare of 1989 caused some concern in the industry. During the months affected, prices for Red Delicious apples dropped significantly, although the prices for other major varieties performed well. With this exception, it appears that the apple industry has established a permanent niche for itself in the United States.

Trends for the future include a shift in focus to emphasize taste. Prior to the 20th century, taste rather than appearance was the determining factor in the success of a particular variety. As the industry became increasingly commercialized, less attention was paid to taste and more to appearance, such as color and shape. Now, the industry is trying to change certain growing practices in response to consumer demand for a better-tasting apple. Consumers have also been instrumental in prompting the industry to reduce its use of chemicals--an issue that has snowballed since the Alar scare. Other changes involve improving various production methods, particularly in the area of labor. Although the industry is highly modernized, the picking of apples continues to be a labor-intensive process.

Keeping abreast of consumer tastes can be difficult for an industry which must plan shifts in production strategies years in advance. Control over what is produced is increasingly becoming a consumer decision, putting many growers in a defensive and vulnerable position. The apple industry has come a long way since its start as a source of cider and ingredient in favorite recipes. As one of the leading fruit industries in the United States, the future will remain bright for those growers who can keep abreast of the latest technological advances and consumer trends.

CHAPTER THREE

A REVIEW OF HEDONIC ESTIMATION TECHNIQUES

Hedonic pricing models were developed as a way to estimate implicit prices for quality attributes of a particular good or service. Development of the theory has been attributed to Andrew Court. In an article published in 1939, Court noted the inability of the U.S. Bureau of Labor Statistics (BLS) to measure and interpret price changes over time in the automobile industry. Court suggested three methods of price comparison to correct the problem: overlapping series, the use of averages with broad definitions, and finally what he termed price-specification comparisons, or hedonic pricing. While the latter method had been used prior to his study, his application was the first for a complex product such as the automobile.

This chapter provides background and support for the application of hedonic pricing techniques to the analysis of apple prices. After a brief definition, this review of the literature explores the theoretical foundations for hedonic pricing, highlights common applications of the technique, reviews recent technical studies on the subject, and closes with a look at some empirical studies using agricultural commodities.

I. DEFINITION

The term hedonic was suggested by Alexander Sachs and represents "price comparisons which recognize the potential contribution of any commodity . . . to the welfare and happiness of its purchasers and the community" (Court, p. 107). In a recent publication, Thompson (1987) stated that hedonic price regression has been a popular method used in the "investigation of the pricing of durable goods . . . The approach assumes that the price of a brand/model of a good is a function of the observable attributes embodied in it" (Thompson, p. 374-75). Willig (1978) described the purpose of hedonic price indexes as an "attempt to measure real rates of inflation, with changes in commodity qualities controlled for by the substitution of pure rates of price change for the actual ones" (Willig, p. 277). In an earlier article, Rosen, who published a major work on hedonic pricing and implicit markets stated

> a class of differentiated products is completely described by a vector of objectively measured characteristics. Observed product prices and the specific amounts of characteristics associated with each good define a set of implicit, or 'hedonic' prices (Rosen, p. 34).

To illustrate the concept of a hedonic index, suppose the same basket of goods is compared in two time periods. The hedonic price index shows how much more the average consumer would have to pay in the base period to obtain a basket of goods identical to the one purchased in the base period, given the qualities available in the present period. Whether the technique is applied to consumer durables or to agricultural commodities, the concept of hedonic pricing is the same. The technique is based on the assumption that purchasers of a good have a demand, not solely for the product, but for the bundle of characteristics it embodies.

II. THE HEDONIC MODEL

Court's effort was revived more than two decades later in an article written by Zvi Griliches (1961). In this paper and a related work by Griliches and Adelman, hedonic price indices were used to correct for quality-induced changes in prices. Both articles used automotive examples to demonstrate the point that price indices failed to adequately incorporate the full effect of quality change over time. This oversight caused index measures to overstate the rate of inflation.

Before the publication of these articles, three methods were used to adjust for quality changes in BLS price indices. The first involved breaking a commodity down into as many separate products necessary to sufficiently reflect quality differences, and then to treat each individual product as a separate entry in the index. The second technique required the observation of one or several narrowly specified types of a product over time for as long as possible. When one type disappeared from the market, another was put in its place. The price of the new variety was then spliced into the index, assuming neither price nor quality had changed. The third method involved changing the notation for the basis of price or quantity from the unit of sale to a unit which more accurately reflected its intrinsic quality (Adelman and Griliches, pp. 535-537).

Adelman and Griliches, noting Court's work, suggested constructing a hedonic price index in conjunction with a chaining procedure. The multiple-regression chain-index technique allowed derivation of the implicit prices for particular quality attributes[1] such as horsepower or the presence of an automatic transmission, from cross-sectional data. This information allowed prices of an item to be adjusted for changes in specifications over time. As Griliches explained,

> One can interpret the procedure as answering the question of what the price of a new combination of qualities of a particular commodity would have been in some base period in which that particular combination was not available, by interpolating or extrapolating the apparent relationship of price to the specifications for models or varieties of the 'commodity' that were available in that period (Griliches, 1961; p. 174).

Griliches observed that most commodities are sold in a wide array of varieties and models. At any point in time a population of prices can be observed, where price becomes a function of embodied characteristics:

$$P_{it} = f_t\,(x_{1it}, x_{2it}, \ldots x_{kit}; u_{it})$$

where
- P = price
- i = index of varietal designation
- t = time period of observation
- x = set of characteristics
- u = the disturbance term

[1]The terms "attribute," "characteristic," and "quality" are used interchangeably throughout the paper. No difference in meaning is suggested by the use of any one term.

Given a sufficient number of observations, dummy variables could be used to derive the average contribution of the characteristic to the price of the item. For qualities that were difficult to measure, such as size or capacity, a proxy dimension could be specified, such as volume or weight. After having estimated such equations, "instead of adjusting the prices or price indexes directly, we can first define an index of quality change and use that to adjust the official indexes" (Griliches, 1961; p. 176).

Some limitations of the technique were also noted. The first concerned the effect of shifts in supply and changes in tastes on the relative prices of characteristics. In this case, Griliches observed "we are back to the classical index number problem of changing weights" (Griliches, 1961; p. 190). As a solution, Griliches suggested reducing the time span of the comparison, computing base and end period weighted indices, and hoping that prices are not too far apart. The second problem noted by Griliches involved the use of proxy variables. In many cases, a proxy variable may not accurately represent the quality characteristic. For example, weight may be a good indicator of size, but its relationship to price may involve factors additional to size. Furthermore, the relationship between the proxy variable and the qualities it represents may change over time. Careful observation and knowledge of the market are needed to avoid pitfalls.

A number of authors elaborated on Griliches' work concerning the inability of price indices to reflect quality change. In a study of refrigerator and freezer prices, Burstein (1961) developed an approach to hedonic pricing based on information about second-hand markets. Burstein restated the quality change problem in terms of a durable good's service stream. Noting that the service yield of a durable good is multi-dimensional in character, he described the situation where long-run comparisons of two goods will exhibit "mixed changes" in their service vectors so that "the longer is the interval separating the points in time for which comparisons are desired the less likely is it that we can find substantial numbers of models that are identical. And this . . . is the quality problem" (Burstein, p. 268).

The use of second-hand market prices[2] to construct hedonic price indices is simple and offers some practical solutions to problems that arise when measuring quality change in the new source market. Burstein was one of the first to use second-hand market prices in an empirical application. As Burstein stated, "It is impossible to discuss problems of measuring price changes of durable goods without introducing second-hand markets" (Burstein, p. 272).

Cagan (1965) also expounded on the theory of using second-hand market information. One distinct advantage is that prices tend to more accurately reflect consumer preferences and evaluations of the goods when prices are not influenced by manufacturers. Also, because the supply of characteristics are exogenous, certain statistical problems are avoided in price studies. The primary drawback, as Cagan pointed out, is the depreciation factor. The underlying assumption is that any quality change (improvement

---

[2]Due to the nature of perishable commodities, the use of second-hand market prices does not apply to the apple industry. However, work on second-hand market theory in the context of hedonic analysis continues to grow in importance.

or decline) depreciates at a rate equal to the product as a whole, so that the value of the quality change remains proportional to the market price over the life of the product (Cagan, p. 218). However, the depreciation rate is often difficult to estimate and does not necessarily follow this rule. Nonetheless, Cagan asserted that the use of second-hand prices can be an effective method with which to provide an "independent check on the accuracy of the hedonic index" (Cagan, p. 220).

Burstein also elaborated on the depreciation problem in using second-hand market information. In an example using refrigerators, he explained the depreciation problem in a different light. Comparing a newer, improved model to a model of the same maker produced one year earlier, he found that the price of the second-hand version can fall below the supply price of the newer model by an amount larger than just the estimated depreciation rate. He stated

> cost conditions in the new-source market prevent this change in relative price from being reflected in supply prices of new output. The failure to consider second-hand price quotations might give inordinate weight to the market transactions of those with strong prejudices against second-hand machines (Burstein, p. 273).

In other words, there may exist a discount, other than just a depreciation factor, that can cause the price of the used model to be lower than the new model. This discount is difficult to estimate and can undermine the merits of using second-hand market prices.

In 1966, Lancaster introduced a new approach to consumer theory which would contribute significantly to the research on hedonic pricing. Lancaster asserted that utility is derived from the properties or characteristics of the good rather than the goods themselves. "Utility or preference orderings are assumed to rank collections of characteristics and only to rank collections of goods indirectly through the characteristics they possess" (Lancaster, p. 133). The assumptions underlying the model were threefold: first, goods possess characteristics which give rise to utility; second, a good possesses multiple characteristics and many characteristics will be associated with more than one good; and third, a collection of goods may possess characteristics different than those possessed by any one good separately. These assumptions gave rise to a fixed proportion (in characteristics) consumption function which according to Lancaster "is many times richer in heuristic explanatory and predictive power" than the traditional model (Lancaster, p. 154). With this in mind, Lancaster developed the following relationships:

$$x_j = \Sigma_k a_{jk} y_k$$

or, in matrix notation: $x = Ay$

where

x_j	is the jth good
k	is the individual activity (characteristic)
y_k	is the level of the activity (quantity of characteristics)
a_{jk}	is the technical coefficient determined by the intrinsic properties of the goods themselves
$x = Ay$	represents the vector of total goods required for a given combination of characteristics

and:

$z_i = \Sigma b_{ik} y_k$ or, in matrix notation: $z = By$

This relationship assumes that each characteristic, k, produces a fixed vector of characteristics, where z_i is the amount of the ith characteristic and b_{ik} is an objectively determined technical coefficient for choices between z_i's.

The relationship between the collections of available characteristics (the z vectors) and the collections of goods available to the consumer (the x vectors) was not a direct one as in the traditional model, but indirect through the activity vector, y. Lancaster then developed the following simplified nonlinear maximization problem:

$$\begin{aligned} &\text{Max } u(z) \\ \text{s.t.} \quad & px \leq k \\ & z = Bx \\ & x,y,z \geq 0 \end{aligned}$$

The four parts of the model are the maximand, u(z), where u is defined in characteristics space; the budget constraint, $px \leq k$ which is defined in goods space; the system of equations, $z = Bx$ which represents a transformation between goods and characteristics space; and finally the non-negativity constraints.

Applying the model, Lancaster described two techniques. First, using the utility function and the budget constraint for indifference curve analysis, the utility function is transformed into goods space and related directly to the budget constraint, or, the budget constraint can be transformed into characteristics space and then related directly to the utility function. Both are useful under different circumstances, but the primary role of the model centers on the $z = Bx$ equation and "the structure and qualitative properties of the matrix B" (Lancaster, p. 137), which represents consumption technology and more importantly, consumer behavior. Lancaster then used his model in various traditional applications including substitution effects and revealed preferences; objective and subjective choice and demand theory; labor, leisure, and occupational choice; consumer durables, assets, and money; new commodities, differentiated goods and advertising; and general equilibrium and welfare analysis.

In 1974, Sherwin Rosen published an article which would "become a starting point for serious efforts to implement hedonic price models" (Murray, p. 327). In "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," Rosen strengthened and applied the theory of hedonic pricing to the "economics of spatial equilibrium in which the entire set of implicit prices guides both consumer and producer locational decisions in characteristics space" (Rosen, p. 34). Choices by buyers and sellers and market equilibrium were examined, and their implications for hedonic price regressions and the construction of indices were discussed.

Earlier work concentrated on a product's utility-bearing characteristics. The theory was based on the assertion that consumers are also producers and that goods, by themselves, do not provide utility. Rather, goods "are purchased as inputs into self-production functions for ultimate characteristics" (Rosen, p. 36). In contrast, Rosen developed a theory where producers package their products in such a way that the final product embodies characteristics in combinations desired by consumers. Producers then earn a rent for serving this intermediary function.

Rosen's primary goal was to create a mechanism for generating observations in a competitive environment and to use this structure to clarify the meaning of estimated implicit prices. Rosen found that price data generally held less information than was commonly supposed, although the suggested method did help to identify the underlying structural parameters. The basic form of Rosen's model is as follows:

$$P_i(Z) = F_i(Z_1, \ldots Z_n, Y_1)\text{: demand}$$

$$P_i(Z) = G_i(Z_1, \ldots Z_n, Y_2)\text{: supply}$$

where the $P_i(Z)$ is the implicit market price for attribute Z_i. In a two-step procedure, a hedonic price function was estimated which resulted in a "family of value functions whose envelope is the market hedonic or implicit price function" (Rosen, p. 40). The estimated implicit prices for these attributes were then used to estimate the demand elasticities for these characteristics. The function P(Z) is identical to a hedonic price function. The market clearing prices given by P(Z) are determined by the distribution of consumer tastes and producer costs. However, Rosen stated that estimated hedonic price characteristic functions could not be used to identify the structure of consumer preferences and producer technologies that generated it. The reason put forth by Rosen was that price differences are equalizing only on the margin--not on the average--in most cases, and that these differences typically identify neither demand nor supply. The price differences Rosen refers to is specifically those differences among goods which are recognized as equalizing differences for the alternative packages they embody.

Instead, Rosen described a "feasible econometric procedure for estimating the underlying generating structure . . . through the use of derivative transformations" (Rosen, p. 54). When constraints are nonlinear (as is the budget constraint in this case), Rosen stated that marginal prices can be used in lieu of average prices. Econometric estimation of the "compensated" functions allows the derivation of measures of both consumer and producer surpluses.

Although development of the hedonic pricing theory has focused primarily on consumer durables, the same concept can be applied to perishable commodities, such as apples, as well as to goods such as real estate, and less tangible goods that are service-related. In fact, many of the theoretical complications that arise in the hedonic modeling of consumer durables, such as depreciation rates, are not present in the modeling of nondurable commodities. Nonetheless, the evolution of hedonic pricing would not be completely understood without close analysis of its connection to consumer durables.

III. CRITICISMS AND MODIFICATIONS OF THE HEDONIC MODEL

Since the early 1960's, hedonic pricing has maintained a steady following. The application of hedonic price models to consumer theory became an especially popular topic during the 1970's and 1980's. Dhrymes (1967) examined the feasibility of using the hedonic method suggested by Court and Griliches for correcting price indices with respect to quality changes. Dhrymes concentrated on the question of homogeneity in the prices of various automobile manufacturers. In an industry dominated by three manufacturers, he stated that

> it would be inadmissible to estimate the pricing equation from a single cross-section, in which several manufacturers are represented. Rather we should estimate each manufacturer's decision rule separately (Dhrymes, p. 501).

A second problem is that "it is still not possible to include in the measurement of quality, the durability, or frequency of repair record, or the economy of operation of an automobile or a refrigerator, due to lack of data" (Dhrymes, p. 501).

Dhrymes concluded that the methods advocated by Court and Griliches can be difficult to apply on a routine basis, because pricing equations for manufacturers are not always homogeneous and because the values of the parameters for these equations can vary significantly over time. For example, weight may represent a quality that retains a positive coefficient and is significant for one producer in a sample year. Yet the next year, weight could prove to be insignificant or have a negative coefficient. How should this result be interpreted?

In another study on the measurement of quality change, Nicholson (1967) stressed that the ability to substitute between commodities, particularly between newer and older models, made it difficult to calculate the precise contribution of each characteristic to the change in a general index number or to real income. He restated the concept of Adelman and Griliches' "constant satisfaction" index:

> a true index of the change in the level of retail prices between two situations is broadly definable as the ratio of money incomes at which a consumer would feel neither better nor worse off in one situation than in the other (Nicholson, p. 526).

Nicholson recommended that the benefits accruing to the consumers should be incorporated not only in an index of retail prices, but also in an index of real income. The benefits (increases in real income and/or reductions in living costs), however, can only be enjoyed by those who are able to purchase the improved product, stressing the importance for separate indices of real income changes for different income groups.

Robert Lucas (1975) published a critical study attempting to "provide a theoretical basis for evaluating alternative interpretations and applications of hedonic price functions estimated from cross-sectional data" (Lucas, p. 157). Specifically, Lucas analyzed Lancaster's "new" approach to consumer theory and Adelman and Griliches' constant satisfaction index and discussed the limitations involved with each. With respect to Lancaster's approach, Lucas raised two issues. First, he asserted that the linear technology of Lancaster's model may be too restrictive for the study of hedonic price functions. Second, he posed the question of whether there is a substantive difference between the consumer theory of Adelman and Griliches and that of Lancaster.

With respect to Adelman and Griliches' method, Lucas focused on the relationship between their hedonic price function and consumer choices. The results were used to reconsider the technique they proposed for constructing a consumer price index when the quality of commodities changes. Lucas stated that complications in Adelman and Griliches' index

> arises from the instability of the hedonic equation as new commodities are introduced, thus rendering Adelman and Griliches' definition of the poly-genetic price changes ambiguous, depending on whether base or current period cross-sectional hedonic equations are employed (Lucas, p. 176).

In conclusion, he asserts that the approach, which utilizes a general utility function--indicated as a weakness of Lancaster's theory--is achieved at the "cost of assuming a continuum of commodities within each class, a continuum of consumers, and each consumer choosing only one commodity within a class" (Lucas, p. 176).

Ladd and Suvannunt (1976) examined two hypotheses about characteristics of consumer goods. The first hypothesis stated that prices paid at the retail level are a weighted linear combination of the implicit prices of a good's attributes. The second hypothesis stated that consumer demand for a good is a function of not only income and price, but also the product's attributes. Ladd and Suvannunt developed the Consumer Goods Characteristics Model (CGCM) in order to explore these two theories. The underlying objective of the model was to analyze a product as a collection of characteristics, with each product containing different kinds, different amounts, or both of certain characteristics. Results of the CGCM suggested that the first hypothesis may lend itself to the application of the marginal implicit prices to grading schemes for consumer products. Analysis of the second hypothesis suggested that the results from the estimation of the CGCM could be used to increase producer profits by incorporating more of the desired attributes in the design of the product. In their concluding remarks, the authors state that "it may not be possible to rank two similar products according to their quality" (Ladd and Suvannunt, p. 510), rather, two similar products may each hold an advantage over the other in individual characteristics. Thus, the two products cannot be compared on a strict "quality" basis.

Robert Willig (1978) used utility theory to derive "several simple and practical new methods for measuring the price-quality rate of substitution of a consumer" (Willig, p. 227). Using only observable demand data, the method developed by Willig enabled the estimation of the effect of a pure price change. In an analysis of consumer welfare using several formulae derived for calculating indifference curves, Willig examined incremental consumer's surplus, a pure repackaging demand function, a cross-product repackaging demand function, and a quality-corrected consumer price index. The latter turned out to be a hedonic price adjustment mechanism for the calculation and construction of consumer price indices with quality adjustments.

Deaton and Muellbauer (1980) applied the hedonic technique to household production theory. Noting two types of empirical forms, single year cross-section regression and pool time-series/cross-section regression, the authors derived the concept of a constant utility index for household production theory. The assumption that all household have the same marginal rates of substitution between the specified variables is necessary if the hedonic price function is to reflect household preferences. In equilibrium, the hedonic price function "reflects both the distribution of marginal rates of substitution over households and the distribution of marginal rates of transformation over firms" (Deaton and Muellbauer, p. 265), an affirmation of the point made by Rosen in his 1974 article.

The choice of an appropriate functional form for hedonic price equations was the topic of a 1981 study by Halvorsen and Pollakowski. Alluding to Rosen's 1974 paper, the authors stated "A hedonic price equation is a reduced-form equation reflecting both supply and demand influences. Therefore, the appropriate functional form for the hedonic equation cannot in general be specified on theoretical grounds (Halvorsen and Pollakowski, p. 37). The lack of theoretical underpinnings for the choice of a functional form has broad implications, since the results of a hedonic estimation is dependent on the functional form used. They noted that the solution to the problem in practice has been based strictly on convenience.

To avoid one of the major pitfalls of this ambiguous approach namely, placing highly restrictive assumptions on the model, they suggested a statistical procedure to select the appropriate functional form for hedonic price regressions. They asserted that the specification of a very general and flexible functional form "yields all other functional forms of interest as special cases (Halvorsen and Pollakowski, p. 37). The methodology was developed from an article by Box and Cox (1964). This method introduced the flexibility in functional form. The model, called the Box-Cox functional form is specified as follows:

$$P^{(\theta)} = \alpha_o + \sum_{i=1}^{m} \alpha_i z_i^{(\lambda)} + \frac{1}{2}\sum_{i=1}^{m}\sum_{i=1}^{m} \gamma_{ij} z_i^{(\lambda)} z_i^{(\lambda)}$$

where P is price
z_i are attributes
$P^{(\theta)}$ and $z_i^{(\lambda)}$ are Box-Cox transformations
$\gamma_{ij} = \gamma_{ji}$

The restrictions $\gamma_{ij} = \gamma_{ji}$ are imposed for purposes of identification only and place no effective constraints on the generality of the form. If the restrictions were not imposed, each coefficient γ_{ij} would be replaced by 1/2 ($\gamma_{ij} = \gamma_{ji}$) and the γ_{ij} and γ_{ji} could not be separately identified (Halvorsen and Pollakowski, p. 39).

Applying the method to a study of the housing industry, the authors stated that one of the advantages is the ability to use likelihood ratio tests to determine the appropriateness of alternative functional forms offered by the Box-Cox technique. They rejected all other functional forms used.

In response to this article, Blackley, et. al. (1983) explained how the Box-Cox technique may result in biased estimates of the coefficient variances due to the use of the OLS covariance matrix. Specifically, use of OLS variances gives rise to miscalculated t-statistics for the parameters. Reliance on these t-statistics was the reason for erroneous results of many studies, including the study by Halvorsen and Pollakowski (1981). Blackley stated that these "studies report t-statistics without any mention of the estimation of the covariance matrix by means of the maximum likelihood method . . ." (Blackley, p. 349). According to Blackley, the role of the t-statistics in determining the explanatory variables of hedonic models is crucial. The purpose of Blackley's article was to examine the extent of this bias. He found that the bias can vary significantly depending on the data set used in the estimation procedure and warned against using the iterative OLS t-statistics in the selection of proper variables to be included in a hedonic model.

Another article, co-authored by Cassel and Mendelsohn (1985) also commented on Halvorsen and Pollakowski's study. The authors assert that the advantages gained from the Box-Cox functional form are gained at the "expense of other important goals" (Cassel and Mendelsohn, p. 135). In particular, the objectives of most hedonic analyses are the estimation of implicit prices for characteristics, measurement of the response to price changes, and/or the prediction of future expenditures. Use of the best-fit criterion in choosing functional forms does not always result in better estimates of the characteristic prices, and in fact, the Box-Cox functional form may even reduce the accuracy of the coefficients which are used to estimate the specific prices. Second, the Box-Cox functional form does not allow the use of data containing negative numbers since any negative number raised to a noninteger real power is imaginary. Third, the authors aver that the predicted untransformed variable will be biased "since the mean predicted value of the untransformed dependent variable need not equal the mean of the sample upon which it is estimated" (Cassel and Mendelsohn, p. 135). Therefore, the Box-Cox technique may be a poor predictor.

On the estimation of structural hedonic price models, Brown and Rosen examine some aspects of Rosen's procedure that can lead to identification problems. According to Brown and Rosen, estimation of marginal attribute prices for buyers and sellers evaluated at the amounts of characteristics actually bought or sold is not as effective as a procedure that uses direct observations on prices. The reason for this problem lies in the fact that the constructed prices are derived from observed sample quantities and

> any new information that they may provide can only come from *a priori* restrictions placed on the functional form of the price function P(Z). In the absence of such additional restrictions, second-stage structural estimation of the sort suggested by Rosen may only reproduce the information already provided by the first-stage estimation of the P(Z) function (Brown and Rosen, p. 766).

To avoid the problem, Brown and Rosen suggested not expressing the marginal price function for each attribute Z as "some exact combination of the arguments of the structural demand or supply functions" (Brown and Rosen, p. 767). Second, repetition of first-stage results could also be avoided if marginal implicit prices were estimated from separately fit equations for "spatially distinct markets and then used to estimate a common underlying structure for all markets" (Brown and Rosen, p. 767). Brown and Rosen did not offer a set of conditions with which to solve the identification problem of

Rosen's model. Rather, the purpose of the article was to highlight one of the pitfalls of the method.

Kanemoto and Nakamura (1986) examined one of Brown and Rosen's suggestions for solving the identification problem inherent in Rosen's model. Specifically, Kanemoto and Nakamura developed an estimation method which restricted the shape of the "bid price function to a certain quadratic form" (Kanemoto and Nakamura, p. 219). They also noted the work of Quigley (1982) in which a similar approach was taken (the utility function was restricted to the generalized CES form). They found that the results from their work and Quigley's work were very different.

The paper begins with a discussion of the fundamental difficulty involved with the estimation of structural equations. The problem involved the use of cross-sectional data in the estimation of structural demand and supply equations which produced a model that was impossible to estimate because there was only one set of prices that created an equilibrium in all markets. Using the example where a bid price function is estimated with no observation errors, no unobserved attributes, and no specification errors, Kanemoto and Nakamura show that the shape of the bid price function cannot be determined, rather, only the points of tangency between price and goods at their optimum levels. This does not give the complete bid price function. In answer to this situation, the authors place *a priori* restrictions on the functional form of the bid price function. Specifically, they added to the original bid price function, denoted by r(a,y) where y represents an individual's characteristics vector and z represents a good's characteristics vector, an additional vector, v, which is a vector of unobserved characteristics of a good.

Kanemoto and Nakamura compared this approach to Quigley's in an application to the Japanese housing market. Marginal rates of substitution were calculated from Quigley's utility function and Kanemoto and Nakamura's bid price function. As stated earlier, the results were quite different. The authors conclude that the selection of an estimation method is very important and that researchers must continue to search for a better method.

McConnell and Phipps (1987) examined preference parameters in hedonic models. The article also focused on the identification problem in hedonic pricing models which they defined as "the recovery of information about preferences for the quality of goods" (McConnell and Phipps, p. 35). The identification problem disappears if market supply is exogenous. McConnell and Phipps claimed that "empirical hedonic analysis using observations on prices and attributes of goods is strictly a consumer demand problem with a nonlinear budget constraint" (McConnell and Phipps, p. 35). They offered two justifications for their assumption: the nature and origin of the endogenous variables are clarified by using the household model and second, use of the traditional economic approach facilitates the use of conventional econometric criteria for identification.

The article addressed three questions. First, what is the objective of estimating a hedonic system? Their study revealed that the hedonic demand function is actually a marginal rate of substitution function with implicit parameters of the preference function. As long as the hedonic equation is nonlinear, "traditional direct or inverse Marshallian and Hicksian demand functions do not exist" (McConnell and Phipps, p. 51). The authors assert that the objective of hedonic price models is to recover the consumer's preference parameters. Second, what circumstances make it possible to estimate preference parameters? It was the answer to this question that touched upon the identification problem inherent in hedonic models. The authors stated that

> Identification (of the preference parameters) . . . requires the imposition of generally untestable and unintuitive restrictions on the functional form of the hedonic and marginal rate of substitution equations. These restrictions often place unknown or unrealistic limitations on the underlying preference or market structure (McConnell and Phipps, p. 51).

Third, do the costs involved with placing restrictions on the model outweigh the benefits? Specifically, the costs include maintaining highly specific and restrictive assumptions about preferences and the hedonic model. Any benefits derived from recovery of the parameters depends on their ultimate use.

The hedonic method has opened avenues in the theory of prices which recognizes a distinct tendency for market prices of a product or commodity to vary with certain physical characteristics. The consumer identifies these characteristics with quality, "and the relation of these characteristics to prices may in many cases be fairly accurately determined by statistical analysis" (Ladd and Suvannunt, p. 504). This generalization has been the basis for a variety of theoretical pricing studies in which the hedonic method has been the focus. Court, Griliches, Rosen, and Lancaster, have been the trailblazers in the area of theoretical development, although many others have contributed. Criticisms have focused primarily on choice of appropriate functional form, selection of appropriate parameters, and overall feasibility of the method to explain quality changes.

IV. EMPIRICAL STUDIES

This section reviews empirical applications of the hedonic model to consumer nondurables, specifically, agricultural commodities. Theory, objectives, and both strengths and weaknesses of the hedonic pricing model have been discussed. The purpose of this review is to provide a basis for the use of a hedonic model in the analysis of apple prices. The following selection of articles chosen are examples of what has already been attempted with other agricultural commodities and should establish a firm setting for an application to the apple industry.

The majority of empirical work using hedonic pricing models has been in the area of consumer durables, particularly automobiles and housing [Triplett (1969), Cowling and Cubbin (1972), Ball (1972), Thompson (1987)]. However, hedonic pricing has also been used in numerous urban studies involving property and land values, amenity valuation, and labor markets [Palmquist (1982), Barnett (1985), Milon, et. al. (1984), Smith (1983)].

Some of the models described in these articles used both log and semilog functions. Triplett (1969) used the semilog function, $\ln p = Xb$, where p is a vector of prices and X a matrix of automobile specifications. The majority of articles use this basic form of the hedonic price equation with some variations. In a model similar to the one specified by Griliches, Thompson (1987) developed the following hedonic equation for automobiles:

$$\log(P_i) = \alpha_o + \Sigma\alpha_j X_{ji} + \Sigma\beta_k V_{ki} + \Sigma\gamma_m Z_{mi} + \delta E_i + \varepsilon_i$$

where X_j, $j = 1 \ldots 6$ are quantitative characteristics of the car model, the V_k, $k = 1 \ldots 6$, are binary variables representing qualitative attributes of the car model, Z_m, $m = 1 \ldots 8$, are dummy variables representing the country of origin, E represents an entry binary variable, equal to one if the model is a new entrant, and ε is a random error term. The objective of the model was to examine quality-adjusted entry discounts associated with car models whose manufacturers were new to the Irish car market. Results from Thompson's analysis supported the hypothesis that there was indeed an entry discount. This discount amounted to about 10.5 percent of the mean pre-tax price for new entrants, after adjustments were made for qualitative attributes. However, when allowance for country of origin was incorporated, the discount fell to about 7.4 percent.

Research on hedonic pricing models for agricultural commodities goes as far back as 1928. Ladd and Martin (1975) discuss the early work of Waugh. In Waugh's study, data on wholesale prices and characteristics of select vegetables were collected to estimate a hedonic regression. The price of vegetables was the dependent variable and its attributes were the independent variables. After calculating implicit prices for the attributes, Waugh found that an additional inch of green color per stalk increased the price of asparagus by 38.45 cents per dozen standard bunches. Furthermore, he discovered that the coefficient on the attributes could not only take on positive values, but negative values as well. A negative value represents a negative relationship between the particular attribute and the price of the product. As Ladd and Martin stated in their conclusion, "some product's characteristics may be inferior characteristics, that is, their presence in any amount reduces the value of the product" (Ladd and Martin, p. 30). The case where characteristics have positive values up to a point and then turn negative is also discussed.

Ball and Ryan (1977) use protein levels to explain fluctuations in the relative prices of wheat varieties. Their model regressed four supply variables against a price ratio of the high and low protein wheats.

$$P_h/P_L = b_o + b_1S_h + b_2S_L + b_3PP_h + b_4PP_L + e$$

where P_h, P_L = price of high and low protein wheats
S_h, S_L = production plus carryover of high and low protein wheat
PP_h, PP_L = average protein percentages of high and low protein crops

The supply variables accounted for the supply of protein available in each variety of wheat. The results showed that "relative price movements between two closely related commodities can be explained by analyzing a common characteristic of the commodities" (Ball and Ryan, p. 532).

Petzel and Monke (1980) used hedonic pricing to analyze quality differences between different varieties of rice. In their model, four characteristics were regressed against price. The independent variables were expressed in binary form, taking on a value of one or zero. The only problem they encountered was that the procedure "suggested no estimable functional form . . . Box and Cox (1964) suggest ways of testing appropriate transformations of the variables. It was found here that the choice of functional form did not affect significantly the explanatory power of the regression" (Petzel and Monke, p. 321). Their results revealed consistent premiums for specific rice qualities over two distinct market periods, noting only one characteristic, parboiled rice, failed to maintain a consistent relationship with regard to the price of a particular variety.

For cotton, Ethridge and Davis (1982) used an hedonic pricing model for cotton lint in an attempt to determine the relative importance of selected characteristics. Data used for the regression was obtained from sample data on observed sales of cotton in order to measure sensitivity of producer prices with respect to quality. The model utilized both quantitative and dummy variables, with the quantitative variables representing grade, length, fiber fineness, and lot size. Using both ordinary least squares and generalized least squares (to correct for expected autocorrelation), they found that quality attributes were not the only factor which affected producer prices. Nevertheless, "the range of prices implied by the variation in explanatory variables . . . has a substitutional effect on producer prices over and above those from formal market fluctuations" (Ethridge and Davis, p. 298).

In another study of cotton, Monke and Petzel (1984) used hedonic pricing as a means to determine whether differentiated products should be treated as a homogeneous commodity, where the homogeneous commodity is recognized to obey the law of one price. International trade analysis requires homogeneity of the commodities. They asserted that the use of hedonic estimation can help to identify the existence of market integration in which a lag extending beyond the "periodicity of the time-series observations" occurs (Monke and Petzel, p. 481). A model similar to the one used in Petzel and Monke (1980) was used with the addition of a time dummy variable, where two distinct time periods were identified by a binary variable. This enabled them to identify any significant price changes between the two periods and to measure shifts in the coefficient values. They explained that the existence of significant linkages between prices may indicate some degree of market integration, but that this "must be assessed on a case-by-case basis augmented by additional information on market structure and production technology" (Monke and Petzel, p. 483).

Brorsen, et. al. (1984) developed and tested a hedonic model for rough rice bid/acceptance levels to examine the legitimacy of using grades to explain observed quality differentials. The study specified four models. The first included only dummy variables for grade and mill price. The results of the regression indicated that the grades provided valuable information for buyers. In the second model, three additional variables were used to represent head yield, mill yield, and test weight--three factors which were considered important in determining rough rice values. Model three was designed to measure the explanatory power associated with the quality characteristics when dummy grade variables were not used. Results suggested that this model was similar to model two with respect to the amount of price variation explained. The fourth model tested the hypothesis that using both dummy grade variables and quality characteristics together would explain variation in prices better than using only one or the other. The fourth model did indeed offer a better explanation.

Wilson (1984) developed a hedonic model to analyze the effect of protein levels and kernel plumpness on the price of malt barley. Randomness and variability in prices across samples resulted in uncertainty for producers, merchandisers, processors, and plant breeders. Wilson's model regressed two intercept shifters for variety and grade, a protein variable, plumpness variable, and the price of feed barley on the price of malt barley. The results suggested that the current grading system for malt barley may have become obsolete. Grade did not have a significant effect on malt barley prices, given the presence of the other variables. Marginal implicit prices for protein were negative, as Wilson projected, implying a discount for high protein levels. The marginal implicit price for plumpness varied across varieties and years and both the premiums for plumpness and the discounts for protein increased over the study period. The results had important implications for the barley industry because large investments are undertaken to improve quality through improved varieties. Wilson's study provided economic information regarding the values associated with protein levels and plumpness which could be utilized by the plant breeders. Furthermore, the results of the study benefited producers in variety selection and production decisions by offering relevant information regarding growing methods, i.e., soil selection and nitrogen use.

Jordan, et. al. (1985) used hedonic pricing to estimate the implicit values of certain quality characteristics of tomatoes. They observed that while the cost of changes in handling techniques or new technologies were known, the benefits derived from implementation were usually much more difficult to estimate. In their model, size, damage, color, and firmness were regressed against the price of tomatoes on a cents per box basis for three separate months--April, August, and September. Their results revealed that for April and September, firmness was the most important quality attribute, followed by color, damage, and size. For the months of April and September, the marginal attribute prices for color and damage were relatively consistent. Firmness drew a higher premium in September, whereas shelf-life became a more important influence on quality in the late marketing season. Finally, the marginal implicit price for damage in August was similar to that for April and September.

The authors used a cost-benefit approach to analyze their results. Specifically, when the marginal cost of the investment is less than the marginal implicit price of the affected attribute, the result is a net benefit. If the marginal implicit price does not exceed the marginal cost, then the resulting price benefit may be insufficient to cover costs. The authors asserted that the hedonic cost-benefit approach can be an effective method with which to evaluate the different handling systems and materials. Furthermore, an analysis of the price-size/quality relationship can assist tomato handlers in decision-making. For example, firmness is a quality characteristic that tomato packers can control.[3]

V. CONCLUSION

This chapter has presented an exhaustive review of literature on the theoretical development, criticisms and modifications, and applications of the hedonic method. Early applications, particularly during its developmental stages, focused on adjusting for quality changes in consumer durables and price indexing. Andrew Court has been credited with discovery of the theory in an early study of automobile pricing. Griliches, Rosen, and Lancaster are also considered pioneers in the establishment of the theory, although many have contributed. Criticisms have focused on proper use of functional forms, selection of appropriate parameters, and feasibility of the method to explain quality changes under exceptional conditions, such as when qualities are known to change.

More recently, the hedonic method has been applied to the field of agricultural commodities. Articles on wheat, tomatoes, barley, rice, and cotton were included in this review in order to provide a background for use of the hedonic method in the study of apple prices.

[3]For other hedonic pricing studies applied to agricultural commodities, see O'Connell (1986) and Veeman (1987).

CHAPTER FOUR
THE MODEL AND RESULTS

This chapter derives and analyzes price differentials of apples for selected quality-related characteristics of apples. An hedonic price function, estimated from the regression of a commodity's observed price on its quality attributes, is developed. For apples, the explanatory variables included in the model consist of seven quality-related characteristics--crop year, region, variety, size, grade, seasonality, storage method, and a variable intended to measure the effect of the Alar scare on Red Delicious apple prices. Not all of these variables relate strictly to the quality of the apple, such as crop year. However, the hedonic function proves a useful way to study nonquality attributes of prices. "At a given point in time, it can identify not just which factors are important in determining the price of a commodity but also how important each factor is and the consistency of its relationship with price" (O'Connell, p. 1).

This chapter presents three hedonic models for the national apple market. All independent variables are expressed as dummy variables. Petzel and Monke (1979) helped establish the validity of this method in a study analyzing rice price differentials. They explain that the use of dummy variables in an hedonic analysis where discrete variables are employed does not undermine the effectiveness of the model in obtaining meaningful results. Model I uses a linear functional form and nominal prices as the dependent variable; Model II utilizes a log-linear functional form; and Model III uses real prices--nominal corrected by the Consumer Price Index (CPI) for the dependent variable. Analysis in the text focuses on Model I. A description and comparison of the alternative models is discussed in Section IV.

I. THE MODEL

The hedonic function used in this analysis of apple prices is expressed as follows:

(Equation 4.1)

$$P_i = \alpha_o + \sum_1^6 \beta_a Y_{ai} + \sum_1^{11} \Lambda_a M_{ai} + \sum_1^3 \delta_a R_{ai} + \sum_1^6 \Phi_a V_{ai} + \sum_1^3 \Gamma_a S_{ai} + \sum_1^2 \vartheta_a G_{ai} + \Pi_a Z_{ai} + \sum_1^3 \Theta_a A_{ai} + \varepsilon$$

where

P	is price
α	is the constant term
Y	is crop year
M	is month (seasonality)
R	is region
V	is variety
S	is size
G	is grade
Z	is type of storage
A	is a variable representing a 1988, Red Delicious price quote
ε	is the disturbance term

Equation 4.1 states that the f.o.b price of a box of apples is a linear function of eight variables representing seven quality characteristics of the apple and a variable included to measure the effects of the Alar scare on prices. The

coefficients represent marginal monetary values of the characteristics--the product of the quantity of the characteristic obtained from the marginal unit of the product consumed and the marginal implicit price of the characteristic.

An hedonic study derives marginal implicit prices of each quality characteristic and reveals which of those characteristics is bringing a premium or discount to its price. For time-series hedonic estimations of marginal implicit prices of quality characteristics, Rosen (1974) strongly suggests that supply response functions also be determined. However, supply of each characteristic was assumed to be perfectly inelastic in this study. This assumption is justified as none of the variables used can be considered as quantitative inputs to the production process. This also eliminates the identification problem posed by McConnell and Phipps (1987) since the model is only concerned with estimating demand parameters.

The hedonic model for apples utilizes a linear functional form with nominal price as the dependent variable and the seven quality characteristics and the Alar variable as the exogenous independent variables. This version will be referred to as Model I. A linear form was selected due to the ease of interpretation of the results. The coefficients on the independent variables using the linear regression method appear in terms of dollars and cents which immediately reveals the price premium or discount associated with each characteristic. The constant term represents the price for the bundle of characteristics selected as standards in each group, and by adding the premium or discount represented by the coefficients for the remaining variables, prices for any type of apple can be estimated.

A log-linear regression (natural log of price regressed on the independent variables) and a version using nominal prices adjusted by the CPI were also run to test the integrity of the model. These two models will be referred to as Models II and III, respectively. Results of these regressions and versions of all three models regressed by ordinary least squares (OLS) are discussed in Section IV of this chapter.

An initial OLS regression of Model I revealed the presence of autocorrelation. The Durbin-Watson statistic of this regression was 0.64 [See Appendix II]. To correct for this problem, the Cochrane-Orcutt (CORC) method for correcting for first degree autocorrelation was used. A CORC regression designed to correct for second degree autocorrelation was also attempted, but results were not significantly different from the run correcting for first degree autocorrelation [See Appendix V]. The corrected model increased the Durbin-Watson to 1.82--acceptable for this study. In all models--I, II, and III--the statistical significance of the overall regression was high.

II. PRICE DATA AND DESCRIPTION OF VARIABLES

Price data was obtained from the Market News Branch of the Agricultural Marketing Service, U.S. Department of Agriculture. Branch offices are located in Yakima, Washington, Rochester, New York, and Benton Harbor, Michigan. In addition to weekly reports, these offices publish annual reports summarizing the crop year's prices. The prices represent f.o.b. quotes for 40-pound boxes. Monthly prices are averaged from weekly price reports. This approach was used to reduce the size of the model.

The model uses seven years of price data, beginning with the 1982 crop and ending with the 1988 crop. Since the crop year is different from the marketing year, the price quotes begin in mid-1982 and continue through mid-1989. Availability of price quotes varies during a season depending on the size of the crop. In addition, the length of marketing season differs across varieties. For example, of the varieties included in the model, Red Delicious is typically the earliest to harvest. Other varieties have a much later harvest date, such as the Granny Smith.

A. Crop Year

The period encompassing crop years 1982 through 1985 can be described as steady, with annual production figures during this period exceeding the average for the previous 10 years. In 1986, a surge in demand combined with a normal supply of apples pushed prices to record levels. The 1987 crop was the largest on record, with the United States producing over 10.5 million pounds, an increase of 2,609 million pounds or 33 percent over the 1986 crop year. Season average prices for the 1987/1988 marketing year fell dramatically, 37 percent below 1986. The 1988 crop was 17 percent smaller than the previous year, and stronger prices were expected. Prices started 80 percent higher than the 1987 crop. But late in February, when the publicity on Alar began, prices fell. By June, prices had dropped 44 percent compared to the week before the Alar scare became a public issue (Buxton, p. 85).

The 1986 crop year is selected as the standard, and signs for most of the remaining crop year variables are expected to be negative. The expected sign for the 1988 crop is difficult to anticipate because of the strong start and unfortunate finish to the season [See Table 4.1]. The variable for crop year took on a value of one if the price was observed in that year, and a zero if otherwise.

B. Month

The next variable was created in an attempt to capture the effects of seasonality on apple prices. The typical marketing season for cold storage apples begins in late August to early September, and ends in late December or in the early part of the next year. In January, the sale of apples stored in controlled atmosphere storage facilities begins and continues through the summer. Some varieties have shorter or longer marketing seasons. Instead of dividing the season into two time periods representing regular and controlled atmosphere stored apples, variables were created for each month.

October was selected as the standard for the reason that the majority of all varieties are sold in some quantity during this month. At the start of the marketing season (August and September), the first of the fresh apples appear on the market. These apples are expected to bring a premium. But the price advantage may depend on the quantity of carryover stocks from the previous year. In the latter case, early fresh apples compete with stored apples. Nonetheless, the coefficient for the August and September variables are expected to bring a premium to the standard (October).

The coefficients for prices in November and December, considered the end of the cold storage season, are expected to be negative. This is due to the leveling off of prices as the marketing season progresses. Also, demand for fruit usually is lower during the winter months.

During January, the last of the cold storage apples and the first of the controlled atmosphere apples appear on the market. As a rule, the first of the apples from controlled atmosphere storage facilities bring a premium to the cold storage apples sold during the same period. The coefficient on the January variable is expected to be negative, but not large in magnitude. It is expected that coefficients for the February through May variables will also be at a discount to the October base. Some cold storage apples are still being sold through March, asserting a downward bias on these monthly coefficients.

The supply of apples during June and July varies from year to year. If sufficient stock remains after May, apples can be sold at higher prices during the summer months. Prices are expected to increase during this time to compensate for storage costs and to reflect increasing demand. The coefficients on these variables are expected to be positive, but not large in magnitude.

C. Region

The third variable represents the region in which the price was quoted. The four regions selected are located in three states--Washington, New York, and Michigan. Currently, these states are the top producing regions in the United States, producing nearly two-thirds of the country's total commercial crop. For Washington, the primary producing regions are the Yakima, Wenatchee, and Chelan-Okanogan Districts, located in the northwest portion of the state. For the model, however, only one variable was assigned to represent the Washington area. The New York branch of the Market News Service quotes prices for three different regions: Hudson Valley, Lake Champlain, and Western/Central New York. Lake Champlain was excluded from the analysis since McIntosh was the only variety for which prices were quoted. In Michigan, there is only one major producing region, located along the eastern coast of Lake Michigan.

Predicting signs for regional variables is predicated on the assumption that certain regions possess sufficient market power to influence the price for an otherwise homogeneous product. Whether perceived or real, regional advantages can make a difference in prices. Washington has been the most aggressive in attempting to promote their regional attribute. They assert that their apples are of a higher quality than other apples of the equivalent U.S. grade, as supported by their more stringent grading standards. Washington was chosen as the standard for the region variables. It is expected that the coefficients for the remaining four regions in New York and Michigan will be at some discount to the standard. In the model, the variable for region assumes a value of one if the price was reported from that region, and zero if otherwise.

D. Variety

The fourth variable represents the variety of the apple. The varieties chosen for the study include Red Delicious, Golden Delicious, McIntosh, IdaRed, Empire, Red Rome, and Granny Smith. To minimize multicollinearity in the data, only those varieties for which prices were quoted in more than one region were selected with the exception of the Granny Smith variety, prices of which are only quoted from the Washington region. This procedure disqualified many varieties which would have been of interest in the analysis, i.e., Winesap, Jonathan, and some of the new varieties of apples. The varieties which were included, however, account for nearly two-thirds of all apples grown in the United States (Bultitude, p. 8).

Signs for Red Delicious, Golden Delicious, McIntosh, and Granny Smith variety are of interest in this analysis due to their nationwide popularity. The remaining three varieties--Law Rome, Red Rome, and Empire--are more popular in the regions in which they are grown.

The Red Delicious variety was selected as the standard since it is the most widely grown and commercially sold variety in the United States. It is expected that the other varieties would be priced at a premium to the standard. The reason for this is the economies of scale that have been achieved by the growers of the Red Delicious variety. The McIntosh, Golden Delicious, and particularly the Granny Smith are specialty varieties, with lower production levels and higher per unit costs of production. Values for the Law Rome, Red Rome, and Empire are expected to be near the standard, but signs are difficult to determine *a priori* .

E. Size

The fifth variable represents size. Apples are sized according to the number that will fit into one standard box which weighs between 40 and 42 pounds. Depending on the size of the apples, a box will hold up to five molded "trays." Tray packing reduces the percentage of bruising when the apples are in transport. Another method of packing utilizes corrugated cardboard dividers to separate the apples within the box , but this is not as common as tray packing. The quantity of apples which fit comfortably into a box represents the size. A value of "125" indicates that approximately 125 apples fit into a box, or 25 apples per tray.

Rather than create a variable for every size, the apples were divided into four groups: extra small, small, medium, and large. Sizes 125 and above are considered small; sizes 72 to 120, medium; 72 and below, large. The extra small category was created to represent "bagged" apples--those which are packed by predetermined weights in plastic bags to be sold at the retail level in bulk. Bag prices are quoted for 12, three-pound bags (36 pounds). The use of grouped data in a regression has been associated with inefficient results and a higher R^2 than would normally be achieved had grouped data not been used (Ball, p. 214). However, the alternative would have made entry of the data cumbersome due to the numerous sizes reported.

The standard chosen for the size variable was medium, the most popular and widely sold size. It is expected that the small and extra small categories will sell at a discount to the medium size. This can be predicted with most confidence for the extra small category which are sold by bags in bulk and thus expected to bring a lower per unit price. The small category, while sold individually, have historically not sold as well as the medium size. The sign for the large apple category is expected to be positive. The quantity of large apples produced is typically very small compared to the small and medium sizes, and the grower is able to demand a higher price for them.

F. Grade

The sixth variable chosen represents the major grade classifications used by the apple industry. On a national level, the United States Department of Agriculture sets grading standards for all apples destined for fresh consumption. These grades include U.S One, U.S. Fancy, and U.S. Extra Fancy. Washington has created its own standards and markets apples under both grades. Both sets are based on richness and consistency of color, and the percentage of defects present on the apple, i.e., bruises, discoloration. The difference between the standards is the strictness that each applies to the respective grades. For example, a box of Washington Extra Fancy apples will possess better color and consistency of color in addition to a lower percentage of defects when compared to a box of the U.S. equivalent (Seitz). At present, the Washington standards are being adjusted to reflect more of a firmness quality in response to consumer pressure for a better tasting apple.

The grades used in this analysis include Fancy, Extra Fancy, and a combination grade consisting of Fancy and Extra Fancy. U.S. One was excluded because it is reported only in one of the regions. It is considered an "escape grade" for apples which are just better than those sent to the processors. Prices for the combination grade are reported in three of the regions and can be considered an intermediate grade between Fancy and Extra Fancy.

The signs on the grade coefficients should not produce any surprises. The Extra Fancy grade was chosen as the standard since it is the premium grade. Compared to the Extra Fancy grade, the other grades, U.S. Fancy and the combination grade, should be sold at a discount.

G. Storage

The sale of cold storage apples often overlaps the sale of controlled atmosphere apples. When the last of the cold stored apples are selling, controlled atmosphere stored apples are being introduced into the market. To avoid duplication, a seventh variable was created. This variable denotes the method of storage and avoids duplication of price series for those months where overlap occurs.

For the standard, the cold storage variable was selected. This leaves the sign of the controlled atmosphere storage variable to be determined. It is expected that the coefficient on the latter will be positive. Controlled atmosphere apples make a strong appearance on the market and appear better able to hold their price advantage than cold storage apples. An additional factor influencing price of controlled atmosphere apples is seasonality. The controlled atmosphere apples are sold throughout the part of the year in which demand for all fruit is typically strongest--the spring and summer months. On the supply side, additional costs must be incurred to store apples. A controlled atmosphere storage facility is a major expense to most packers. These costs cause growers to require a higher price.

H. Alar Variable

The final variable was created as a means to measure the effect of the growth regulator, commercially known as Alar, on the 1988 crop of Red Delicious apples. The Red Delicious variety was purported to be the most adversely affected, although demand for all apples in general declined during this period (Buxton, p. 85). The relevant dummy variable represents the months February through July 1988, for the Red Delicious variety in each of the regions.

Four Alar variables were created. The first one represented only the Red Delicious variety sold during the months of February, 1989 through July, 1989 for all regions and was selected as the standard. The remaining three variables recognize the regions of Washington, Michigan, and the Hudson Valley region of New York. It is expected that the Washington Red Delicious Alar variable will show the most significant price effect. While Michigan and New York produce a significant amount of Red Delicious, the variety is not their top seller in terms of volume. Signs for these two regions are also expected to be negative, but smaller.

(Table 4.1)

TABLE OF EXPECTED AND ACTUAL SIGNS FOR THE COEFFICIENTS

Variable	Expected Sign	Actual Sign
Crop of:		
1988	?	-
1987	-	-
1985	-	-
1984	-	-
1983	-	-
1982	-	-
Month:		
January	-	-
February	-	-
March	-	-
April	-	-
May	-	-
June	+	-
July	+	+
August	+	+
September	+	+
November	-	-
December	-	-
Region:		
Hudson Valley, NY	-	+
Western/Central, NY	-	+
Michigan	-	+
Variety:		
Golden Delicious	+	-
McIntosh	+	+
Ida Red	?	+
Granny Smith	+	+
Empire	?	+
Rome	?	+

(Table 4.1, continued)

Variable	Expected Sign	Actual Sign
Size:		
Extra Small	-	-
Small	-	-
Large	+	+
Grade:		
Fancy	-	-
Combination	-	-
Storage Method:		
Controlled Atmosphere	+	+
Alar Variable:		
Washington	-	-
Hudson Valley	-	-
Michigan	-	-

(Table 4.2)

TABLE OF RESULTS: MODEL I

Variable	Coefficient	T-Statistic	Significance Levels
Constant:	12.93	37.94	.000
Crop Year:			
1988	(0.57)	(1.55)	.120
1987	(2.57)	(7.40)	.000
1985	(0.92)	(2.74)	.006
1984	(1.11)	(3.08)	.002
1983	(1.59)	(4.30)	.000
1982	(2.85)	(7.89)	.000
Month:			
January	(0.74)	(5.88)	.000
February	(0.84)	(5.90)	.000
March	(0.85)	(5.43)	.000
April	(0.83)	(5.27)	.000
May	(0.43)	(2.56)	.010
June	(0.04)	(0.17)	.864
July	1.18	4.32	.000
August	1.11	3.86	.000
September	1.15	9.10	.000
November	(0.36)	(3.47)	.001
December	(0.51)	(4.16)	.000
Region:			
Hudson Valley, NY	0.58	1.33	.184
Western/Central, NY	1.15	2.86	.004
Michigan	0.54	1.27	.206

(Table 4.2, continued)

Variable	Coefficient	T-Statistic	Significance Levels
Variety:			
Golden Delicious	(0.07)	(0.33)	.742
McIntosh	0.27	1.69	.092
Ida Red	0.17	0.65	.518
Granny Smith	5.04	14.71	.000
Empire	0.53	1.80	.072
Rome	0.05	0.20	.842
Size:			
Extra Small	(3.63)	(8.15)	.000
Small	(1.53)	(9.73)	.000
Large	1.79	9.74	.000
Grade:			
Fancy	(1.30)	(3.44)	.001
Combo	(1.45)	(4.64)	.000
Storage Method:			
Controlled Atmosphere	1.28	11.19	.000
Alar Variable:			
Washington	(2.72)	(6.47)	.000
Hudson Valley	(1.04)	(1.43)	.152
Michigan	(0.67)	(1.14)	.256

Statistics of Regression:

R^2:	0.86	Adjusted R^2:	0.86
Durbin-Watson:	1.83	F-Statistic:	313.73

Note: Coefficients in parentheses indicate a negative number

(Table 4.3)

TABLE OF RESULTS: MODEL III
(Dependent Variable is Real Price*)

Variable	Coefficient	T-Statistic	Significance Levels
Constant:	10.92	40.13	.000
Month:			
January	(0.98)	(8.66)	.000
February	(1.08)	(8.42)	.000
March	(1.07)	(7.70)	.000
April	(1.05)	(7.54)	.000
May	(0.67)	(4.53)	.000
June	(0.32)	(1.62)	.104
July	0.73	2.97	.003
August	0.74	2.90	.004
September	1.05	9.38	.000
November	(0.31)	(3.40)	.001
December	(0.45)	(4.13)	.000
Region:			
Hudson Valley, NY	0.13	0.29	.769
Western/Central, NY	0.76	1.82	.069
Michigan	(0.02)	(0.05)	.961
Variety:			
Golden Delicious	(0.14)	(0.69)	.488
McIntosh	0.13	0.85	.396
Ida Red	0.10	0.40	.687
Granny Smith	4.38	13.19	.000
Empire	0.44	1.61	.108
Rome	(0.006)	(0.03)	.977
Size:			
Extra Small	(3.22)	(7.61)	.000
Small	(1.40)	(9.73)	.000
Large	1.69	10.06	.000

(Table 4.3, continued)

Variable	Coefficient	T-Statistic	Significance Levels
Grade:			
Fancy	(0.97)	(2.81)	.005
Combo	(1.06)	(3.60)	.000
Storage Method:			
Controlled Atmosphere	1.13	10.97	.000
Alar Variable:			
Washington	(2.11)	(5.56)	.000
New York	(0.99)	(1.50)	.133
Michigan	(0.60)	(1.13)	.260
Statistics of Regression:			
R^2:	0.85	Adjusted R^2:	0.85
Durbin-Watson:	1.88	F-Statistic:	356.78

*Prices are in terms of 1986 dollars

III. RESULTS

Table 4.2 shows the results of the linear regression using nominal prices as the dependent variable. Table 4.3 shows the results from Model III in which real prices were substituted for nominal prices as the dependent variable. The regression of Model I produced a constant term of 12.93, a price representing the bundle of characteristics selected as standards--an Extra Fancy, Red Delicious, cold stored, medium-sized apple grown in Washington and appearing on the market in October of 1986.

The first group of coefficients includes the crop year variables. Signs on each variable were as predicted, showing a discount to the 1986 crop year. Both 1987 and 1982 crop years carried the highest discounts, with the 1988 crop year (the crop affected by the Alar scare) showing the smallest discount. The reason for the latter is probably the strong start in prices, which offset the late downward drift in prices caused by the Alar scare. The coefficient for the 1987 crop year reflects the weak prices caused by the record crop. Each variable was significantly different than zero at the five percent level with the exception of 1988. This result is most likely due to a correlation of the 1988 dummy with the Alar variables. When the Alar variables were omitted from the regression, all coefficients were significant.

The next group reveals some interesting results. Signs on coefficients for the monthly dummies were as predicted with the exception of June. The coefficient for June was the only seasonal variable that was insignificant, therefore, a price differential cannot be clearly defined for the month.

The values of the coefficients for the monthly dummies suggest a definite seasonal pattern. The months of July through September offer the highest apple prices, with premiums of more than one dollar per box relative to October. The remaining months show a discount to October, but with a distinct pattern of price movement. Except for June, all the coefficients had highly significant values.

The next group of variables represents the region where the apples were grown. Expected signs for each of these coefficients were not supported by the results. These results suggest a recent change in the apple market. Season average prices for each of the regions covering a time period of 50 years showed that for the entire period up to the most recent five years, Washington did prevail as a price leader (Agricultural Statistics). A previous regression using only five years worth of data produced premiums for Washington that were almost twice the values shown in Table 4.2 [See Appendix VI]. By extending the time period two years, the premium earned by Washington decreased by nearly half.

Only the variable representing the Western/Central New York region is significant; both Hudson Valley and Michigan were not significantly different than zero at the five percent level. Extending the time period might have shown these variables to be significant; but such results do not appear in this analysis. If Washington did possess a price advantage over the other regions, region could be considered a distinct quality characteristic, but this analysis suggests that it is not important. The coefficients on the Hudson Valley, New York and Michigan regions were very close, with a difference of only 0.04. In contrast, the coefficient for the Western/Central region of New York showed a much higher premium of $1.15. If these variables had proven to be significant, results suggest that the Western/Central region holds a price advantage over the other region of New York as well as Michigan.

The third group of coefficients represents variety. Of the six varieties (excluding Red Delicious), five were insignificant at the five percent level. The only significant coefficient represented the Granny Smith variety with a premium of over five dollars per box. Coefficients for the remaining varieties, while not significant in explaining price, do not differ greatly from the standard, with each showing a discount or premium of less than one cent. Variety, as a quality characteristic, does not appear to have a strong effect on prices. The exception appears to be the Granny Smith variety which holds a distinct price advantage over the other varieties in the markets in which it is sold. Currently, the Granny Smith is grown primarily in the Western states where it is very popular.

The next characteristics represent size and grade. As expected, small and extra small apples sell at a discount to the standard size of medium, whereas the large size sells at a premium. The significance levels indicate a strong relation between the size of an apple and its price. Each coefficient was highly significant at the five percent level, an indication that size and the price of an apple are highly correlated. Signs for the grade category were correctly predicted, with the regression producing negative coefficients. The quality characteristics for size and grade show the most consistent relationship with price.

The coefficients on the storage category were as expected. Controlled atmosphere apples bring a premium to cold stored apples. The premium is sizeable at $1.28 and statistically significant. This premium reflects a higher cost situation but could also imply a higher quality associated with controlled atmosphere stored apples. These variables do not reflect seasonality in prices, which are already accounted for by the monthly dummy variables.

The final group of dummies represents the Alar variables. Signs on the coefficients were as predicted, with each region showing a discount to the 1986 Red Delicious apple. The coefficient on the Washington variable produced the largest discount at $2.72. The Hudson Valley and Michigan regions suffered much smaller discounts of $1.04 and 67 cents, respectively. The levels of significance are also very different among the regions. The Washington Alar variable was the only one with a significant coefficient. This implies that the prices in other regions were not significantly affected by the Alar scare. In addition, this analysis shows that not only did Washington experience a drop in prices for Red Delicious apples, this drop was highly significant.

For the overall regression, statistics indicate that the variables selected explain the model very well, with an R^2 and an Adjusted R^2 of 0.86. Autocorrelation was nearly eliminated as exhibited by a Durbin-Watson statistic of 1.83. The F-statistic was 313.73, with 35 degrees of freedom.

IV. ALTERNATIVE MODELS

Log-linear (Model II) and real price versions (Model III) were also run to test the integrity of the basic model. Both models produced results similar to those of Model I [See Appendix I and Table 4.3]. Coefficients of the log-linear regression represent the elasticity of the dependent variable with respect to the independent variables, instead of premiums and discounts. For Model III, the time shift variables representing crop year were omitted. The CORC method of correcting for first degree autocorrelation was employed in both alternative models.

A. Model II

Comparison of Models I and II revealed some slight differences. The log-linear functional form displayed a good fit with an R^2 of 0.89. The Durbin-Watson statistic was also slightly higher than Model I at 1.88. However, both versions indicate a strong relationship between the size, grade, and seasonality categories, and price.

In total, there were five differences between the two models worth noting. First, the coefficient on the 1988 crop year dummy becomes significant in Model II. The variable for the Empire variety becomes significant in Model II. The coefficient on the Rome variable is negative, implying that the variety earns a discount instead of a premium indicated in Model I. The latter two differences do not change the underlying message of the model, since the majority of the coefficients in the variety category remain insignificant in Model II. The high incidence of insignificant variables in this group suggests that variety is not a characteristic which influences price with the exception of the Granny Smith variety. In addition, the magnitudes of these coefficients are small, with Empire showing the largest elasticity of 0.05. The remaining varieties--Golden Delicious, McIntosh, Ida Red, and Rome--show elasticities of -0.02, 0.01, 0.0008, and -0.01, respectively, indicating that--assuming the variables were significant--price is not sensitive to changes in variety. This is the same conclusion drawn from Model I.

The remaining differences occur in the seasonality category. Although the June coefficient continues to be insignificant at the five percent confidence level in Model II, it becomes more significant. The August variable becomes insignificant, but reasons for this shift are not clear.

B. Model III

Model III used prices corrected by the CPI as the dependent variable. The dummy variables for crop year were excluded from the model. Otherwise, the model is identical to Model I. In this version, two coefficients have opposite signs and one coefficient becomes insignificant when compared to Model I. For region, the previously significant coefficient for the region of Western/Central New York becomes insignificant and the sign on the variable for Michigan becomes negative.

For the variety category, Rome reveals a discount of 0.6 cents in contrast to a premium of five cents in Model I. However, the magnitude of the coefficients are small. The highest differential, excluding Granny Smith, is associated with the Empire variety, showing a premium of 44 cents. The others differ from the standard by less than 15 cents per box. For the overall regression, Model III shows a lower R^2 of 0.856 but a slightly higher Durbin-Watson statistic of 1.88. Despite these differences, the tradeoffs offered by Model III do not render it better than Model I, and more importantly, the conclusions do not change.

C. OLS Regressions

Appendices II, III, and IV show the results from OLS regressions run for Models I, II, and III. These results provide some additional insight into the methodology used. Each of the OLS regressions produces results similar to the CORC counterpart. However, the Durbin-Watson statistic in each case indicates a high degree of autocorrelation. The F-statistics and the R^2 are lower in the OLS versions, but the overall regressions remain highly significant. Therefore, the use of the CORC method of correcting for autocorrelation was a reasonable step in achieving a statistically satisfactory model, and does not alter the story emerging from the initial OLS results.

V. CONCLUSION

This chapter showed the results of a hedonic model for apple prices. By breaking down the apple into separate quality-related components (quality characteristics) and econometrically estimating coefficients on these variables, price differentials of the characteristics were derived. The variables chosen were crop year, seasonality (month of the price quote), region, variety, size, grade, storage method, and a variable created to measure the effect of the Alar scare on apple prices for the 1988 crop year.

Three versions of the model were developed in addition to running an OLS regression of each model. Model I, the model used for analysis, regressed the eight variables on nominal prices for seven recent crop years, employing a linear functional form. Results from Models II and III were compared to Model I in order to show that there was no bias involved in selecting Model I, as all the models produced very similar results.

Principal findings of the analysis are as follows: region and variety are not characteristics for which a differential can be attached; the coefficients on the monthly variables revealed a definite seasonal pattern in prices; the size, grade, and storage method categories exhibited a strong relationship to price in terms of earning consistent premiums and discounts; the Alar variable was able to provide some insight into the degree to which prices in each of the major producing areas were affected. The Washington crop was the most severely affected and there was no significant change in prices for Michigan and New York.

Statistics for the overall regressions indicated that the variables chosen explained the dependent variable, price, very well and that the incidence of autocorrelation, which was present in the OLS version of each model, was reduced to acceptable levels in Models I, II, and III by use of the CORC method of regression. The result was a highly explanatory model which offered some very useful and interesting insights into the nature of apple prices. A longer time series may have changed the signs on the region variables. The time period used--seven years--is a relatively short time span for a commodity which has a history as long as the apple. However, the results obtained in this analysis accurately reflected the price behavior for the shorter time period.

Having attempted three different regressions which produced similar results reinforces the validity of the fundamental model. Clearly, any of the three versions could have been selected for the final analysis as only slight differences were observed, none of which affected the outcome.

CHAPTER FIVE

IMPLICATIONS FOR ARIZONA APPLE GROWERS

Since the late 1970's, the area in and around Willcox, Arizona, located approximately 70 miles southeast of Tucson, has developed a respectable apple growing industry. Recently, however, growth rates have declined because of several mitigating factors: tax structures, high water costs, climatic conditions, and competitive markets. Changes are needed to break the rut in which the industry is entrenched. This study has estimated an hedonic price model for the national apple market. The results showed some factors had a strong and consistent relationship to the price of an apple. Therefore, the results from this study may find a practical application to the Arizona apple industry.

Four applications will be examined: a closer look will be taken at the seasonal trends suggested by the coefficients for the monthly variables; the size factor will be examined for its potential to improve current prices in Willcox; the benefits from adding controlled atmosphere facilities will be examined; and an analysis will be made of the values of different grades. Currently, Arizona uses the U.S. grading system. However, plans are underway to implement a grading system that will be unique to Arizona.

I. PROFILE OF THE ARIZONA APPLE INDUSTRY

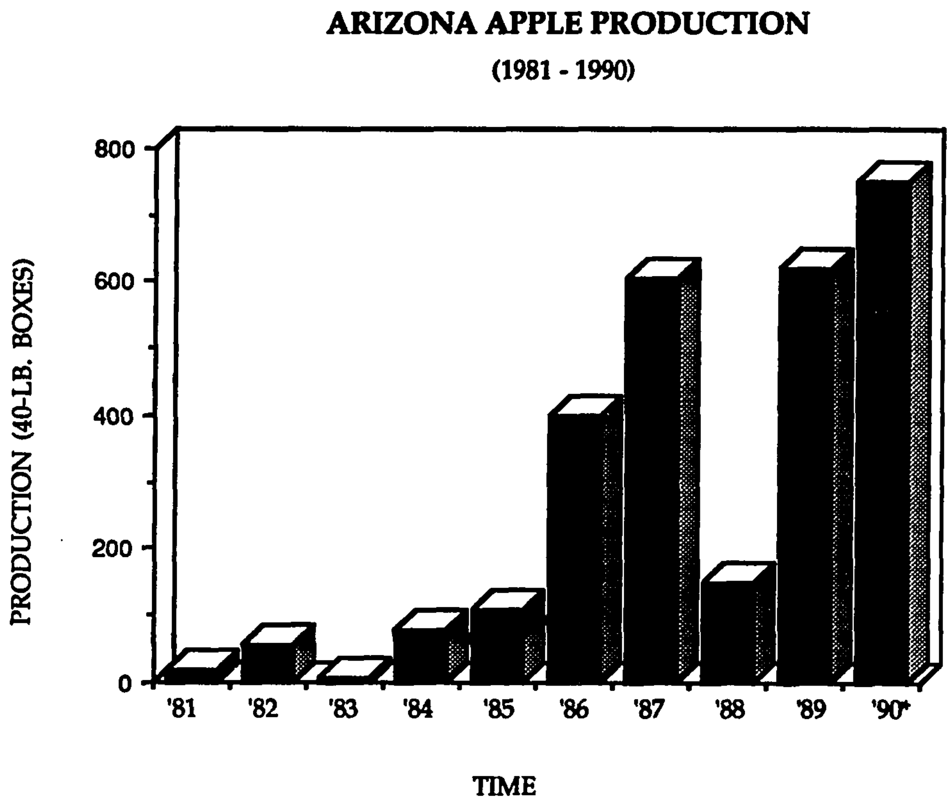
Currently, approximately 4,100 acres of apple trees are planted in Willcox. Contrary to forecasts made in 1987 (Wright and Gibson, Pt. I), no new trees have been planted in the last three years. According to the study, planted acreage was projected to double to approximately 8,000 acres by the year 1996.

The reasons for the sudden halt in expansion are mainly economic. Foremost are changes in tax laws and the high cost of pumping water. Prior to 1986, depreciation on capital investments followed the Accelerated Cost Recovery System (ACRS) which allowed investors to deduct the full cost of an investment over 15 years by taking the cost, dividing the figure by 15, and deducting this fraction each year for 15 years. The Tax Reform Act extended the period to 27.5 years, effectively reducing the deduction by almost half. Capital gain tax laws were also affected. Specifically, gains from the sale of capital after 1986 are 100 percent taxable, whereas prior to 1986, only 40 percent of the gain was taxable. As a result of these changes, agriculture has found it more difficult to attract investment:

> Tax laws prior to the Tax Reform Act of 1986 were certainly conducive to the formation of limited partnerships and other financial instruments for the purpose of investing non-agricultural income in farming ventures . . . . the large investments in Willcox apple orchards were made between 1980 and 1985 (Wright and Gibson, Pt. II, p. 6).

Production for the 1990 crop year is expected to be around 750,000 40-pound boxes (Traubel). This figure is the highest production level reached by the Willcox area since 1981. Part of the success has been attributed to good weather experienced during the 1990 harvest period. Figure 5.1 shows production for Arizona for the period 1981 through 1990:

(Figure 5.1)



Source: Arizona Daily Star, October 22, 1990. P. D-8.
* Preliminary, Source: Larry Traubel, Treasurer, Arizona Apple Growers Association

The full potential of current acreage has not been reached because many growers cannot afford to maintain all of their bearing acreage. Further acreage is not likely until growers utilize what is currently planted.

Therefore, it is difficult to forecast when maximum production on current planted acreage will be reached.

Currently, almost 100 percent of the planted trees have reached bearing age. Four major varieties are grown: Granny Smith, Red Delicious, Golden Delicious, and Gala. Approximately 40 percent of the area is devoted to Granny Smith, 30 percent to Red Delicious, 10 percent to Golden Delicious, and 10 percent to Gala and miscellaneous varieties.[4]

Of the 750,000 boxes harvested in 1990, approximately 175,000 were fresh packed. The remainder, approximately 525,000 boxes, were sent to the processed market (Traubel). The percentage of fresh to processed differs from year to year in Arizona. On a national level, approximately 55 percent is sold fresh, a share that has been constant over the recent past. A processed apple is easier to grow because the quality requirements are not as high as those for an eating apple. Also, the market for processed apples is usually more reliable. Buyers for processors are not so influenced by factors which play a role in the fresh markets, such as origin or perceived quality differences.

Twelve growers in the Willcox area own most of the acreage. This figure has declined by almost half in the last decade (Traubel). A shuffling of packing house ownership has occurred more recently. In 1989, there were four packing houses, run by Arizona Sweet-Apples, Bonita Valley, Valley Farms, and the Willcox Apple Packing Company (WAPCO). Today, there are

---

[4]Miscellaneous varieties include Rome, Jonathan, Criterion, Northern Spy, Lunna Red, Summer Treat, Fuji, and Braeburn.

two: Arizona Packing and Cold Storage, the parent company of Arizona Sweet-Apples, and Valley Farms. The latter took over operation of the Bonita Valley packing shed, and Arizona Packing and Cold Storage took over WAPCO.

Consolidation of the packing houses is a result of the economic difficulties experienced by the Arizona apple farmers. Apparently, growers are trying to minimize financial risks by leaving the packing business. The packing houses which relinquished controls were operated by persons who also owned their own orchards. The existing packing houses are currently operated by out-of-state entities. Arizona Packing and Cold Storage, for example, is managed by a Washington corporation.

Through the use of brokers and self-marketing, Arizona producers sell their apples all over the world, including Germany, the United Kingdom, and Taiwan. However, about 70 percent of Arizona apples are sold in the Los Angeles area (Arizona Daily Star, p. D-8). Exports have not played a major role in the Arizona apple industry in the past, but there are hopes that exports might provide some market opportunities in the future.

Current expectations are that growth will be negligible. Two changes in the cost of production could change this outlook. First, a decrease in water costs would allow more planted acreage to come into production sooner than would otherwise occur. For Arizona apple growers, the costs associated with pumping water are the greatest expense in their budget. Second, a change in current tax structures may make investment more attractive. Another category of change involves efforts to increase the value of Arizona's apples. The latter option serves as the focus of this chapter.

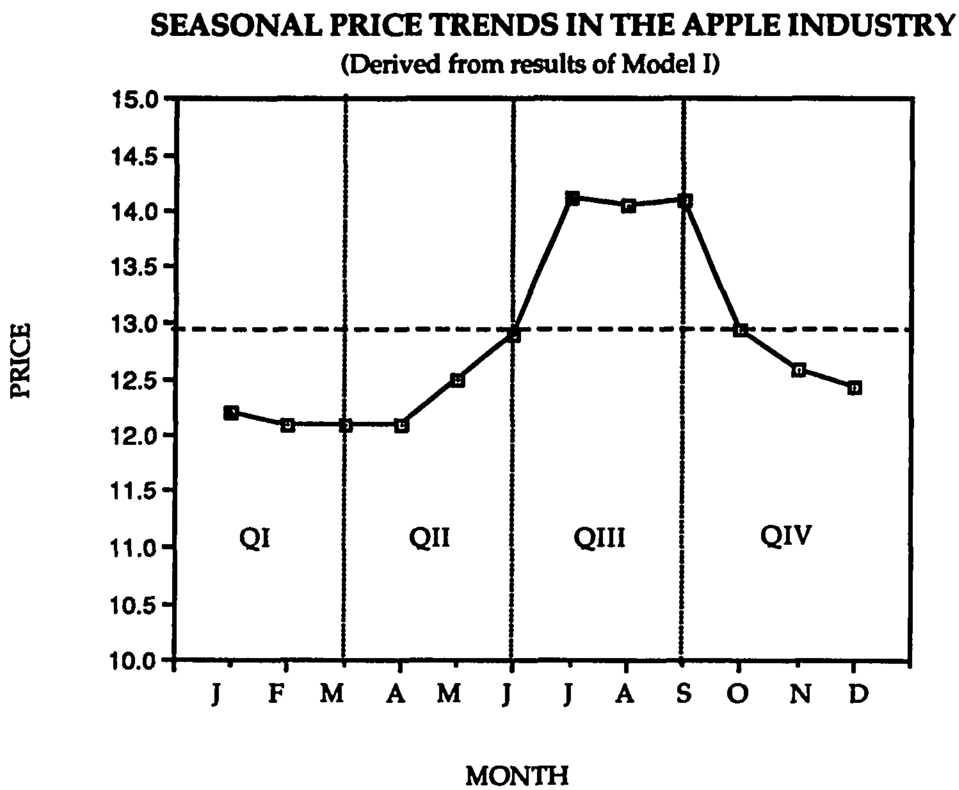
II. A STRATEGY FOR THE ARIZONA APPLE GROWERS

The hedonic analysis of the U.S. apple industry established some findings which may be applied to the local industry. Seasonal price trends, sizes, grades, and storage method were shown to have strong and consistent relationships to the price of an apple. An attempt will now be made to apply these findings to Arizona.

A. Seasonal Trends

A distinct pattern in the movement of prices over the marketing year was established by the model. Figure 5.2 illustrates the seasonal fluctuation in prices using the coefficients for the monthly variables produced by Model I.

(Figure 5.2)



The dashed line drawn horizontally through the middle of the graph and intersecting the October price represents the constant term from the regression of Model I. All points lying above the line indicate that a premium is being earned vis-a-vis the standard, whereas all points below the line indicate a discount to the standard. These results show how a grower could time the most profitable way that apples could be brought to market.

To expedite the analysis, the graph has been divided into four different sections as observation suggests a quarterly movement of prices. These sections have been labeled QI, QII, QIII, and QIV. Quarter I represents the time of year when prices are lowest. Coefficients on the variables for these months produced by Model I reflected the largest discounts to the standard. The difference among the highest and lowest monthly prices during this time of year is only eleven cents, indicating steady demand. The average discount during this quarter (relative to the October price) is 81 cents per box, or two cents per pound. This is also the time of the year when the apples stored in controlled atmosphere facilities first appear on the market and the last of the cold storage apples are being sold. At the present time, Arizona does not market any controlled atmosphere apples.

Quarter II shows a very rapid increase in prices. The difference among the highest and lowest monthly prices is almost 80 cents. Prices remain an average of 43 cents per box, or one cent per pound, below the October price of $12.93. Demand typically surges during this time of year as marketing moves into the summer months. To enter the market during this quarter, controlled atmosphere facilities are required. As the marketing year progresses, growers experience positive gross returns to controlled atmosphere storage.

During Quarter III, prices are highest. This time of year encompasses both the end and the beginning of the marketing season. This creates a double opportunity for growers--if stocks are large enough from the previous crop year, they can simultaneously sell stored apple stocks in July and possibly into August, and fresh apples, usually harvested in late August and September. The average premium earned during this quarter is $1.15 per box, or three cents per pound. The benefits to selling apples during this quarter is five cents per pound more than Quarter I and four cents per pound greater than Quarter II--a factor of five and four, respectively. Large financial gains can be earned if a grower can sell apples during these months. This is also a hectic time of year for the apple industry as the harvesting and packing of the entire crop must be accomplished within a period of 60 days beginning in August or September.

For Arizona, the benefits from getting apples to market as soon as possible are very clear since participation in the marketing year is limited by storage capabilities. Due to the climate in Arizona, growers are able to harvest their apples 10 to 20 days earlier than the more established regions, such as Washington (Wright and Gibson, Pt. I, p. 8). This means that Arizona is able to take advantage of marketing opportunities during half of this quarter (mid-August through September).

The strategy of marketing windows (Ray, p. 6) considers three types of windows: a harvest window, a market window, and a profit window. Because Arizona is able to harvest apples early, the existence of a harvest window can be assumed. The market window opens when the opportunity arises to enter a market without much competition. This approach is often only a short-run strategy because others realize the opportunity to earn economic rents, and also enter the window. Competition increases to the point where no one earns higher than normal profits.

While the concept of the market window sounded promising, a source in the Arizona Apple Growers Association has stated that this strategy has not been as successful as they had hoped (Seitz). Specifically, the source explained that controlled atmosphere stocks from the larger regions have virtually eliminated the opportunity to earn premiums above what is already indicated by the model, reducing rents they might have been able to earn otherwise. In other words, it appears that the prediction that the window would have a short life span has rung true. Nevertheless, the benefits for early harvest still exist and Arizona continues to capture premiums during this time.

The final quarter reflects a decline in prices. As the winter months approach, demand drops off and prices fall. The quarter begins with the standard month of October, so during this month, no premium or discount is being earned. From this point, prices decline sharply, with the quarter ending with a 51 cent discount during the month of December. The average discount for this quarter is 29 cents per box, or 0.7 cents per pound. This amount is less than the discounts recorded in Quarters I and II. Prices remain low as the cycle begins again with Quarter I.[5]

B. Size

Apple size can be affected by using a combination of cultural practices, including watering, fertilization, and pruning. Other indirect ways of controlling size include the selection of varieties. A possibility for the future involves the biological manipulation of apple genetics. This technology has

[5]The same analysis using the real price regression (Model III) produces slightly different premiums and discounts for each quarter, but the overall differences between the quarters are the same.

been used for other perishable commodities, such as the tomato, but has yet to be applied to the apple.

The results of the hedonic model indicated that the size of an apple has a distinct relationship to price. An inverse relationship exists between price and the size of the apple. Extra small and small apples (any size falling in the range of 120 and above) receive a discount to the standard (medium size, with a range of 80 to 113), and a large apple (any size falling in the range of 72 and below) receives a premium to the standard. These coefficients show a sizeable difference between the price for an extra small and a large apple. Adding the discount for extra small, $3.63, to the premium for large, $1.79, reveals a price difference of $5.42, or 14 cents per pound between the extreme sizes.

The harvest from a tree follows a normal distribution with the medium size representing the bulk of the curve. The smaller and larger sizes fall in the tails. Because size cannot be totally controlled, the distribution is occasionally skewed to one of the extremes. In this case, as suggested by the results of the hedonic model, the grower would prefer a skewing to the larger sizes. Clearly, the benefits to be gained from a distribution favoring the larger end of the scale are considerable given the price difference between an extra small and a large apple.

C. Grade

Grade variables were also shown to have a significant effect on price, evident over several different versions of the model. Among the quality characteristics chosen for this analysis, grade is the characteristic which most closely reflects the physical quality of the apple. Grades are based on the consistency and deepness of color and the percentage of defects present on the apple. These factors can be influenced in the growing process. To achieve good color, several methods are currently practiced in Willcox (Traubel). Cool nights two to three weeks before harvest are critical to the development of the color of an apple. In Arizona, cool temperatures must often be encouraged by evening sprinkling or daily watering to cool the ground.

A second method involves planting cover crops such as weeds or grass. This prevents the reflection of heat from the ground; reflected heat can cause the fruit to sunburn and fade the color of the apple. Another method currently used by Arizona apple growers to expedite harvest and improve color is the application of the chemical Ethrel. Ethrel increases the ethylene content in the apple which helps speed up the rate of maturation. However, Ethylene must be used simultaneously with cool evenings. Otherwise, the apples will mature without sufficient color, forcing harvest before the apples have developed good color.

Bruising usually occurs during harvesting and packing. The only method of prevention is added care in the handling of the apples by pickers and packers.

The results of the model indicated that both the Fancy and combination grades (consisting of Fancy and Extra Fancy apples), were at a discount to the standard of Extra Fancy. The discounts were $1.29 and $1.45, respectively. Of the regions selected in this analysis, Washington is the only state with its own grading system. Their system is more stringent than the

U.S. system and is thought to have helped Washington to gain a price advantage over the other regions. The Washington grade is implicitly recognized because it was selected as the standard for the regional variables. Therefore, a premium for the Washington Extra Fancy grade--not exceeding the discounts for each of the remaining grades ($1.29 and $1.45)--can be attributed to the fact that it is a Washington grade. The balance of this differential is attributed to the discount associated with the lower quality grade. Further research would be required to estimate the precise premium associated with the Washington grade.

According to sources in the Arizona Apple Growers Association, growers in the Willcox area are planning to create a grading system unique to Arizona. Unlike Washington, the Arizona grading system would not be based on U.S. standards. Instead, Arizona will try and capitalize on the sweeter taste of their apples. Because of relatively high temperatures during the period before harvest, apples are 10 to 15 percent higher in sugar content than apples grown in other areas. If the program is successful in differentiating apples grown in Arizona, conclusions drawn from the hedonic analysis indicate that this could possibly provide the local industry with a welcome boost.

D. Storage

Currently, no controlled atmosphere storage facilities are available to Arizona growers. Controlled atmosphere storage controls the exchange of nitrogen and oxygen in the air, thereby delaying the ripening process. Results of the model indicated that apples stored in controlled atmosphere facilities earned a consistent premium over the cold stored apples. The price advantage to controlled atmosphere storage is $1.28 per box. This premium is earned during Quarters I, II, and III, when apples are brought out of controlled atmosphere storage.

Arizona growers have not pursued controlled atmosphere storage for several reasons. Current production in the Willcox area is small on a national scale--less than one percent of total U.S. production--and the supply of apples is generally depleted by the end of the calendar year. Additionally, the early market for apples has been sufficiently strong. If apples were difficult to sell during the first half of the marketing season, controlled atmosphere storage might be more attractive. Further, young bearing trees, which comprise a large share of the Arizona crop, do not produce apples which are conducive to long-term storage. The fruit is not as durable and tends to break down faster. Controlled atmosphere is best for apples produced by fully mature trees (Traubel).

The seasonal trend analysis, which presents some very similar implications for controlled atmosphere storage, divided the marketing year into four quarters. Quarters I, II, and III represent the time of year when controlled atmosphere stored apples are sold. The hedonic model produced coefficients on the monthly variables which represented the premiums and discounts earned during each month. Currently, Arizona is only concerned with the pricing situation in the months of August through December, although the possibility of extending the season into Quarters I through III has not been completely ruled out (Traubel). An analysis of costs and returns may reveal that controlled atmosphere storage would be beneficial. The decision is contingent on the costs associated with maintaining such storage facilities and if this cost would exceed the returns suggested by the hedonic model.

Table 5.1 lists revenue per box for each month of the marketing year. Prices for January through July are calculated from the sum of the coefficients on the monthly variables from Model I and the premium for controlled atmosphere storage ($1.28). August shows two prices, $14.04 and $15.32, which represent the cold storage and controlled atmosphere storage prices, respectively since both types are sold during this month. September through December prices are for cold storage apples.

(Table 5.1)

PRICES FOR STORED APPLES ($/40-POUND BOX)
(Nominal 1988 prices)

Month	Price	Average Price for the Quarter
Quarter I:		
January	13.47	13.40
February	13.37	
March	13.36	
Quarter II:		
April	13.38	13.78
May	13.78	
June	14.17	
Quarter III:		
July	15.39	15.36 (avg. for July-Aug.)
August	15.32/14.04	14.06 (avg. for Aug-Sept)
September	14.08	
Quarter IV:		
October	12.93	12.64
November	12.57	
December	12.42	

The highest prices occur in the first half of the third quarter, the period just before Arizona harvests. To sell apples during this period, controlled atmosphere facilities are required, since apples will not stay fresh for one year using regular cold storage. The average revenue per box is $15.36 over this six-week period (July through mid-August), an increase of $1.30 per box over prices in the second half of QIII when Arizona opens the season with fresh apples, and an increase of $2.72 per box over prices in Quarter IV. These amounts represent the gross return to apples put in storage in October. Further calculations are needed to determine if these gains justify investing in a controlled atmosphere facility (Seitz).

Future plans by Arizona packers include construction of controlled atmosphere facilities if profitable opportunities arise. Presently, there are two controlled atmosphere-capable rooms. These have been equipped with the required insulation, but do not have the necessary refrigeration mechanisms.

IV. CONCLUSION

A profile of the Willcox apple industry revealed a stagnant production sector. With no new plantings since 1987, previous forecasts of rapid growth have been tempered. There are no plans for expansion in the near future. The halt in growth has been attributed to two exogenous factors--increased costs of pumping water, an important input in the production process, and the ramifications of the Tax Reform Act of 1986.

Restrictively high costs coupled with unpredictable revenue has put Arizona in a situation of declining profitability. Since changes in production costs are not anticipated in the near future, the only solution appears to be a strategy which would increase revenue. Establishing a niche to provide Arizona with a price advantage in such a competitive market may also be a lofty idea. However, the results of this analysis may provide some support for such a strategy. This chapter applied the results of the hedonic model to

Arizona, and examined the influences of size, grade, season, and storage facilities on price.

The application of seasonal trends to the Arizona apple industry utilized an approach that divided the marketing year into four quarters. Results from the hedonic model showed that the highest premiums are earned during the months of July through September and the lowest prices occur during the months of January through March. The months of April through June and October through December are transitional periods when prices are increasing and decreasing, respectively, to reflect shifts in demand. Currently, Arizona producers begin harvesting during mid-August, 10 to 20 days earlier than Washington, when prices are relatively high. Accordingly, early harvesting of apples continues to be emphasized by Arizona growers.

Price differentials for size revealed significant gains to production methods that could favor larger sizes and produce fewer extra small apples. The gain is $5.42 per box or 14 cents per pound, the sum of the discount associated with extra small and the premium associated with large. To the extent that size can be controlled through cultural practices, such as watering, pruning, and fertilization, the farmer should be aware of the substantial benefits to doing so.

The coefficients on the grade variables indicated that Extra Fancy earns a premium over Fancy and the combination grade. The premium over the lower quality grades has implicitly incorporated the value associated with the Washington region. Therefore, the maximum benefit that can be attributed to the regional factor is equal to $1.45, the largest discount which was represented by the coefficient on the combination grade. Currently, Arizona is planning to implement a grading system which would be unique to Arizona. Due to the warmer temperatures, Arizona is able to grow apples that are higher in sugar content than the other major regions. If Arizona's experience is similar to Washington's, the results of the model suggest that the gains to establishing a state grade are only between one and three cents per pound. But if consumers have a substantial willingness-to-pay for sweetness, the premium could be larger.

The hedonic model indicated that controlled atmosphere stored apples earned a premium of $1.28 over cold stored apples. This premium is applicable to the months of January through August, when apples from controlled atmosphere storage are sold. Addition of this premium to the seasonal price coefficients revealed that there may be gains to investing in long term storage, particularly for sales during July and early August. The average value per box of apples sold during this period in which Arizona currently does not sell apples, $15.36, exceeded the average price per box of apples sold during the second half of QIII by $1.30, and average prices during Quarter IV by $2.72. Investment in controlled atmosphere facilities depends on whether the costs of investing and maintaining the facility exceed these gains.

CHAPTER SIX

CONCLUSION

This thesis developed an hedonic price model for the national apple market. Seven quality-related characteristics of the apple and a variable included to measure the effects of the Alar scare on the 1988 crop of Red Delicious apples were regressed on a seven-year monthly time series of prices. The results highlighted four specific characteristics that have a consistent relationship with price--size, grade, seasonality, and storage method. These conclusions were subsequently applied to the Arizona apple industry.

Development of the hedonic theory has been traced back to the early 1900's with an article by Andrew Court. In this article, the hedonic method was applied to the study of automobile prices. The method has been applied to nondurable goods as well. Application to agricultural commodities has been more common in the last 20 years with studies published on rice, cotton, barley, tomatoes, wheat, various vegetables, and lamb carcasses.

The theory is based on the assumption that a demand exists for a product's individual quality characteristics. This demand can be analyzed in much the same way as the demand for an aggregate product. The coefficients from a regression of these quality characteristics on prices represent the implicit prices associated with the individual characteristics of the product.

A. Overview of the Model

The independent variables used in the hedonic model for the apple industry were expressed as dummy variables. This method has proven to be effective in the case where the variables are discrete in nature. The quality characteristics chosen included crop year, seasonality, region, variety, grade, size, storage method, and a variable created to measure the effects of the Alar scare on the 1988 Red Delicious crop.

Prices were obtained from branch offices of the Market News Service, Agricultural Marketing Service--a department of the U.S. Department of Agriculture. Monthly price data was derived from weekly prices published in annual summaries by the Market News Service. The four regions selected for the model were Washington, Michigan, Hudson Valley, New York, and the Western/Central region of New York. Together, these four regions produce nearly two-thirds of the nation's total apple crop. Washington alone is responsible for almost half.

A time series of seven years was used, beginning with the 1982 crop year and ending with the 1988 crop year. The varieties chosen were Red Delicious, Golden Delicious, McIntosh, Granny Smith, Red Rome, Ida Red, and Empire. Together, these seven varieties account for about two-thirds of total consumption of apples. The sizes selected included extra small, to represent bagged apples, small, medium, and large. Grades included Fancy, Extra Fancy, and a combination of Fancy and Extra Fancy. Currently, there are only two types of storage used on a large scale--regular cold storage and controlled atmosphere storage. These were included in the model for the storage category. The seasonality variable was represented by a series of dummy variables for each month of the year. Values for the Alar variables were determined from a combination of data entered for crop year, region, variety, and seasonal categories.

Three different versions of the model were formulated. Model I, the version chosen for final analysis, employed a linear functional form with nominal price as the dependent variable. Model II used a log-linear functional form, regressing the eight independent variables on the natural log of price. Model III was identical to Model I with the following exceptions: real price was substituted for nominal price and the seven crop year variables were omitted. To correct for autocorrelation, the Cochrane-Orcutt regression method for correcting for first degree autocorrelation was used.

The results from Models I, II, and III were very similar, and lead to the same conclusions. Model I was selected to represent the analysis because the results were simple to interpret. Specifically, the coefficients on the variables were expressed in terms of dollars and cents which immediately revealed the price premium or discount associated with each characteristic. In contrast, a log-linear form produces coefficients which represent the elasticity of the dependent variable with respect to the independent variables, instead of premiums and discounts.

B. Results

The model provided a good picture of recent price behavior for apples in the United States. The majority of the signs on the coefficients were consistent with predictions. Furthermore, the statistical significance of each model was highly satisfactory with R^2 statistics falling in the 0.8 to 0.9 range and Durbin-Watson statistics close to two.

The model revealed that of the eight variables selected, six were particularly relevant in explaining price behavior. The variables representing region and variety were insignificant at the five percent level in Models I, II, and III. This implied that prices are not significantly influenced by either of these factors on a consistent basis.

The characteristics which were significant in each of the models were crop year, size, grade, seasonality, storage method, and the Alar variables. The Alar variables provided some interesting insights into the impact the Alar scare had on the three different regions. Washington was the only major region significantly affected by the Alar scare. Washington Red Delicious prices declined by nearly three dollars per box, compared to insignificant discounts suffered by Michigan and New York of 67 cents and $1.04, respectively. The variable representing crop year supported observed price behavior in the industry over the seven-year period. The coefficients on each crop year revealed a discount to the base year of 1986, when prices were their strongest.

The remaining four characteristics--size, grade, storage method, and seasonality--were highly significant in explaining price in each of the model versions. These were considered to hold the greatest potential for application to the Arizona apple industry. Coefficients on the size category indicated that discounts are associated with extra small and small, and a premium is paid for large apples. For grade, the Extra Fancy grade earned a premium compared to Fancy and the combination grade. Coefficients on the storage variables revealed that apples from controlled atmosphere storage earned a premium to regularly stored apples, and the coefficients on the monthly variables indicated a very definite seasonal pattern in prices.

C. Conclusions for Arizona

A profile of the current situation in Willcox revealed that there have been no new plantings since 1986. Causes for the stagnation in growth have been attributed to high production costs and restrictive tax laws. A record harvest of approximately 750,000 40-pound boxes is expected for the 1990 crop year because of exceptional weather. Despite the record crop, the future for Arizona remains uncertain. Changes are needed to break the Arizona apple industry out of a situation of declining profitability. Devising a strategy to increase the value of Arizona apples was the focus of the previous chapter. Using the results of the hedonic model, the benefits from altering certain production methods were analyzed.

Analysis of the monthly variables indicated a seasonal pattern in prices. The marketing year was divided into four quarters--QI, January through March; QII, April through June; QIII, July through September; and QIV, October through December. The coefficients on the monthly variables showed the highest premiums are earned during Quarter III; prices are lowest during Quarter I; and Quarters II and IV are transitional periods when prices are increasing and decreasing, respectively.

The quantity of apples produced in the Willcox area is not large enough to last into the second half of the marketing year, which begins in January. Most are sold by the end of December. As a result, only half of the seasonal pattern in prices is relevant to the Arizona industry (Quarters III and IV). Quarter I revealed an average discount of 81 cents per box to October (the base month); Quarter II, a 43 cent per box discount; Quarter III a $1.15 per box premium; and Quarter IV, a 51 cent per box discount to the base.

Quarter III, the time of year when prices are highest, encompasses the end of one marketing season and beginning of the next. Due to the Arizona climate, apples are harvested 10 to 20 days earlier than in the larger regions and Arizona growers sell apples during half of Quarter III (mid-August through September). Controlled atmosphere storage facilities would be necessary to store apples and sell during the first half of Quarter III.

Results of the model also implicated size and grade as having a consistent relationship with price. However, size and certain aspects of grade are limited by biological factors. Technology has provided some cultivation practices which can influence the size of the apple, such as pruning, increased water application, and fertilization. The size distribution of apples typically follows a bell curve pattern, with the medium size accounting for the bulk of the curve. Skewing of the distribution is common and when it occurs, growers indicate a preference toward the larger size.

This assertion is clearly supported by the results of the model, with a premium of $1.79 per box associated with large, and a discount of $3.63 per box for the extra small size. Thus, for each unit increase in production of large apples and consequent decrease in production of extra small apples, the gains are substantial--$5.42 per box, or 14 cents per pound. The desirability of such a strategy depends on the costs of altering production methods to increase output of large apples.

To the degree that grade can be controlled, the model strongly suggests that there are premiums to be earned by grades which reflect a higher quality. Currently, the Arizona growers are designing a unique grading system. The new system will be based on sugar content.

Coefficients on the grade variables showed that the Fancy and combination grades earned a discount of $1.29 and $1.45 per box, respectively, to the base grade of Extra Fancy. Implicit in the differentials is the Washington origin, as Washington was selected for the standard for the regional variables. The premium attributed to the state grade thus cannot exceed the values of the discounts for the Fancy and combination grades. This implies that the gains to successfully establishing a state grade is only between one and three cents per pound, substantially less than the gain associated with increasing size. Nevertheless, Arizona may discover that a grade based on sugar content may have a greater value than the Washington grades.

The implications for controlled atmosphere storage were similar to those indicated for seasonality in prices. The model showed that apples from controlled atmosphere storage are worth $1.28 per box more than those from cold storage. By adding this figure to the coefficients produced by the model for the months January through August, the gains to storage accrued during the last weeks of the marketing season (July through mid-August) increase to $2.43. This figure is derived by subtracting the October base price of $12.93 from the average price for the first half of QIII, $15.36. Using the same analysis, prices for Quarters I and II showed average gains of 47 cents and 85 cents per box respectively, over the October base price. Therefore, controlled atmosphere storage will be a good investment if costs do not exceed the premiums indicated.

APPENDIX I
MODEL II: RESULTS

Variable	Coefficient	T-Statistic	Significance Levels
Constant:	2.58	87.60	.000
Crop Year:			
1988	(0.07)	(2.04)	.041
1987	(0.26)	(8.80)	.000
1985	(0.12)	(3.98)	.000
1984	(0.15)	(4.73)	.000
1983	(0.17)	(5.12)	.000
1982	(0.32)	(9.99)	.000
Month:			
January	(0.08)	(8.40)	.000
February	(0.10)	(8.45)	.000
March	(0.10)	(7.79)	.000
April	(0.10)	(7.60)	.000
May	(0.05)	(4.11)	.000
June	(0.03)	(1.91)	.056
July	0.05	2.19	.029
August	0.02	0.93	.351
September	0.10	10.79	.000
November	(0.04)	(5.20)	.000
December	(0.06)	(6.34)	.000
Region:			
Hudson Valley, NY	0.05	1.33	.185
Western/Central, NY	0.11	3.34	.001
Michigan	0.05	1.27	.203
Variety:			
Golden Delicious	(0.02)	(0.96)	.339
McIntosh	0.01	0.51	.609
Ida Red	0.0008	0.04	.968
Granny Smith	0.38	13.36	.000
Empire	0.05	2.14	.032
Rome	(0.01)	(0.69)	.493

(Appendix I, continued)

Variable	Coefficient	T-Statistic	Significance Levels
Size:			
Extra Small	(0.34)	(9.34)	.000
Small	(0.12)	(9.64)	.000
Large	0.13	8.59	.000
Grade:			
Fancy	(0.13)	(4.36)	.000
Combo	(0.11)	(4.35)	.000
Storage Method:			
Controlled Atmosphere	0.13	13.93	.000
Alar Variable:			
Washington	(0.24)	(6.99)	.000
New York	(0.11)	(1.93)	.053
Michigan	(0.06)	(1.39)	.166
Statistics of Regression:			
R^2:	0.89	Adjusted R^2:	0.89
Durbin-Watson:	1.88	F-Statistic:	403.94

APPENDIX II
OLS REGRESSION OF MODEL I: RESULTS

Variable	Coefficient	T-Statistic	Significance Levels
Constant:	12.98	59.15	.000
Crop Year:			
1988	(0.77)	(4.59)	.000
1987	(2.63)	(16.22)	.000
1985	(1.09)	(7.06)	.000
1984	(1.27)	(7.84)	.000
1983	(1.71)	(10.27)	.000
1982	(2.87)	(17.87)	.000
Month:			
January	(0.61)	(3.23)	.001
February	(0.77)	(3.52)	.000
March	(0.79)	(3.16)	.002
April	(0.87)	(3.40)	.001
May	(0.61)	(2.21)	.028
June	0.15	0.43	.668
July	1.40	3.37	.001
August	0.69	1.51	.130
September	1.03	4.34	.000
November	(0.25)	(1.30)	.195
December	(0.35)	(1.82)	.069
Region:			
Hudson Valley, NY	0.61	2.26	.024
Western/Central, NY	1.06	4.40	.000
Michigan	0.47	1.86	.064
Variety:			
Golden Delicious	0.25	1.84	.065
McIntosh	0.64	5.01	.000
Ida Red	0.27	1.28	.200
Granny Smith	5.54	25.76	.000
Empire	0.75	3.01	.003
Rome	(0.006)	(0.03)	.976

(Appendix II, continued)

Variable	Coefficient	T-Statistic	Significance Levels
Size:			
Extra Small	(3.40)	(10.11)	.000
Small	(1.70)	(12.05)	.000
Large	1.54	9.12	.000
Grade:			
Fancy	(1.56)	(4.67)	.000
Combo	(1.60)	(7.20)	.000
Storage Method:			
Controlled Atmosphere	1.28	7.81	.000
Alar Variable:			
Washington	(4.61)	(10.65)	.000
New York	(0.33)	(0.43)	.665
Michigan	(0.63)	(1.00)	.316
Statistics of Regression:			
R^2:	0.74	Adjusted R^2:	0.73
Durbin-Watson Statistic:	0.64	F-Statistic:	139.61

APPENDIX III
OLS REGRESSION OF MODEL II: RESULTS

Variable	Coefficient	T-Statistic	Significance Levels
Constant:	2.58	140.74	.000
Crop Year:			
1988	(0.08)	(5.54)	.000
1987	(0.27)	(19.79)	.000
1985	(0.13)	(10.26)	.000
1984	(0.15)	(11.31)	.000
1983	(0.17)	(12.24)	.000
1982	(0.31)	(23.33)	.000
Month:			
January	(0.07)	(4.57)	.000
February	(0.09)	(4.95)	.000
March	(0.09)	(4.47)	.000
April	(0.10)	(4.75)	.000
May	(0.07)	(3.16)	.002
June	(0.03)	(0.90)	.371
July	0.06	1.70	.090
August	(0.01)	(0.32)	.747
September	0.10	5.01	.000
November	(0.03)	(1.86)	.063
December	(0.04)	(2.78)	.005
Region:			
Hudson Valley, NY	0.06	2.50	.013
Western/Central, NY	0.11	5.26	.000
Michigan	0.04	1.93	.053
Variety:			
Golden Delicious	0.02	1.37	.172
McIntosh	0.05	4.34	.000
Ida Red	0.02	0.89	.371
Granny Smith	0.41	22.94	.000
Empire	0.08	4.02	.000
Rome	(0.02)	(1.10)	.272

(Appendix III, continued)

Variable	Coefficient	T-Statistic	Significance Levels
Size:			
Extra Small	(0.34)	(12.07)	.000
Small	(0.14)	(12.18)	.000
Large	0.01	7.03	.000
Grade:			
Fancy	(0.15)	(5.40)	.000
Combo	(0.13)	(6.91)	.000
Storage Method:			
Controlled Atmosphere	0.13	9.77	.000
Alar Variable:			
Washington	(0.43)	(12.01)	.000
New York	(0.04)	(0.56)	.578
Michigan	(0.06)	(1.09)	.275
Statistics of Regression:			
R^2:	0.78	Adjusted R^2:	0.77
Durbin-Watson Statistic:	0.59	F-Statistic:	170.79

APPENDIX IV
OLS REGRESSION OF MODEL III: RESULTS

Variable	Coefficient	T-Statistic	Significance Levels
Constant:	10. 79	54.99	.000
Month:			
January	(0.90)	(4.69)	.000
February	(1.08)	(4.88)	.000
March	(1.06)	(4.22)	.000
April	(1.12)	(4.33)	.000
May	(0.72)	(2.59)	.010
June	(0.26)	(0.72)	.471
July	0.94	2.25	.024
August	0.30	0.66	.508
September	0.91	3.77	.000
November	(0.21)	(1.09)	.277
December	(0.30)	(1.52)	.129
Region:			
Hudson Valley, NY	(0.12)	(0.46)	.648
Western/Central, NY	0.46	1.95	.052
Michigan	(0.42)	(1.73)	.084
Variety:			
Golden Delicious	0.39	2.86	.004
McIntosh	0.57	4.41	.000
Ida Red	0.33	1.53	.126
Granny Smith	4.66	21.70	.000
Empire	0.74	2.95	.003
Rome	(0.003)	(0.02)	.986
Size:			
Extra Small	(3.31)	(9.84)	.000
Small	(1.51)	(10.67)	.000
Large	1.53	8.96	.000

(Appendix IV, continued)

Variable	Coefficient	T-Statistic	Significance Levels
Grade:			
Fancy	(0.57)	(1.71)	.086
Combo	(0.89)	(4.15)	.000
Storage Method:			
Controlled Atmosphere	1.14	6.92	.000
Alar Variable:			
Washington	(4.45)	(10.69)	.000
New York	(0.54)	(0.71)	.476
Michigan	(0.55)	(0.88)	.378
Statistics of Regression:			
R^2:	0.66	Adjusted R^2:	0.66
Durbin-Watson Statistic:	0.51	F-Statistic:	117.79

APPENDIX V
MODEL I USING CORC METHOD OF CORRECTING FOR SECOND-DEGREE AUTOCORRELATION: RESULTS

Variable	Coefficient	T-Statistic	Significance Levels
Constant	13.02	41.47	.000
Crop Year:			
1988	(0.63)	(1.91)	.057
1987	(2.56)	(8.13)	.000
1985	(0.95)	(3.12)	.002
1984	(1.18)	(3.62)	.000
1983	(1.61)	(4.85)	.000
1982	(2.87)	(8.85)	.000
Month:			
January	(0.75)	(5.84)	.000
February	(0.86)	(5.97)	.000
March	(0.87)	(5.56)	.000
April	(0.82)	(5.24)	.000
May	(0.42)	(2.57)	.010
June	(0.06)	(0.28)	.782
July	1.19	4.34	.000
August	1.10	3.89	.000
September	1.13	9.33	.000
November	(0.37)	(3.73)	.000
December	(0.53)	(4.28)	.000
Region:			
Hudson Valley, NY	0.56	1.35	.177
Western/Central, NY	1.10	2.93	.003
Michigan	0.48	1.20	.229
Variety:			
Golden Delicious	(0.03)	(0.17)	.868
McIntosh	0.27	1.69	.091
Ida Red	0.18	0.68	.500
Granny Smith	4.99	15.14	.000
Empire	0.54	1.85	.064
Rome	0.06	0.25	.804

(Appendix V, continued)

Variable	Coefficient	T-Statistic	Significance Levels
Size:			
Extra Small	(3.59)	(8.24)	.000
Small	(1.54)	(9.81)	.000
Large	1.74	9.43	.000
Grade:			
Fancy	(1.31)	(3.49)	.000
Combo	(1.43)	(4.68)	.000
Storage Method:			
Controlled Atmosphere	1.25	11.02	.000
Alar Variable:			
Washington	(2.80)	(6.95)	.000
New York	(1.07)	(1.46)	.144
Michigan	(0.64)	(1.13)	.261
Statistics of Regression:			
R^2:	0.87	Adjusted R^2:	0.86
Durbin-Watson Statistic:	1.99	F-Statistic:	319.51

APPENDIX VI
MODEL I USING FIVE YEARS OF PRICE DATA: RESULTS

Variable	Coefficient	T-Statistic	Significance Levels
Constant	12.62	29.41	.000
Crop Year:			
1988	0.06	0.16	.874
1987	(2.07)	(5.64)	.000
1985	(0.88)	(2.41)	.016
1984	(1.28)	(3.21)	.001
Month:			
January	(0.77)	(5.13)	.000
February	(1.09)	(6.40)	.000
March	(1.05)	(5.69)	.000
April	(0.99)	(5.36)	.000
May	(0.51)	(2.63)	.009
June	(0.07)	(0.23)	.818
July	1.71	5.03	.000
August	1.42	4.11	.000
September	1.11	7.30	.000
November	(0.34)	(2.81)	.005
December	(0.51)	(3.53)	.000
Region:			
Hudson Valley, NY	1.08	1.92	.055
Western/Central, NY	1.46	2.84	.005
Michigan	0.74	1.35	.177
Variety:			
Golden Delicious	0.18	0.69	.492
McIntosh	0.43	2.10	.036
Ida Red	0.26	0.79	.429
Granny Smith	5.26	8.67	.000
Empire	0.50	1.58	.115
Rome	(0.07)	(0.24)	.811

(Appendix VI, continued)

Variable	Coefficient	T-Statistic	Significance Levels
Size:			
Extra Small	(4.05)	(9.00)	.000
Small	(1.66)	(8.02)	.000
Large	1.96	8.51	.000
Grade:			
Fancy	(1.12)	(3.09)	.002
Combo	(1.49)	(4.02)	.000
Storage Method:			
Controlled Atmosphere	1.42	10.38	.000
Alar Variable:			
Washington	(3.96)	(4.77)	.000
New York	(0.36)	(0.50)	.620
Michigan	(0.34)	(0.57)	.570
Statistics of Regression:			
R^2:	0.85		
Durbin-Watson Statistic:	1.80	F-Statistic:	230.00

REFERENCES

Adelman, Irma and Zvi Griliches (1961). "On an Index of Quality Change." American Statistical Association Journal. September, pp. 535-548.

Agricultural Statistics. United States Department of Agriculture. (1982-1988).

Anderson, Bruce L. Strategic Alternatives for the New York Apple Industry. Department of Agricultural Economics, Cornell University, Ithaca, NY. September, 1989. A.E. Res. 89-15.

"Apple Prices and Shipments." Agricultural Marketing Service, Fruit and Vegetable Division. United States Department of Agriculture. June 20, 1989.

Bale, Malcolm D. and M. Ryan (1977). "Wheat Protein Premiums and Price Differentials." American Journal of Agricultural Economics. pp. 530-532.

Ball, M.J. (1973). "Recent Empirical Work on the Determinants of Relative House Prices." Urban Studies. Vol. 10, pp. 213-233.

Barnett, Colin J. (1985). "An Application of the Hedonic Price Model to the Perth Residential Land Market." Economic Record. Vol. 61(172): March, pp. 476-481.

Blackley, P., J.R. Follain, Jr., et. al. (1984). "Box-Cox Estimation of Hedonic Models: How Serious is the Iterative OLS Variance Bias?" Review of Economics and Statistics. Vol. 66, pp. 348-353.

Brorsen, Wade B., Grant, W.R., and Rister, M.E. (1984). "A Hedonic Price Model for Rough Rice Bid/Acceptance Markets." American Journal of Agricultural Economics. Vol. 66: May, pp. 156-163.

Brown, J.N. and Rosen, H.S. (1982). "On the Estimation of Structural Hedonic Price Models." Econometrica. Vol. 50(3): May, pp. 765-768.

Bultitude, John (1983). Apples: A Guide to the Identification of International Varieties. Macmillan Press: London.

Burstein, M.L. (1961). "Measurement of the Quality Change in Consumer Durables." Manchester School. Vol. 29, pp. 267-279.

Buxton, Boyd M. (1989). "Economic Impact of Consumer Health Concerns About Alar on Apples." Commodity Economics Division, Economic Research Service, USDA.

Cagan, Phillip. "Measuring Quality Changes and the Purchasing Power of Money: An Explanatory Study of Autos." in Griliches, 1971.

Carlson, R.F., et. al. (1970). North American Apples: Varieties, Rootstocks, Outlook. Michigan State University Press: East Lansing, Michigan.

Cassel, Eric, and Mendelsohn, Robert (1985). "The Choice of Functional Forms for Hedonic Price Equations: Comment." Journal of Urban Economics. Vol. 18(2): September, pp. 135-142.

"Cochise County Polishes Its Image." Arizona Daily Star. October 22, 1990. p. D-8.

"Commission Targets Media with 'Quality' Message." Washington Apples. October 21, 1989. pp. 6C-8C.

Court, Andrew T. (1939). "Hedonic Price Indexes with Automotive Examples." The Dynamics of Automobile Demand. General Motors Corporation, New York..

Cowling, K. and J. Cubbin (1972). "Hedonic Price Indexes for U.K. Cars." Economic Journal. Vol. 82, pp. 963-978.

Deaton, Angus, and J. Muellbauer (1980). Economics and Consumer Behavior. New York: Cambridge University Press, Chpt. 10.

Ethridge, D.E. and B. Davis (1982). "Hedonic Price Estimation of Commodities: An Application to Cotton." Western Journal of Agricultural Economics. Vol. 7, pp. 293-300.

Griliches, Zvi (1961). "Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change." The Price Statistics of the Federal Government. General Series, No. 73: National Bureau of Economic Research, New York.

Griliches, Zvi, ed. (1971). Price Indexes and Quality Change: Studies in New Methods of Measurement. Cambridge, Mass.: Harvard University Press.

Halvorsen, R. and H.O. Pollakowski (1981). "Choice of Functional Form for Hedonic Price Equations." Journal of Urban Economics. Vol. 10(1): July, pp. 37-49.

Jordan, Jeffrey L., et. al. (1985). "Estimating Implicit Marginal Prices of Quality Characteristics of Tomatoes." Southern Journal of Agricultural Economics. Vol. 17(2): December: pp. 139-146.

Kanemoto, Yoshitsugu, and Ryohei Nakamura (1986). "A New Approach to the Estimation of Structural Equations in Hedonic Models." Journal of Urban Economics. Vol. 19, pp. 218-233.

Ladd, George W. and M. Martin (1975). "Prices and Demands for Input Characteristics." American Journal of Agricultural Economics.

Ladd, George, W. and V. Suvannunt (1976). "A Model of Consumer Goods Characteristics." American Journal of Agricultural Economics.

Lancaster, Kelvin J. (1966). "A New Approach to Consumer Theory." Journal of Political Economy. Vol. 74: April, pp. 132-156.

Lancaster, Kelvin J. (1971). Consumer Demand: A New Approach. Columbia University Press: New York, 1971.

Lape, Fred (1979). Apples and Man. Van Nostrand Reinhold Company: New York.

Lucas, R.E.B. (1975). "Hedonic Price Functions." Economic Inquiry. Vol. 13, pp. 157-178.

Maynard, Harold H. (1923). Marketing Northwestern Apples. The Ronald Press Company: New York.

McConnell, K.E., and T.T. Phipps (1987). "Identification of Preference Parameters in Hedonic Models: Consumer Demands with Nonlinear Budgets." Journal of Urban Economics. Vol. 22, pp. 35-52.

Milon, J.W., J. Gressel, and D. Mulkey (1984). "Hedonic Amenity Valuation and Functional Form Specification." Land Economics. Vol. 6, pp. 378-387.

Monke, Eric and Todd Petzel (1984). "Market Integration: An Application to International Trade in Cotton." American Journal of Agricultural Economics. Vol. 66(4): November, pp. 481-487.

Murray, Michael, P. (1983). "Mythical Demands and Mythical Supplies for Proper Estimation of Rosen's Hedonic Price Model." Journal of Urban Economics. Vol. 14, pp. 327-337.

Nicholson, J.L. (1967). "The Measurement of Quality Changes." Economic Journal. Vol. 77, pp. 512-530.

O'Connell, J. (1986). "A Hedonic Price Model of the Paris Carcase Lamb Market." European Review of Agricultural Economics. Vol. 13(4), pp. 439-450.

Palmquist, Raymond B. (1982). "Measuring Environmental Effects on Property Values without Hedonic Regressions." Journal of Urban Economics. Vol. 11, pp. 333-347.

Petzel, Todd E. and Eric Monke (1979). "The Integration of the International Rice Market." Food Research Institute Studies. Vol. XVII(3), pp. 307-326.

Quigley J.M. (1982). "Nonlinear Budget Constraints and Consumer Demand: An Application to Public Programs for Residential Housing." Journal of Urban Economics. Vol. 12, pp. 177-201.

Ray, Derek. "The Marketing of Apples from Willcox, Arizona: Discussion Document." Wye College and the University of Arizona. April 5, 1989.

Rosen, Sherwin (1974). "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." Journal of Political Economy. Vol. 82, pp. 34-55.

Seitz, Alan. President, Arizona Apple Growers Association. Personal Communication, Fall, 1990.

Smith, Kerry V. (1983). "The Role of Site and Job Characteristics in Hedonic Wage Models." Journal of Urban Economics. Vol. 13, pp. 296-321.

Smock, R.M. and A.M. Neubert (1950). Apples and Apple Products. Interscience Publishers, Inc.: New York.

Thompson, R.S. (1987). "New Entry and Hedonic Price Discounts: The Case of the Irish Car Market." Oxford Bulletin of Economics and Statistics. Vol. 49(4): November, pp. 373-384.

Traubel, Larry. Treasurer, Arizona Apple Growers Association. Personal Communication, Fall, 1990.

Triplett, Jack E. (1969). "Automobiles and Hedonic Quality Measurement." Journal of Political Economy. Vol. 77, pp. 408-417.

"U.S. Not a Top Country in Apple Trade or in Per Capita Consumption." Apple News. International Apple Institute. Volume XX, No. 13. February 2, 1990. p. 8.

Veeman, Michele (1987). "Hedonic Price Functions for Wheat in the World Market: Implications for Canadian Wheat Export Strategy." Canadian Journal of Agricultural Economics. Vol. 35, pp. 535-552.

Warner, Geraldine. "Industry Assures Public of Reduced Chemical Use." Washington Apples. October 21, 1989.

Warner, Geraldine. "New Firmness Standard Eliminates U.S. No. 1." Washington Apples. October 21, 1989.

Willig, R.D. (1978). "Incremental Consumer's Surplus and Hedonic Price Adjustment." Journal of Economic Theory. Vol. 17, pp. 227-253.

Wilson, W.W. (1984). "Hedonic Prices in the Malting Barley Market." Western Journal of Agricultural Economics. Vol. 9, pp. 29-40.

Wright, N.G., H. Ayer, and L.J. Gibson. Willcox Area Apple Industry Analysis. Part I. University of Arizona, June, 1987.

Wright, N.G., H. Ayer, and L.J. Gibson. Willcox Area Apple Industry Analysis. Part II. University of Arizona, June, 1987.

Wynne, Peter (1975). Apples. Hawthorn Books, Inc.: New York.