ECONOMETRIC ESTIMATION OF TART CHERRY SUPPLY RESPONSE TO LOSS OF PESTICIDE ALTERNATIVES

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A PLAN B PAPER

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Agricultural Economics

1997

ABSTRACT

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Many agricultural producers are faced with the prospect of fewer chemical alternatives to mitigate damage from pests such as disease, weeds, insects, and rodents. Decreased pesticide availability can arise from health and environmental standards stipulated in federal and state regulations. Pesticide alternatives can also be lost due to natural pest resistance and economic considerations. The loss of pesticides due to economic considerations is especially troublesome to specialty crop producers such as fruit, fresh vegetable, and ornamental growers. Although these producers may use pesticides more intensively per acre than the major crop producers, the total acreage devoted to specialty crops is often not enough to warrant the pesticide registration costs faced by the chemical manufacturers.

The potential loss of important chemical alternatives could significantly affect the supply and price of specialty crops. This research develops an econometric supply and demand model of the tart cherry industry to estimate the supply response to the loss of the pesticides Difolitan™, Guthion™, and Funginex™. The tart cherry industry is representative of many specialty crops in that data on specific pesticide applications, pesticide expenditures, and other important variables are not readily available. Thus, the

tart cherry model illustrates the type of analysis that can be undertaken in the face of limited data.

The forecast model indicates that there are some important changes on the horizon for the tart cherry industry. Some of these changes appear to be influenced or exacerbated by the loss of pesticide alternatives, while other trends seem inevitable regardless of pesticide availability. A downward trend in grower prices is predicted over the next decade, however, this decline may be overwhelmed by the positive relationship between production losses (due to yield and acreage effects) and grower price. Bearing acreage is also predicted to decline over the forecast period. The decline appears to be slightly mitigated by the price increases associated with the loss of Guthion™. Yield predictions of course vary according to pesticide availability, with yield declining by up to 1000 pounds per acre when Guthion™ is assumed lost. Finally, the model predicts a declining trend in tart cherry demand over the next decade. Price increases associated with pesticide losses amplify this trend.

Direct estimation of the supply response through new plantings and orchard block removals was not possible due to data limitations. A more comprehensive supply response analysis, as well as improved accuracy in the model's predictions, could be obtained with the availability of data on new plantings, orchard block removals, pesticide applications levels, pest damage levels, and orchard characteristics (tree age, tree height, tree width, tree density, etc.).

ACKNOWLEDGMENTS

I would like to extend my gratitude to my committee members, Dr. Scott Swinton, Dr. Sandra Batie, and Dr. Richard Baillie, for their patience and guidance during this research endeavor. I would also like to acknowledge the valuable suggestions and feedback provided by Dr. Donald Ricks and Dr. Jake Ferris.

Many thanks to my friends at MSU--Dave Jones, Nicole Owens, and Karin Steffens. And finally, on the homefront, I'd like to thank my parents, Eugene and Jolana Rozanski, my brother, Steve, and my friend Melissa Kielion for their support.

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Chapter One: Introduction

1.1 Introduction

Chemical applications play an important role in most agricultural production in the United States. Growers apply chemicals to improve soil fertility and mitigate damage from pests such as disease, weeds, insects, and rodents. Pesticide applications are particularly important for agricultural crops in which product quality and cosmetic appearance are key determinants of grower price. Like many other fruit and fresh vegetable crops, tart cherry is a crop that falls into this category.

Prices received by tart cherry producers are strongly determined by fruit quality and appearance. According to regulations from the federal Food and Drug Administration (FDA), there is a zero tolerance for cherry fruit fly maggots in processed cherries. If a maggot is detected in a load of fruit, all of the cherries from that particular orchard will be rejected for sale. Other types of pest damage affect the grade (quality standard) of the fruit and hence the price growers receive (Ricks, 1996). Obviously, the effectiveness of pest control has important economic implications for tart cherry growers.

According to standard economic theory, tart cherry growers should apply pesticides until the marginal value product of pesticide applications is equal to the marginal costs of application. In other words, the grower should continue to apply pesticides so long as the value of the benefits from application (reduction in pest damage) is greater than the cost. The optimal application level occurs when the additional benefits are just equal to the additional costs of application. In practice, however, optimal pesticide applications are unlikely to be achieved. Pesticide labels report prescribed application rates. In such instances, the marginal benefits from increased applications may exceed the additional costs, but growers are not legally able to increase pesticide use. Also, the marginal benefits associated with pesticide applications are difficult to determine. Benefits from pest control depend on the potential for crop damage and losses due to pests. This potential for damage is uncertain and depends on factors that are difficult to predict such as weather, disease outbreaks, and pest infestations. Thus, in hindsight, actual pesticide applications may be greater or less than the optimal level.

Even if a grower is able to achieve the privately optimal rate of pesticide applications, it is unlikely that the application rates are socially optimal. Considering numerous environmental and toxicology tests, it appears that there is often a divergence between the private and social costs of pesticide applications. Pesticide applications have specifically been targeted by the U.S. Environmental Protection Agency (EPA) and the U. S. Department of Agriculture (USDA) as a source of environmental pollution that can lead to negative health effects. For instance, chemical and fertilizer residues have been found in groundwater and surface water. Over seventy-four pesticide residues (many linked to normal agricultural use) have been detected in groundwater sources (EPA). These residues can compromise the safety of drinking water. Contaminated surface water can diminish recreational opportunities such as fishing and swimming. Wildlife species or non-target organisms in the production environment are also susceptible to adverse health effects due to chemical applications. In addition to wildlife health, persons who are exposed to agricultural chemical residues through pesticide application or their proximity to chemically treated areas may be at risk. Finally, the consumption of chemical residues on raw and processed foods have been implicated in adverse health effects such as cancer, reproductive disorders, and developmental problems in children (Rushefsky, 1986; Antle, 1995).

In order to reduce the negative externalities associated with agricultural chemicals, pesticides must be registered by chemical manufacturers prior to their use by farmers. This registration process involves complying with the standards and requirements of the Federal Food, Drug, and Cosmetic Act (FFDCA) for pesticide residues in food and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) for pesticide handling and use. According to the Food Quality Protection Act of 1996, 33 percent of all existing tolerances are to be reviewed within 3 years, 66 percent within 6 years, and all of the existing tolerances are to be reviewed within 10 years (EPA, 1996).

Reregistration compliance involves several tests (and hence expenses) for chemical manufacturers. First, toxicity tests for humans, animals, and the environment must be completed for each chemical (Palmer, 1992). Chemicals that are probable carcinogens will not be reregistered for future use (Winter, 1993). Second, chemical manufacturers must determine pesticide residues and the resulting health implications for specific pesticide uses (Palmer, 1992). For example, if Guthion™ is used on both tart cherry and apple crops, separate tests must be performed for each crop. Chemicals that do not satisfy the FIFRA and FFDCA standards for a particular use will not be reregistered. Chemicals that are environmentally benign may be removed from the market simply because the chemical manufacturer's cost to reregister the pesticide for a particular use may exceed the expected revenue from future sale of the chemical. In this case, the pesticide manufacturer may opt to forego the reregistration process and discontinue the pesticide for that particular use.

1.2 Problem Statement

The loss of pesticides due to economic considerations is especially troublesome to specialty crop producers such as tart cherry growers. Even though specialty crop producers, such as fruit, fresh vegetable, and ornamental producers, may use pesticides more intensively per acre than major crop (corn, wheat, soybeans, wheat, or rice) producers, the total acreage devoted to specialty crop production is typically not enough to warrant pesticide reregistration. Experts have estimated that up to 4000 minor uses (such as applications on specialty crops) could be lost in the reregistration process (Palmer, 1992).

Accordingly, specialty crop producers such as tart cherry growers may see a reduction in the number of available pesticide alternatives due to economic and environmental considerations. The potential loss of important chemicals could significantly affect the supply and price of minor use crops. Fewer pesticides alternatives will reduce the supply of tart cherries at a given price and quality level. This research aims to develop an econometric supply and demand model for the U.S. tart cherry industry to estimate the supply response likely to result from the loss of pesticide alternatives (Guthion™ and Funginex™) for tart cherry.

1.3 Objectives

The objectives of this study include:

1. Review the relevant literature related to econometric supply response models, including perennial supply response estimation.
2. Review the relevant literature devoted to the economics of pesticide use to determine how to incorporate pesticide effects, given the available data, in an econometric model for the tart cherry industry.
3. Specify and estimate an econometric supply and demand model for tart cherry based on the information gleaned from the literature reviews as well as knowledge about the tart cherry industry.
4. Analyze and evaluate the findings of the econometric model. Particular attention will be given to determining the quality and accuracy of information about pesticide effects in the face of limited data.
5. Discuss implications of pesticide regulations for tart cherry prices and production based on research findings. Propose further research needs.

1.4 Significance of the Study

Researchers examining the economics of pesticide use and analyzing the policy implications of pesticide laws and regulations often lament the difficulty of their jobs due to data limitations. In the past, pesticide data series were highly aggregated (e.g., pounds of fertilizer applied to agricultural crops, pounds of other chemicals applied to agricultural crops, average expenditures on agricultural chemicals). Only recently have data on *specific* chemical applications on *specific* crops been reported. Even though there have been great strides is collecting pesticide use data, it is still difficult to locate data of this nature at the national, regional, and farm level.

Given that is likely to be several decades before complete pesticide data sets are available, it is important to determine what econometric models can be estimated with currently available data. Even more pressing is the need to assess whether the findings from econometric models based on such limited data are informative and accurate enough to justify the cost and effort associated with the estimation. The tart cherry industry is representative of many specialty crops in that data on pesticide applications, pesticide expenditures, and other input and price data are not readily available. Thus, econometric estimation of a model of the tart cherry industry will illustrate the type of analysis that can be undertaken given current data availability and will help identify the focus of current and future data collection efforts.

1.5 Organization of the Paper

The next chapter will be devoted to a review of the relevant literature about econometric supply response models for perennial crops as well as the literature about the incorporation of pesticide issues in econometric models. Chapter Three will provide basic background on the tart cherry industry and describe the specification and estimation of an econometric model for the U.S. tart cherry industry. The econometric model will then be analyzed and evaluated in Chapter Four. Finally, Chapter Five will summarize research conclusions and provide recommendations for future research needs.

Chapter Two: Literature Review

2.1 General Supply Estimation

Traditional supply function estimation captures the relationship between output price and production, holding all other factors constant. Often times, however, one is interested in the response of output to price changes, while allowing other factors to vary. Common factors that may cause supply to shift include:

- changes in profitability of complementary and competing crops
- technological changes (may influence yield and costs of production)
- changes in prices of joint products (commodities that are produced together)
- changes in level of price/yield risks faced by the producer
- changes in factor prices (fertilizer, seed, labor, land, pesticides, water)
- institutional constraints such as farm programs, pesticide regulations, insurance and disaster programs (Tomek and Robinson, 1990).

This research addresses the last category of supply shifters; analyzing how tart cherry production responds to changes in grower prices, while pesticide alternatives for tart cherry are removed from the market.

Time is an important factor in analyzing supply response. In the short run, one or more factors of production cannot be altered by individual producers due to a variety of circumstances. For example, biological lags in crop production (particularly important in perennial crops), short-term capital constraints, equipment delivery schedules, and various government permits may hinder a producer's ability to alter factors of production.

Specifically, in the short run, tart cherry producers may have to substitute less effective or more expensive chemical and non-chemical alternatives for "lost" pesticide alternatives. Over time, however, growers may become more adept at using the new alternatives, new alternatives may be introduced, and new crops or improved varieties may be planted. Consequently, industry supply is likely to be less elastic in the short run, as compared to the long run where producers can vary all factors of production (Tomek and Robinson, 1990).

2.2 Factors Affecting Perennial Supply

Perennial crop supply is affected by several mechanisms. Perennial crops are crops "which continue to produce without annual or biennial reseeding or replanting"(Herren and Donahue, 1991). In the case of tart cherries, trees, once planted, take approximately 5-6 years to begin producing a marketable yield and can continue to produce cherries for 20 to 25 years (Ricks, 1991). The long term nature of perennial crop production makes perennial supply response estimation a unique and challenging task.

The main supply response effects for perennial crops take place through **investment, disinvestment**, and **yield** mechanisms. Some of these supply mechanisms are under the direct control of the growers, while other factors are beyond their control. Growers can directly manipulate current and future production possibilities by planting new trees or removing existing trees (i.e., orchard blocks). Investment in an orchard by planting new tree blocks will increase future production potential. Disinvestment, or tree block removal, decreases current and future perennial crop production potential. Potential production is also heavily influenced by yield per acre or per tree. Production and management decisions such as varietal choice, soil management, pest management, and harvesting affect yield. Likewise, tree age of orchard blocks can have a great effect on potential production as yield typically varies by tree age. This phenomenon, called the "vintage effect," is determined by the grower's planting and removal decisions. Weather conditions, pest infestations, and other stochastic factors can also substantially affect marketable yield. These latter factors are outside the growers' control, but their effect on yield may be mitigated by production and management decisions.

In accordance with standard economic assumptions, perennial tree fruit producers are assumed to maximize expected profits from their orchards by deciding what to produce, how to produce, and how much to produce. Once the decision is made to produce tart cherries, growers are assumed to choose new planting, removals, pest management, and other management plans to produce output such that the marginal costs of production are equal to expected marginal revenue. Thus, the individual supply curve for a tree fruit producer is the upward sloping portion of the marginal cost curve, while industry supply is defined as the summation of each individual firm's production at various price levels (Tomek and Robinson, 1990).

2.3 Perennial Supply Response Literature

Given the numerous factors (producer decisions and stochastic factors) affecting perennial crop supply, much of the literature on perennial crops is devoted to formulating and estimating econometric models to capture all or some of these influences. The specification and formulation of these models have varied considerably due to data availability and research objectives. Ideally, one would like to estimate a structural model for perennial supply response analysis. This structural specification allows better understanding of the supply response by disaggregating the overall effect into its various components.

A structural model is described by Varian (1992) as a "system of equations, each equation involving some relationships among the exogenous variables, the endogenous variables, and the parameters." As described in the previous section, perennial tree fruit producers can respond to changes in expected profitability by changing new plantings, removals, pest management strategies, and other management decisions such as irrigation, fertilization, varietal choice, and harvesting.

These management decisions and stochastic factors, such as pest infestations and weather, influence the major determinants of perennial crop supply: investment, disinvestment, and yield. The mechanisms of supply response have important implications for policy and how soon the supply response is felt in the market. Disinvestment and yield effects (including yield quality) may influence current production and hence may have an immediate impact in the market, while there is a time lag between investment behavior and its effect on the market. Accordingly, a thorough analysis of the supply response a perennial tree fruit producer would include equation estimation of the following key variables:

- Grower Price
- Non-Bearing Acres (including New Plantings)
- Orchard Block Removals

•Bearing Acreage

•Yield per Acre

These variables and their relationships reveal information about the nature of perennial supply response. Grower price plays a key role in several of the supply response mechanisms. Grower price is assumed to be determined by several demand and supply characteristics. Then, orchard investment (new plantings) and orchard disinvestment (removals) are influenced by expected profitability of the orchard. Expected profitability is often proxied by current and past grower prices in empirical supply response studies (French et al, 1985; Hartley et al., 1987; Elnagheeg and Florkowski, 1993; Willet, 1993; Wu, 1977). Bearing acreage and yield equations reveal information about the yield mechanism of supply response. Changes in bearing acres by age and yield by age compromise the vintage effect. Other yield effects due to input use and cost, pest infestations, and weather can also be determined if the appropriate data are available.

2.3.1 Simultaneous and Recursive Supply Response Models

Ideally, one would estimate a simultaneous or recursive supply and demand model using the variables presented above. In the case of perennial crops, supply response models are likely to be recursive given the biological lags in production, the long-term investment of perennial crop supply, and the dynamic effect of management decisions (i.e., decisions made in the current period determine producer options in the future [tree stocks, tree ages]).

This type of supply response model facilitates policy analysis and forecasting by combining information from both sides of the market into one model. The structural fruit supply equations are combined with demand side information to formulate recursive or simultaneous supply and demand models. This joint consideration of the demand and supply sides of a market allows both price and quantity to be endogenous to the model. Two such models developed for perennial crops include the research by Willett (1993) and Wu (1977). Willett's work develops a framework for predicting prices and production in the various niches of the apple industry (fresh, juice, and dried markets). This specification highlights the importance of fruit quality (part of the yield effect) in determining marketing avenues, and hence production and price in the various markets. Wu's unpublished dissertation develops a forecasting model for Michigan tart cherry production. Wu's study will be referenced further in Chapter Three in describing the construction of the tart cherry model for the United States.

2.3.2 Structural Supply Response Models

In instances where demand side data are not available or the research is focused on the supply side of the market, the price equation is excluded from the model. These supply side models are still informative, but are not as useful as the recursive and simultaneous models in facilitating policy analysis and forecasting. In addition to lack of demand side data, other data needed to estimate the structural supply equations (non-bearing acres, removals, bearing acres, and yield) may not be available. As a result, only a few of the structural equations may be estimable.

One study that had more data than are usually available for perennial crops was conducted by French et al. (1985), who investigate the cling peach market in California. Detailed data on acreage of trees by age, acreage of new plantings, removals by age, yield by age, farm prices, and net returns allowed estimation of a new planting equation and a removal equation for cling peaches. The specification used by French et al. is presented below.

> ***New Planting** = f (average deflated returns per ton, expected average annual production from existing tree stock in fifteen years relative to current production potential)*

> ***Removals** = f (expected returns in the previous time period, institutional factors in the cling peach market)*

This specification illustrates the importance of the investment, disinvestment, and yield effects in perennial supply response and indicates the factors that influence the supply response mechanisms. For instance, the new planting equation aims to describe investment in cling peach orchards. The authors' inclusion of the average returns variable is consistent with standard economic theory. One would assume that expected profitability of the cling peach enterprise would effect orchard investment. The inclusion of the variable representing future production potential relative to current production potential indicates the importance of the vintage effect. Given the standard negative relationship between price and quantity, one would expect that high future production potential relative to current production (and hence lower prices in the future relative to today, ceteris paribus), would have a negative effect on orchard investment. The removal equation also reflects the influence of profitability (if expected returns are likely to be high next year, a grower is likely to forego tree removal for at least another year), as well as institutional factors such as the volume-control marketing order.

The new planting and removal equations are quite informative in understanding the cling peach supply response, as well as perennial supply response in general. However, without bearing acres, yield, and grower price equations, the total supply response cannot be analyzed sufficiently.

Another structural perennial supply response model that highlights the importance of expected profitability and vintage effects in investment and disinvestment in orchards was conducted by Hartley et al. (1987). The authors rely on data for newly planted and replanted areas, deflated rubber prices, subsidies, wage rates, age distributions of tree stocks by area, and the average age-yield profiles to estimate the following equations for rubber production in Sri Lanka:

> ***Area replanted*** *= f (expected prices, current prices, wages, subsidies for higher yielding varieties, areas with trees older than the truncation point of the tree age-yield distribution)*
>
> ***New plantings*** *= f (existing stock, expected prices, wage rate)*
>
> ***Harvesting*** *= f (potential output of existing stock, current and expected prices, wage rate, trend)*

The specification and explanatory variables in this study are similar to the Cling peach study. One unique factor in this study is the estimation of a harvesting equation.

Harvesting decisions may have an important effect on the supply of some perennial crops. Growers may choose to forego harvesting their crops if grower prices are expected to be lower than harvesting costs. In the case of tart cherry industry (where prices in some years have been below harvesting and transport costs), growers may still harvest their fruit, even if they do not intend to sell it, to facilitate future production potential and health of the tree stock.

2.3.3 Reduced Form Supply Response Models

In cases where fewer data are available or the researchers are only interested in the aggregate supply response, reduced form supply response models are estimated. One such study about the southern U.S. pecan industry was conducted by Elnagheeb and Florkowski (1993). The authors explore approaches for estimating the number of non-bearing trees in the face of limited data. This non-bearing tree equation could then be substituted into other equations to obtain a reduced form supply response model.

Nonbearing trees = f (past pecan prices, production costs)

Although the mechanisms of supply change are not clear, the estimated aggregate supply response is revealed through the reduced form approach. Thus, the output from these models can be used for general predictive purposes, but policy analysis is troublesome given the limited understanding of the impetus of the supply response.

As illustrated in the literature, estimation of the supply response for perennial crops is difficult due to the unique nature of these crops. The complexity of the model to be estimated and it's capacity for policy analysis is extremely dependent on the available data. In order to estimate the effect of institutional changes such as pesticide regulations, pesticide use data are necessary, in addition to the data previously mentioned. As will be shown below, pesticide data availability plays an important role in determining how pesticide issues can be analyzed in an econometric model.

2.4 Literature Review of Econometric Models and Pesticide Issues

Pesticides are frequently used by growers to maintain crop yields and quality. Crop quality for tart cherry and other fruits and fresh vegetables, determines if the crop is acceptable for sale, and if so, what price it fetches in the various fresh and processed markets. Given the important role pesticides play in reducing yield and price risks, growers and consumers alike are concerned about the effect of impending losses of certain pesticides from the market.

2.4.1 Pesticides as a Unique Production Input

Pesticides differ somewhat from traditional production inputs such as labor, water, and fertilizer. Traditional inputs, over a certain range of application, increase potential output. Pesticides, on the other hand, do not *increase* potential output, rather they *reduce damage* to potential output (Lichtenberg and Zilberman, 1986). This distinction can best be illustrated in the case where there is no threat of pest damage. If no pests exist, then pesticide applications will lead to increased grower input costs and yield may even be negatively effected by pesticides. Thus, in most instances, pesticides are used to reduce potential damage to crops, not to improve potential yield.

Another distinguishing characteristic of pesticides is their binary or incremental nature. Because pesticides are required to be registered by the EPA, there are certain rules that govern their use. Some pesticides are not legally available for use on certain crops. Even when pesticides are approved for use, pesticide labels state that "...it is a violation of Federal law to use this product in a manner inconsistent with its labeling." Compared to the flexibility of labor inputs that growers can use in various amounts (no labor inputs, work a fraction of an hour, or work several hours), growers may be able to use zero pounds of pesticide per acre (if the chemical is banned) or must adhere to specific requirements such as "application of 1 and 1/2 pounds per 100 gallons of water per acre." Restrictions as to when in the growing season the chemical can be applied, weather restrictions (e.g., wait 7 days after rain), and other stipulations (e.g., wait 14 days between applications) also limit a grower's flexibility in using this input.

2.4.2 Methods of Incorporating Pesticides in Econometric Supply Estimation

There are three primary methods for examining pesticide effects in an econometric model. Traditionally, a production function specification for yield was estimated with pesticides as one of the inputs. In cases where little pesticide data are available, researchers may have to rely upon dummy variables and other imperfect proxy variables to represent structural or institutional changes related to pesticides. More recently, the damage control or abatement function specification has been advocated as the correct way to estimate the effect of damage control inputs such as pesticides. Each of these approaches is examined below.

The Production Function Approach

One of the first econometric estimates of the productivity of agricultural pesticides was conducted by J.C. Headley in 1968. Headley used aggregate production function analysis to estimate the marginal productivity of agricultural chemical expenditures. State-level data from the United States Department of Agriculture (USDA) were used in the analysis and the results indicate that agricultural pesticides were, on average, underutilized. Headley estimated that the marginal value of one dollar of expenditures on agricultural chemicals was worth approximately four dollars of output.

Another study almost a decade later concurred with Headley's claim that agricultural chemicals were underutilized. Campbell (1976) used data from tree-farms in British Columbia to estimate a Cobb-Douglas production function. Based on this estimation, the marginal value of one dollar of expenditures on agricultural chemicals was calculated at twelve dollars worth of output (Campbell, 1976).

The basic specification used in these two studies, and many others of the time, is as follows:

Yield = f(pesticide expenditure) or

Yield = f (pesticide application levels).

Because of the findings that pesticides were being under-utilized, some researchers questioned the specification and functional form of the associated models. Lichtenberg and Zilberman (LZ) thought that the production function specification may not be appropriate for damage control inputs such as pesticides. Due to the unique nature of pesticides, Lichtenberg and Zilberman (1986) claimed that treating pesticides as traditional (or production enhancing) inputs in the standard production function models can result in strategic biases that overestimate the marginal value product of pesticide expenditures.

The Damage Control or Abatement Function Approach

LZ proposed that econometric models be specified such that potential output is a function of productive inputs (traditional inputs such as labor and water) **and** abatement or damage control inputs (such as pesticides). The generalized specification of their model is as follows:

Yield = f(traditional/productive inputs (Z), damage abatement, G(X))

where G(X) is the abatement function

X is the vector of damage control inputs (pesticides)

G(X) has properties similar to a cumulative distribution function in that it "gives the proportion of the destructive capacity of the damaging agent eliminated by the application of a level of control agent X" (Babcock et al., 1992). As G(X) approaches one, there is total control of the damage agents. When G(X) is zero, there is zero control or maximum damage potential.

A 1992 study by Carrasco-Tauber and Moffitt developed an empirical example using the LZ damage control specification. This study used the same data as in the Headley production function study and produced similar results. Several functional forms for the damage control function were estimated, but only the exponential specification of the abatement function resulted in a marginal value product of pesticides expenditure that suggests that pesticides are overused. Although this specification[1] did not lead to the results that LZ expected, this functional form is still advocated because it more realistically approximates the relationship between pests, damage control inputs, and their effect on yield.

Dummy Variable Approach

In instances where data on pesticide applications, pesticide expenditures, damage caused by insects, and damage caused by disease are not available, researchers have to rely on dummy variables to represent "event or structural changes" related to pesticide regulations and use. Dummy variables will be used to estimate the effect of pesticide regulations on the tart cherry industry. The results of the model will be compared with the output from the LZ specification to contrast the amount and quality of information that can be gleaned from the different models.

[1] A detailed description of an adaptation of the LZ model will be presented in Chapter Four.

Chapter Three: Econometric Modeling of the Supply Response to Loss of Pesticides Used on Tart Cherry

3.1 Background on the Tart Cherry Market

Tart cherry is a relatively minor crop in U.S. agriculture. In 1994, there were 46, 175 bearing acres planted to tart cherry. These bearing acres produced 287.8 million pounds of tart cherries (MACMA, 1994). Average annual U.S. production in recent years (from 1993 to 1996) was 311.4 million pounds (USDA, 1996). Tart cherry production is limited to two geographic areas in the U.S.; the "Lake States" area (Michigan, Wisconsin, New York, and Pennsylvania) and the "Western" production area (Oregon, Washington, and Utah). The largest tart cherry producing state is by far Michigan, with an average of over 70 percent of national production. For instance, in 1994, 210 million pounds of the 287.7 million pounds of tart cherries produced nationally came from Michigan (MACMA, 1994) Utah and New York each produces approximately 8-9 percent of the national total, while Washington, Wisconsin, Oregon, and Pennsylvania each produces 2-3 percent of the nation's tart cherry supply (Ricks, 1991).

Tart cherry production is highly variable and year to year fluctuations can be quite pronounced. For example, 161.1 million pounds of tart cherries were produced in 1963 while 546.7 million pounds were produced in 1964. More recently, 189.9 million pounds were produced in 1991 as compared to tart cherry production of 335.1 million pounds in 1992 (MACMA, 1992). The great variability in tart cherry production can be attributed to annual supply fluctuations and to the long term supply cycle. Annual supply fluctuations are mainly due to stochastic factors such as weather effects and pest infestations.

The long term supply cycle arises because tart cherry is a perennial crop. Growers plant new trees or remove trees based on the long run expected profitability of the tart cherry orchard. These decisions have long run implications since the productive life of a tart cherry tree is 20-25 years and cherry yields vary depending on tree age (Ricks, 1991).

Tart cherries are used in both fresh and processed markets. However, the majority of the tart cherry crop is used for processing. Approximately 6 million pounds (around 2 percent) of tart cherry production is diverted to the fresh market while the rest of the crop is divided among several processing markets (MACMA, 1992). The largest market for tart cherries is frozen cherries. Over the period from 1986-1989, 70 percent of national tart cherry production was utilized by the frozen cherry market. The second largest tart cherry market is the pie filling market which has accounted for 17 percent of tart cherry production in recent years. Finally, the remaining tart cherry crop is used by the canning, juice, dried, and export markets. Each of these latter markets accounts for less than 10 percent of national tart cherry production (Ricks, 1991).

Because most tart cherries are processed, cosmetic appearance and damage is not as important as it would be with crops that are marketed in fresh markets. However good damage control is still important. The fruit must be free of maggots if the fruit is to be sold at all, and price may also vary by several cents per pound depending on other signs of damage (Ricks, 1996).

3.2 Data Used in the Supply Response Estimation

Annual data from 1966 to 1994 were collected from various sources in order to econometrically estimate demand and supply equations for the U.S. tart cherry market.

Some of the estimated equations are based on fewer than 28 observations due to the use of lagged explanatory variables. Many of the data series were readily available in U.S. government publications such as the Fruit and Tree Nuts Situation and Outlook Report from the USDA and the Michigan Agricultural Statistics series. Additional series were obtained from Dr. J. Ferris, Michigan State University, and other empirical studies that focus on Michigan cherry production (Wu, 1977; Woods, 1992). Data sources and mean values for the relevant variables are reported in Appendix 3-2. Data from 1966 to 1994 was used in the estimation process, however some equations are based on fewer than 29 observations due to lagged explanatory variables. The variables used in the model estimation are defined in the following list:

Variable	Description
AAP	= Average Grower Price for Apples, in cents/lb.
ACRE	= Bearing Acres of Tart Cherries, in acres
ATCP	= Average Grower Price for Tart Cherry (all utilizations), in cents/lb.
CPI	= Consumer Price Index (1982-1984 = 1.0)
DDIFOLITAN	= Dummy Variable for Years Difolitan Registered for Use on Tart Cherry (available = 1.0, not available = 0)
DFUNGINEX	= Dummy Variable for Years Funginex Registered for Use on Tart Cherry (available = 1.0, not available = 0)
DGUTHION	= Dummy Variable for Years Guthion Registered for Use on Tart Cherry (available = 1.0, not available = 0)
DOUT	= Dummy Variable for Outlier observations
FRUTIL	= Fresh Utilization of Tart Cherries, in millions of lbs.
MOVMT	= Processed Tart Cherry Movement, in million lbs.

POP	= U.S. Population, January, in millions
QTY	= Tart Cherry Production, in million lbs.
STOCKSTC	= Frozen and Canned Tart Cherry Stocks, in million lbs.
TCA	= Tart Cherry Abandonment, in million lbs.
UTIL	= Utilized Tart Cherry Production, in million lbs.
VARCOST	= Deflated Variable Costs for Tart Cherry Production, in dollars/acre

<u>**Generated Variables**</u>

C	= Constant
GMARGIN	= {(PRICETC*YIELDTC)/100 - VARCOST} gross margins for tart cherry, in $/acre
PFRUTIL	= FRUTIL/POP (per capita fresh utilization of tart cherries), in lbs./person
PMOVMT	= MOVMT/POP (per capita processed tart cherry movement), in lbs./person
PQTY	= QTY/POP (per capita production of tart cherry), in lbs./person
PRICEAP	= AAP/CPI (deflated average apple price) in cents/lb.
PRICETC	= ATCP/CPI (deflated average tart cherry price) in cents/lb.
PSTOCK	= STOCKSTC/POP (per capita frozen & canned tart cherry stocks), in lbs./person
PTCA	= TCA/POP (per capita tart cherry abandonment), in lbs./person
PUTIL	= UTIL/POP (per capita utilization of tart cherry production), in lbs./person
TIME	= Time Trend where 1965 = 1,...,1995 = 31
YIELDTC	= (QTY/ACRE)*1,000,000 (average yield of tart cherries) in lbs./bearing acre

As indicated in the above list, most of the data used in the analysis were national U.S. data, in aggregate units (bearing acres, tart cherry stocks. population), average units (average tart cherry yields, average grower prices), or in per capita terms (per capita utilization, per capita stocks). Regional data were used in instances to proxy for national averages when the national data were not available. Specifically, the data on variable costs for tart cherry production and tree densities per acre were based on regional data from Michigan. These data were assumed to be realistic proxies for the national level since Michigan produces the majority of tart cherries.

3.3 The Econometric Supply Response Model for the Tart Cherry Market

Ex ante choice of functional form for the model was a difficult task. Several criteria for selecting functional form prior to estimation include: theoretical consistency, domain of applicability, flexibility, computational facility , and factual conformity (Lau, 1986). The first two criteria were not readily applicable to the tart cherry model. These guidelines are more useful when one is estimating an individual firm's profit function or specifying a complete system of demands. In these instances, theoretical consistency checks such as homogeneity requirements and the signs and magnitudes of cross-elasticities are easily determined. Due to the nature of the equations that are estimated for the tart cherry model, the theoretical consistency checks were not as discernible.

A linear functional form was chosen for the model equations in order to facilitate estimation and interpretation. As for factual conformity, Lau (1986) states there are not many known empirical facts in economics to assist in functional form choice. Hence, other empirical supply response studies were consulted (Wu; Woods; Willet; Hanson and

Ricks) and the biological characteristics of tart cherry and managerial behaviors were explored for clues in choosing the appropriate functional form.

The typical management activities in tart cherry production are presented in Table 3.1. Growers make management decisions at various times during the year, with different information available at these various times. A typical growing season[2] for tart cherry producers and the information available at each decision point is described. The time period *t* represents one year in the production of tart cherries (April 1st - March 31st).

TABLE 3.1: TART CHERRY GROWING SEASON

Month	**April**	**May-July**	**July/August**	**August-March**
Management Activity	New Plantings(t) Fertilization(t)	Pest Management(t)	Harvesting(t) Sale(t)	Orchard Block Removal(t)
Information Used in the Decision Making Process	grower price for tart cherry in period t-1 and earlier input/production costs for tart cherry in period t output prices for substitutes and complements in consumption for tart cherry in period t-1 and earlier grower prices for alternative production enterprises in period t-1 and earlier input/production costs for alternative production enterprises in period t interest rates for period t	grower price for tart cherry in period t-1 and earlier input/production costs for tart cherry in period t output prices for substitutes and complements in consumption for tart cherry in period t-1 and earlier input/production costs for alternative production enterprises in period t	grower price for tart cherry in period t harvesting and transport costs for tart cherry in period t	grower price for tart cherry in period t and earlier input/production costs for tart cherry in period t and earlier grower prices for alternative production enterprises in period t and earlier input/production costs for alternative production enterprises in period t and earlier interest rates for period t

Source: Ricks, 1996

[2] The management decisions and information available to growers are basically the same in the various production regions, however, the timing of the management decisions may vary slightly across production regions due to weather and climatic factors. The information is representative of a typical production year in Michigan.

Flexibility as a selection criteria will be discussed in terms of the specific estimation equations below.

3.3.1 The Price Equation

As shown in the table above, grower price is one of the primary information sources growers rely upon to make management decisions. According to the standard profit maximization assumptions, growers will plant new trees, remove trees and apply inputs (irrigation water, fertilizer, damage control products) such that the expected marginal value product of the inputs are equal to their respective marginal input cost. The individual supply curve, and hence industry supply (the summation of individual supply curves), is an increasing function of output price (Varian, 1992). In order to provide a link between the demand and the supply sides of the model, a grower price equation was estimated.

A price dependent equation (PRICETC) was chosen for several reasons. A price dependent equation is appropriate if the quantity purchased is largely predetermined by the quantity produced (Ferris, 1994). This assumption appears to be reasonable for a highly perishable crop like tart cherry. The quantity purchased in this instance refers to processor demand, not consumer demand. Tart cherries usually undergo several processing transformations before reaching consumers in their final form. Initially, however, tart cherries are highly perishable in their raw form. Consequently, the amount of tart cherries purchased by processors and cooperatives for use and storage is largely determined by production.

Another reason for choosing the price dependent demand equation is that there are few data on tart cherry consumption. Again, because tart cherries are highly processed before reaching consumers, it is difficult to trace the product through the marketing chain. Thus data on per capita consumption of tart cherries are elusive. The second equation estimated, per capita processed tart cherry movement (PMOVMT), will serve as a proxy for annual consumption.

The equation below predicts deflated national average tart cherry prices (PRICETC) measured in cents per pound. Several other specifications were estimated before choosing Equation (1). Factors such as disposable income and substitute goods were considered in accordance with traditional demand theory. Average disposable income was found to be statistically insignificant. This corresponds to Wu's finding in his Michigan tart cherry price equation. One possible explanation for the insignificance of income may be that for the historical range of disposable income, the income elasticity for tart cherry demand is zero. In other words, over a certain income level, individuals consume a fixed number of cherry pies (e.g. only on special occasions, holidays, etc.) and income would have to drop severely before there would be any change in tart cherry demand. This "fixed" consumption level may also explain why frozen apple supply (production), a consumption substitute for tart cherries, was found to be insignificant in explaining tart cherry price. If an individual is consuming a fixed portion (and a relatively small portion compared to other foods) it is not likely to make up a great proportion of their food expenditures. Thus, the consumer is not likely to be responsive to changes in the price of substitute or complementary goods.

Finally, the original specification of this equation had serial correlation problems according to the Durbin Watson statistic. A first-order autoregressive scheme, denoted as AR(1), was incorporated to remedy this problem. Appendix 3.2 plots actual tart cherry prices received by growers (PRICETC) against prices predicted by Equation (1), (PRICETCF).

The regression is based on 28 observations, using data from 1967 to 1994. The values in parenthesis are t-statistics and the corresponding critical t values are $t(0.05, 27)$ = 2.05 and $t(0.01, 27)$ = 2.77.

$$\text{(1)}\quad \mathbf{PRICETC} = \underset{(24.27)}{\mathbf{100.29}} - \underset{(-16.08)}{\mathbf{1.08TIME}} - \underset{(-10.57)}{\mathbf{32.95PUTIL}} - \underset{(-7.59)}{\mathbf{203.85PSTOCK}} +$$

$$\underset{(5.79)}{\mathbf{343.18PSTOCK2}} + \underset{(8.68)}{\mathbf{20.80DOUT}} - \underset{(-4.49)}{\mathbf{0.71AR(1)}}$$

Adjusted R-squared = 0.94 **Mean of the dependent variable = 29.2 cents/lb.**

All of the regression coefficients are significantly different from zero at the 1 percent level and lower. The adjusted R-squared value of 0.94 means that the independent variables explain 94 percent of the variation in average tart cherry prices. This R-squared value is consistent with the explanatory power of similar price equations. Hanson and Ricks and Wu achieved R-squares ranging from 0.75 to 0.96 for their price equations.

According to equation (1), the real average grower price for tart cherries (PRICETC) is negatively affected by per capita tart cherry production (PUTIL) as expected. All other things equal, if tart cherry production increases by one pound per capita, grower price will fall by approximately 33 cents per pound. This change may not seem like a large effect, but one must keep in mind the magnitude of tart cherry production variability. It is not uncommon for tart cherry production to fluctuate by more than one million pounds from year to year. As more cherries become available for sale through increased production, average grower prices are depressed. A squared UTILCAP term was also examined, but proved to be insignificant.

Large stocks of frozen and canned tart cherries at the beginning of the marketing year (July) augment production to create a larger pool of cherries that are available for sale. This available pool also has a dampening effect on grower price. In fact, one pound increase in beginning stocks per capita has a greater negative effect on grower price[3] than an equal increase in production (PUTIL), -$0.85 versus -$0.33.

The dummy variable, DOUT, was included to capture unusual circumstances that occurred in 1978 and 1979 that resulted in extremely high average grower prices. Prices at these levels have not reoccurred. The years 1978 and 1979 were unusual in that the industry was at a low point in the long term acreage cycle (bearing acres low). This factor, coupled with adverse weather conditions that negatively affected yield over this time period, resulted in unusually high prices (Ricks, 1993).

Finally, according to the coefficient on the variable TIME, there has been trend towards declining real grower prices over time, with prices falling annually by approximately one cent per pound. This downward trend could be the cumulative effect of several factors. The variable TIME could be capturing some consumer demand shifts such as the trends towards more healthful eating and the consumption of more convenient foods. Tart cherries are used in making pies and other dessert items that are often high in sugar and fat. Also, tart cherry products often involve substantial preparation time.

3.3.2 The Demand Equation

The second equation to be estimated was per capita processed tart cherry movement (PMOVMT). This variable was chosen to serve as a proxy for national per capita consumption. Processed tart cherry movement tracks the use of tart cherry production. At the beginning of the marketing year (July), tart cherry stocks plus production from the current period are available for use. The difference between this pool of cherries and what is left in storage at the end of the marketing year is the "movement." Although this measure does not track the movement of all cherries, it does account for the largest utilization markets for frozen and canned cherries. Frozen and canned cherries are used by processors or by final consumers and compromise 75 percent to 85 percent of total tart cherry use. By estimating the PMOVMT equation, one can approximate future tart cherry stocks[4] (shown in equation (1) to have a significant effect on grower price). PMOVMT is calculated by determining the annual movement or utilization out of the current period production, as well as movement out of frozen and canned tart cherry stocks (PSTOCK). Equation (2) predicts national annual movement of frozen and canned tart cherries in pounds per capita. The regression equation is based on 29 observations (data from 1966 to 1994) and the corresponding critical values are $t(0.05, 28) = 2.05$ and $t(0.01, 28) = 2.76$.

$$\textbf{(2)}\quad \mathbf{PMOVMT} = \underset{(11.80)}{\mathbf{1.46}} - \underset{(-6.56)}{\mathbf{0.02TIME}} - \underset{(-7.56)}{\mathbf{0.01PRICETC}} + \underset{(1.06)}{\mathbf{0.01PRICEAP}}$$

Adjusted R-squared = 0.75 Mean of the dependent variable = 0.97 lbs./capita

[3] Evaluated at mean per capita stocks of 0.17 lbs.

[4] PSTOCK(t) + PUTIL(t) - PMOVMT(t) = PSTOCK(t+1)

All of the regression coefficients are significantly different from zero at the 1 percent level and lower, except for the coefficient on real apple prices (PRICEAP). The adjusted R-squared of 0.75 implies that 75 percent of the variation in tart cherry movement is explained by the independent variables. No other estimated equations for tart cherry movement could be found for comparison of Equation (2)'s explanatory power.

The signs of the estimated coefficients are as expected. For instance, one expects tart cherry consumption (and hence movement) to be negatively related to price. According to Equation (2), as the price of tart cherries increases by 1 cent per pound, per capita movement (demand from processors and consumers) decreases by 0.01 pounds, *ceteris paribus*.

The variable PRICEAP was left in the equation even though its coefficient was insignificant because the sign of the coefficient was consistent with prior beliefs. Apples are the number one fruit for pie filling in the U.S. and compete with cherries in this market. Consequently, as the price of apples increase, one would expect tart cherry movement to increase as consumers substitute away from apples to cherries. Again, per capita disposable income was hypothesized to influence per capita tart cherry movement but no income effect was found.

Finally, the coefficient on the TIME trend indicates that annual tart cherry consumption is declining by approximately 0.02 pounds per capita. This trend may be explained by consumer preferences for convenience in food preparation and healthy foods --two areas in which most tart cherry products do not excel. Appendix 3.3 plots actual per capita movement (MOVMTCAP) against predicted movement (MOVMTF).

3.3.3 The Bearing Acres Equation

The two equations estimated above facilitate prediction of grower prices and the demand side of the tart cherry market. Modeling the supply side of the market is difficult given the biological lags in tart cherry production and the perennial nature of the crop. There is a six year lag from planting to bearing and the typical life of a tart cherry tree is 20-25 years (Wu; Ricks, 1982). As noted in the literature review, estimation of new plantings, removals, and a yield equation (to be discussed in Section 3.3.5), in addition to the price equation, are needed in order to fully capture the complete supply response.

New plantings and removals are important because investment and disinvestment in tart cherry orchards are two mechanisms through which tart cherry supply is altered. One would expect growers to respond to changes in expected profitability by altering new plantings (investment) and orchard block removals (disinvestment). In the case of tart cherry, the higher gross margins were six, seven, and eight years ago, the more likely new planting were put in six years ago. This past planting cumulates in having a positive impact on bearing acreage in the current period because the new planting made six years ago are coming into their bearing years. On the other hand, lower gross margins in the past are more likely to lead to tree removal, resulting in fewer bearing acres in the present period.

Unfortunately, the available data were not adequate to estimate these two structural equations for the tart cherry market. New planting and removal data could not be found at the national level and regional data were incomplete or nonexistent for some production regions. The only national data that were available were figures for bearing acreage. Hence, instead of estimating a new planting, removal, and yield equation, the supply side of the tart cherry model will be represented by bearing acreage and yield equations.

Bearing acreage reflects past planting and removal decisions, however the precise influence of each of these factors cannot be discerned from the data. On the other hand, one can determine the general trend in investment and disinvestment by comparing bearing acreage over time. If the bearing acreage in time t is greater than the bearing acreage in the previous period (t-1) then the removals made over the last five years must have been less than the new acres planted in t-6. This inability to disaggregate the supply response mechanisms and the time lag needed to ascertain general trends makes supply estimation cumbersome.

Several functional forms were considered for the bearing acreage equation. Wu specified several geometric distributed and polynomial distributed lags in his study. He found that the geometric lag formulations seemed to have better explanatory power for Michigan tart cherry acreage. Choosing polynomial distributed lags as the functional form is problematic because one must choose the degree of the polynomial, any beginning or ending restrictions, as well as the degree of the lag. Industry representatives have claimed that past gross margins influence planting decisions (Wu, 1977). Thus, several polynomial distributed lags, geometric, and linear forms of lagged gross margins were explored, but the specification presented in equation (3) provided the best fit.

The magnitudes of the coefficients of lagged gross margins in equation (3) are decreasing with time. It makes sense that the most recent gross margins are in the forefront of a grower's mind when making planting decisions, while older gross margins are less influential. Gross margins lagged greater than eight years were found to be insignificant. Gross margins lagged fewer than six years were also found to be insignificant. This finding is logical given that gross margins lagged less than six years are assumed to influence new plantings made in the past five years--which should not affect current bearing acreage since they could not be of bearing age. Other variables such as lagged real interest rates for farmland and the price of alternative enterprises such as gross margins for apples were considered, but were found to be insignificant.

Lagged (one year) bearing acreage was also included as an explanatory variable in the bearing acreage equation. This variable was chosen because growers are not likely to change management plans drastically at the first sign of changes in expected profitability. Growers are aware that prices are affected by factors such as weather and the long run tart cherry cycle so often there must be significant evidence of a new trend if growers are to remove trees that may have productive capacity for 20 more years. As a result, bearing acreage should not change drastically from one period to the next.

The equation below predicts bearing tart cherry acreage for the United States. Data from 1966 to 1994 are used in the analysis, however the number of observation used in the estimation is reduced due to the use of lagged gross margins (6 and 7 year lags) as explanatory variables. The regression equation is based on 21 observations and the corresponding critical values are $t(0.05, 21) = 2.09$ and $t(0.01, 21) = 2.85$.

$$\textbf{(3)}\quad \mathbf{ACRE = \underset{(0.51)}{680.4} + \underset{(17.87)}{0.94ACRE(-1)} + \underset{(3.89)}{1.51GMARGIN(-6)} + \underset{(2.92)}{1.07GMARGIN(-7)}}$$

Adjusted R-squared = 0.95 **Mean of the dependent variable = 45863 acres**

Equation (3) has high explanatory power, with an adjusted R-squared of 0.95. This value is comparable with values obtained by Wu for explaining Michigan bearing acreage.

According to the highly significant coefficient on the lagged bearing acres variable, tart cherry bearing acreage is declining by 6 percent per year, ceteris paribus. Some factors that might explain this downward trend include the pressure to sell orchard land for residential and commercial development (Wiesing, 1997). Attempts to capture this phenomena were unsuccessful. Data on orchard land values over time were not available. Regional population figures for the tart cherry production regions were also explored as a proxy variable for capturing development/land use pressure. These variables were not included in the final specification because they were found to be insignificant, possibly because these figures do not include seasonal population (which could be a significant portion of the population in many of the tart cherry production areas).

The signs of the coefficients on lagged real gross margins for tart cherry production variable (GMARGIN) are as expected. According to equation (3), an additional dollar in gross margins per acre six years past, increases bearing acreage in the current period by 1.51 acres. An equivalent increase in gross margins seven years ago increases current bearing acres by 1.07 acres.

Appendix 3.4 plots actual bearing acres (ACREBEAR) against predicted bearing acres (ACREF). The bearing acres equation can be used, along with the yield equation (discussed below) to predict total tart cherry production. The identity ACRE*YIELDTC predicts the aggregate supply response.

3.3.4 The Yield Equation

Thus far we have examined grower price, and investment and disinvestment effects (indirectly through bearing acreage). To complete the model, a yield equation was estimated. Since pest management is the primary focus in this study, this equation will be particularly important for the analysis.

Pest management effectiveness can affect several of the supply response mechanisms. However, the primary effect of damage control is revealed through the yield equation. Damage agents such as disease, insects, rodents, deer, and weeds can affect fruit quantity and quality. Babcock, Lichtenberg, and Zilberman (BLZ) define quantity damage as premature fruit drop or poor fruit set. On the other hand, fruit quality is determined after harvest. Fruit damage is determined by the fraction of harvested fruit with disease or insect damage (assessed according the USDA standards). Some diseases and pests can affect tree health, leading to reduced fruit quality and quantity, as well as tree death (Brumer, 1996; Mink and Jones, 1996). Damage control can also influence new plantings and removals (and hence bearing acres) through damage control input costs and their effect on expected profitability (fruit price depends on fruit production and quality).

Chemical damage control methods have historically played an important role in pest management for tart cherry. Due to the zero tolerance for maggots, many growers relied on calendar sprays to control damage. Even as growers have begun to embrace integrated pest management strategies, chemical controls are still one of the main tools for damage control. Table 3.2 lists several insects and mites that affect cherry production in

North America. Cherry fruit fly and plum curculio are the most problematic insects to tart cherry producers due to the zero tolerance for maggots (Swinton and Scorsone, 1996).

Tart cherry trees are also susceptible to a number of diseases. Tart cherry diseases are caused by viruses, phytoplasmas, bacteria, fungi, and undefined sources (Mink and Jones, 1996). A list of several of the diseases and the resulting damage is presented in Table 3.3.

TABLE 3.2: SELECTED MITES AND INSECTS THAT DAMAGE TART CHERRY

Insect or Mite	Latin Name	Damage Caused by Pest
Plum curculio	Conotrachelus nenuphar	Scars on fruit and internal fruit feeding
Cherry fruit fly	Rhgoletis sp.	Larvae feed in fruit
Oblique-banded leafroller	Pandemis pyrusana	Consumes foliage and may damage fruit
Cherry fruitworms	Grapholita packardi	Feeds on fruit
Lecanium scale, brown scale	Parthenolecanium corni	Sucks plant sap, reducing of twigs and limbs
Two spotted spider mite	Tetranchus urticae	Reduces photosynthetic ability of leaves
Peach Tree borer	Synanthedon pictipes	Girdles tree trunk, causing death
Lesser peach tree borer	Synanthedon pictipes	Girdles tree trunk, causing death
American plum borer	Euzophera semifuneralis	Girdles tree trunk, causing loss of vigor

Source: Adapted from Brunner, 1996, Table 15.1

TABLE 3.3: SELECTED TART CHERRY DISEASES

Disease	Damage Caused by Disease
Cherry leaf spot	Defoliation of trees can lead to uneven ripening and poor fruit quality, reduces tree vigor and winter hardiness of flower buds and wood
American brownrot	Attacks blossoms and fruit, leading to rotten fruit
European brownrot	Attacks blossoms and spurs, killing twigs
Powdery mildew	Reduces growth of young trees, causes early defoliation
Armillaria root rot	Trees exhibit poor terminal growth for several years before dying
Bacterial canker	Causes cankers on branches and twigs, killing buds and causing lesions on immature fruit
Crown gall	Formation of tumors/galls on tree roots

Source: Mink and Jones, 1996

The most disturbing fungal disease to tart cherry growers is cherry leaf spot. Damage caused by this disease can lead to poor fruit quality, defoliation, and tree death. Brown rot is another important disease that can lead to premature rotting of the fruit before and after harvest (Mink and Jones, 1996).

In order to determine the supply response to the loss of specific minor use pesticides, one would like to estimate the productivity of these damage control inputs. As described in the literature review, precise data for specific chemical applications and many other orchard and environmental characteristics are needed for a rigorous analysis of the supply response to loss of pesticide alternatives. If one is also interested in the productivity of damage control inputs in terms of fruit quality, data on the percentage of insect and disease damage to fruit are needed in addition to the data mentioned above.

Unfortunately, pesticide use data, weather data, and orchard characteristic data are lacking for tart cherry. The only data available with respect to damage control inputs used on tart cherry were the dates that specific chemicals were registered for use on tart cherry. Thus, pesticide effects were incorporated in the model through the use of dummy variables that represent the years that Difolitan™, Guthion™, and Funginex™ were available for use on tart cherry.

DDIFOLITAN is the variable name assigned to the dummy variable that represents the years that Difolitan™ was registered for tart cherry use. This fungicide was available for use on tart cherry to control scab and as a wound protectant for trees from 1970 to 1989 (Tomlin, 1994). The EPA has determined that Difolitan™ is oncogenic in mice and rats (Federal Register, 1103 (1985)). Funginex™ is a fungicide that has been used by growers in recent years to control brown rot and blossom blight. However, this chemical was recently withdrawn by its manufacturer, so only remaining stocks will be available for use on tart cherry. Guthion™ is an insecticide currently used by growers to control numerous insect pests such as fruit flies, plum curculio, lesser peach tree borer and the fruit tree leafrollers. The future availability of this chemical is questionable since Guthion™ has appeared in residue tests performed by the EPA and has been found to be an endocrine disrupter (Agricultural Marketing Service, 1994; Benbrook, 1996).

The following yield equation was estimated using historical data from 1967 to 1994 on tart cherry yields and the pesticide dummy variables (DDIFOLITAN, DGUTHION, and DFUNGINEX). Several specifications and functional forms were tested before selecting the above yield equation. In an attempt to capture the increasing use of damage control inputs over time (to be discussed further in Chapter Four), the pesticide dummy variables were interacted with the time trend variable. The coefficients on the interaction terms proved to be insignificant; perhaps due to multicollinearity among these variables. Michigan tree density, a proxy for national tart cherry tree density per acre, was also dropped from the specification due to its lack of significance. Finally, several functional forms for the equation (log-log and log-linear) and for past yields (various lag lengths, polynomial distributed lags, geometric and linear lags) were estimated. Equation (4) presented below provided the best fit among the various specifications. The regression is based on 28 observations and the corresponding critical values are $t(0.05, 27) = 2.05$ and $t(0.01, 27) = 2.77$.

$$\textbf{(4)}\ \mathbf{YIELDTC = \underset{(8.33)}{9297} - \underset{(-5.27)}{0.91YIELDTC(-1)} - \underset{(-3.41)}{0.54YIELDTC(-2)}}$$

$$\mathbf{+ \underset{(4.32)}{2017DDIFOLITAN} + \underset{(5.84)}{2348DGUTHION} + \underset{(4.93)}{4078DFUNGINEX}}$$

Adjusted R-Squared = 0.62 **Mean of the dependent variable = 5033 lbs./acre**

All of the regression coefficients are significantly different from zero at the 1 percent level. The adjusted R-squared of 0.62 is satisfactory, particularly given the limited data. According to equation (4), 62 percent of the variation in yield can be explained by the variation in past yields and pesticide availability. Many of the shortcomings of equation (4) can be attributed to the exclusion of a variable to capture weather effects. Yearly fluctuations in tart cherry yields are quite pronounced and often attributed to weather effects. However, it is difficult to incorporate weather effects into this national model. Factors for which data series are available such as average temperature or rainfall are not as important in explaining yield fluctuations as are extreme temperatures at specific periods during the growing season.

All three variables used as proxies for damage control efforts (DDIFOLITAN, DGUTHION, and DFUNGINEX) were found to be significant. According to equation (4), the availability (and presumed use) of these chemicals are shown to have a significant effect on tart cherry yield. For example, the availability of Difolitan™ for use on tart cherry is associated with an approximately 2018 pound increase in yield per acre, ceteris paribus. Guthion™ availability increases tart cherry yield by 2348 pounds per acre, all other things equal, while the availability of Funginex™ increases yield per acre by 4078 pounds.

Previous tart cherry yields are also found to explain current yield. As shown in equation (4), a one pound increase in last year's yield will decrease current yield by approximately one pound. A one pound increase in yield two years ago is associated with a one half pound decline in current yields, ceteris paribus. Lagged yields from three years past or earlier were found to be insignificant. The influence of past yield (from one and two years ago) on current yield may be due to tree health/vitality effects. For example, high yields in the past two years may compromise tree health/vitality resulting in slightly lower yields in the current period, while higher yields three years past and earlier are not significant because the trees have had sufficient time to recover. Appendix 3.5 presents a graph of actual yield per acre (YIELD) plotted against predicted yield per acre (YIELDF).

Because one of the main objectives of this study is to determine the quality of the information that can be gleaned from a model estimated with less than ideal data, the next chapter will be devoted to further examining model results. Particular attention will be given to interpreting the yield equation and comparing these findings to the results available with the "fuller" specification suggested by BLZ.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Results and Conclusions from the Tart Cherry Supply Response Model

Once the best specification for each equation was decided, the individually estimated equation were used to form the tart cherry supply response model. System estimation was considered because if the errors are correlated across equations, then a systems estimation technique such as Seemingly Unrelated Regression Estimation (SURE) technique will be more efficient than separately estimating each equation. However, the systems estimation approach was foregone due to expected biases in several of the equations (the biases will be discussed further in Section 4.2.1). The estimated model equations are presented below.

$$\text{(1)}\quad \mathbf{PRICETC} = \underset{(24.27)}{100.29} - \underset{(-16.08)}{1.08\text{TIME}} - \underset{(-10.57)}{32.95\text{PUTIL}} - \underset{(-7.59)}{203.85\text{PSTOCK}} + \underset{(5.79)}{343.18\text{PSTOCK2}} + \underset{(8.68)}{20.80\text{DOUT}} - \underset{(-4.49)}{0.71\text{AR(1)}}$$

$$\text{(2)}\quad \mathbf{PMOVMT} = \underset{(11.80)}{1.46} - \underset{(-6.56)}{0.02\text{TIME}} - \underset{(-7.56)}{0.01\text{PRICETC}} + \underset{(1.06)}{0.01\text{PRICEAP}}$$

$$\text{(3)}\quad \mathbf{ACRE} = \underset{(0.51)}{680.4} + \underset{(17.87)}{0.94\text{ACRE(-1)}} + \underset{(3.89)}{1.51\text{GMARGIN(-6)}} + \underset{(2.92)}{1.07\text{GMARGIN(-7)}}$$

$$\text{(4)}\quad \mathbf{YIELDTC} = \underset{(8.33)}{9297} - \underset{(-5.27)}{0.91\text{YIELDTC(-1)}} - \underset{(-3.41)}{0.54\text{YIELDTC(-2)}} + \underset{(4.32)}{2017\text{DDIFOLITAN}} + \underset{(5.84)}{2348\text{DGUTHION}} + \underset{(4.93)}{4078\text{DFUNGINEX}}$$

By examining the relationships between the estimated equations and performing comparative statics, one can predict the supply response to pesticide loss. According to equation (4), the loss of damage control inputs (Difolitan™, Guthion™, and Funginex™) will have a significant effect on yield. Predicted yields for the 1997 season under various pesticide availability scenarios are presented in the table below.

TABLE 4.1: EXPECTED YIELD UNDER VARIOUS PESTICIDE SCENARIOS

Damage Control Inputs Assumed to be Unavailable in 1997	Expected Yield (lbs./bearing acre)
Difolitan, Funginex	4347
Difolitan, Funginex, Guthion	1999

Difolitan™ has been unavailable for use on tart cherry since 1989. Also, since Funginex™ has been recently withdrawn, it is reasonable to assume that it will not be available in 1997. If Difolitan™ and Funginex™ are not available in 1997, expected yield would be approximately 4347 pounds per acre. This predicted value is below the mean yield of 5033 pounds per acre for the historical period. The yield effect is even greater if Guthion™ is also unavailable in 1997. If all three chemicals are assumed to be unavailable in 1997 (DDIFOLITAN, DGUTHION, and DFUNGINEX = 0), predicted yield for the season falls to 1999 pounds per acre, assuming past yields at the historical mean level.

A reduction in yield due to pesticide loss (either Funginex™ or Funginex™ and Guthion™) will result in a decline in total tart cherry supply (assuming bearing acreage does not change much in the short run, in accordance with equation (3)). A decline in supply increases grower price, all other things equal, according to equation (1). Price increases are shown to have a negative effect on processed tart cherry movement. This decline in demand may cause tart cherry stocks to rise, depending on the magnitude of the demand decline and production. Increased stocks could depress next year's grower price, offsetting the price increase due to reduced production. The price flexibility with respect to stocks (-\$0.85) is greater in magnitude than the price flexibility with respect to utilization (-\$0.33). Changes in grower price will affect bearing acreage through investment and disinvestment effects. Decreased gross margins due to reduced yield may increase tree removals and reduce new plantings, resulting in a declining trend in bearing acres. The exact magnitude and timing of these effects depends on the relationships between the various components of the model and the assumptions that are made about the future values of the exogenous variables. Forecasting the model over several periods will facilitate recognition of the relationships among the various components of the model. This process allows prediction of the longer run effects of pesticide loss (discussed further under *Predictive Power* in Section 4.2.3).

4.2 Usefulness and Reliability of the Tart Cherry Supply Response Model

Judging the usefulness and reliability of a model is a difficult task. Several criteria that are often used in evaluating a model include: parsimony, identifiability, goodness of fit, theoretical consistency, and predictive power (Gujarati, 1986). Goodness of fit was already discussed in Chapter Three. All models were found to fit the data reasonable well, with adjusted R-squared values ranging from 0.62 to 0.95. Parsimony, identifiability, theoretical consistency, and predictive power will be examined in the following sections.

4.2.1 Parsimony and Identifiability

A good model simplifies a complex system by relying upon key variables and relationships. The tart cherry model is relatively simple for a recursive supply and demand formulation. Unfortunately, the model is too simple for supply response analysis to loss of pesticide alternatives. Key variables are missing due to data limitations, making it impossible to recover some parameters that are of interest. The ideal model for examining the supply response to the loss of pesticide alternatives is a structural model that includes yield, new plantings, orchard block removals, bearing acreage, and grower price equations. Data limitations prevented the estimation of new planting and removal equations in the case of tart cherry. As a result, it is not possible to identify the direct effect of pesticide loss on investment and disinvestment in tart cherry trees. The bearing acreage equation can reveal general trends in tart cherry investment/disinvestment, but forecasting at least 6 years into the future is necessary to reveal the trend due to the biological lags in tart cherry production.

The available data did permit estimation of grower price and yield equations. It is easiest to recognize the identification limitations of these estimated equations by comparing the "ideal specification" with the estimated tart cherry equations. The ideal yield equation is represented by an adaptation of the BLZ (1992) approach used for apples. This specification is also appropriate for tart cherry given the similarities between the crops. Both crops are perennial tree fruits that are biologically similar. Many of the management practices are the same and the crops share some of the same pests (e.g., plum curculio). In fact, in the Eastern production region, many tart cherry growers also grow apples (Michigan Agricultural Statistics Service Rotational Survey Fruit, 1991).

Fruit Quantity

BLZ estimate three equations (one quantity and two quality) in order to examine the efficacy of damage control inputs. Their quantity specification (adapted to the case of tart cherry) is presented below.

$$\ln yield_{it} = \beta_0 + \beta_1 \ln freezes_{it} + \beta_2 \ln rainfall_{it} + \beta_3 \ln height_{it} + \beta_4 \ln width_{it} + \beta_5 \ln diameter_{it}$$
$$+ \beta_6 \ln treeage_{it} + \beta_7 \ln space_{it} + \beta_8 \ln density_{it} + \beta_9 \ln canopy\,rating_{it}$$
$$+ \ln[1 - \exp(\alpha_0 + \alpha_1 canopyrating_{it} + \alpha_2 fungicide_{it}) * (1 - \exp(\alpha_3 + \alpha_4 insecticide_{it})] + \mu_{it}$$

Where

yield	= tons of harvested cherries per acre
freezes	= number of days in growing season with temperatures at or below freezing
rainfall	= number of days in growing season with at least 0.01 inches of rainfall
height	= average tree height in feet
width	= average tree width in feet
diameter	= average tree diameter in inches
tree age	= average tree age in years
space	= average area of open ground around trees in square feet
density	= number of trees per acre
canopy rating	= average tree canopy rating, with 1 representing ideal pruning and 5 representing no pruning
fungicide	= amounts of fungicide applied, measured in pounds of active ingredients per acre
insecticide	= amounts of insecticide applied, measured in pounds of active ingredients per acre
disease damage	= fraction of cherries with disease damage assessed according to USDA standards
insect damage	= fraction of cherries with insect damage assessed according to USDA standards
humidity	= number of days in growing season with relative humidity at or above 85percent

subscripts i and t indicate that the observation is from orchard i in time period t.

A quick glance reveals that the BLZ specification is more complex and detailed as compared to the tart cherry yield equation (4). The functional form of the abatement function in the yield equation assumes that disease and insect damage are independent and that disease is controlled by fungicide inputs and improved pruning while insect damage in controlled by insecticide applications (BLZ, 1992). Some of the variables omitted from equation (4) due to data limitations include weather variables (humidity, freezes, rainfall), orchard characteristics (tree height, width, diameter, age, space density), damage control inputs (chemical applications and pruning), and fruit quality information (fraction of fruit damage due to insects and disease). If the omitted variables are not correlated with any of the included explanatory variables in the yield equation, then only the constant coefficient will be biased. On the other hand, if any of the omitted variables are correlated with the included explanatory variables, the estimated coefficients will be biased and inconsistent (Gujarati, 1986).

It appears likely that some of the variables that are omitted from the tart cherry yield equation are correlated with the included variables. A description of the likely biases and the direction of these biases are presented below. First, the estimated coefficients on lagged tart cherry yields in Equation (4) are likely to be biased due to the omission of damage control input levels (application amounts), tree/orchard characteristics, and weather variables.

Specifically, poor yields last year may lead to greater pesticide applications in the current year, thus lagged yields, YIELDTC(-1) and YIELDTC(-2), are likely to be correlated with the error term (which contains the omitted pesticide application levels). Since pesticide applications in time t and lagged yields are assumed to be negatively correlated and current pesticide applications and current yield are assumed to be positively correlated, the coefficients on lagged yields are likely to exaggerate the negative effect of lagged yields on current yield. In other words, the biased coefficients tend to overestimate the effect of past yields in explaining current yields due to the omission of pesticide application variables.

On the other hand, the omission of orchard characteristics such as tree height, width, age, diameter, space and density may result in the under-estimation of the negative effect of past yields on current tart cherry yield. This assertion will hold assuming that orchard characteristics are positively correlated with past yields and are positively related to current yield.

The overall direction of the biases in the estimated coefficients on lagged yields cannot be identified. Both upward and downward biases are expected due to omitted variables and the aggregate effect will depend of the magnitude of the correlation coefficients between lagged yields and the omitted variables and the magnitude of the relationship between the omitted variables and current yield.

The estimated coefficients on the pesticide dummy variables (DDIFOLITAN, DGUTHION, and DFUNGINEX) may also be biased due to omitted variables. Had the data been available, the damage function approach suggested by BLZ would have been utilized. The BLZ specification relies on data such as pounds of pesticides applied per acre. In the case of tart cherry production, the only way to represent chemical applications was through the use of the dummy variables that represent the legal availability of these damage control inputs for use by growers.

In reality, chemical applications are likely to vary over time. For instance, according to the technology adoption literature, new technologies are likely to be used by few farmers upon their introduction. In the instance of new pesticides, growers may have stocks of other pesticides to be used before purchasing new products. Some growers will want to see how the product performs for others (the early innovators) before adopting the new technology. Thus while the acreage treated with chemical applications will vary over the registration period, the dummy variable cannot capture this trend. Interaction terms between the pesticide dummy variables and the time trend were explored to try to capture this phenomena. These variables proved insignificant, possibly due to multicollinearity. Consequently, assuming that the omitted pesticide application variables are positively correlated with the dummy variables representing availability and with current yield, then the estimated coefficients on DDIFOLITAN, DGUTHION, and DFUNGINEX will be upwardly biased.

In summary, the BLZ specification allows identification of numerous factors affecting yield, that are not revealed in our tart cherry yield equation, such as weather effects, orchard characteristic effects, the vintage effect, and the effect of damage control inputs. Furthermore, the relationships that were estimable in our model are likely to be biased and inconsistent due to omitted variables. Due to the biases in the estimated coefficients and the biased estimator of the true variance in the yield equation, the conclusions and statistical significance attributed to the yield equation are likely to be misleading (Gujarati, 1986).

The direction of the biases in the estimated coefficients on the lagged yield variables is unclear since omitted orchard characteristics and weather variables are likely to lead to an underestimation of the lagged yield effect, while the omission of pesticide application levels are likely to lead to an overestimation of the lagged yield effect on current yield. In contrast, the estimated coefficients on the pesticide dummy variables are likely to be upwardly biased. These likely biases should be considered when interpreting the model's results.

Fruit Quality

The equations used by BLZ to examine the efficacy of damage control inputs with respect to fruit quality are presented below. The equations were specified as logistic equations since the data on damage were in fractional form.

$$\begin{aligned} \textit{disease damage}_{it} &= \partial_0 + \partial_1 \textit{humidity}_{it} + \partial_2 \textit{freezes}_{it} + \partial_3 \textit{rainfall}_{it} + \partial_4 \textit{height}_{it} + \partial_5 \textit{width}_{it} + \\ &\partial_6 \textit{diameter}_{it} + \partial_7 \textit{treeage}_{it} + \partial_8 \textit{space}_{it} + \partial_9 \textit{density}_{it} + \partial_{10} \textit{canopy rating}_{it} + \partial_{11} \textit{fungicide}_{it} + \mu_{it} \end{aligned}$$

$$\begin{aligned} \textit{insect damage}_{it} &= \partial_0 + \partial_1 \textit{humidity}_{it} + \partial_2 \textit{freezes}_{it} + \partial_3 \textit{rainfall}_{it} + \partial_4 \textit{height}_{it} + \partial_5 \textit{width}_{it} + \\ &\partial_6 \textit{diameter}_{it} + \partial_7 \textit{treeage}_{it} + \partial_8 \textit{space}_{it} + \partial_9 \textit{density}_{it} + \partial_{10} \textit{canopy rating}_{it} + \partial_{11} \textit{insecticide}_{it} + \mu_{it} \end{aligned}$$

These equations allow one to examine the effect of orchard characteristics, weather, and damage control inputs on fruit quality. None of these variables, except for tree density per acre, were available to estimate comparable damage equations for tart cherry. This is unfortunate because BLZ found that ignoring fruit quality effects leads to an underestimation of the productivity of damage control inputs. Furthermore, fruit quality is often a significant determinant of grower price. Had a damage or fruit quality variable been available, it would have been appropriate to include this variable as an explanatory variable in the grower price equation. However, assuming that fruit quality is not correlated with any of the included explanatory variable in the price equation (production, stocks, time), then the estimated coefficients in the price equation will be unbiased.

4.2.2 Theoretical Consistency

The tart cherry model was constructed and specified according to economic supply and demand theory and assumptions. Aggregate tart cherry supply is assumed to be the summation of tart cherries supplied by individual profit maximizing growers. Hence, the investment and disinvestment decisions made by profit maximizers (reflected through bearing acreage data) were assumed to be influenced by expected revenues and costs (captured by the GMARGIN variable). The demand side of the model was based on the premise that consumers try to maximize their utility subject to a budget constraint. Thus, several demand equation specifications were explored that included variables such as per capita disposable income and price of substitute goods. Finally, the demand equation (PMOVMT) was specified in accordance with the "law of demand." The biological nature of tart cherry production was also taken into account by specifying the yield and gross margin variables with time lags that represent the delay from new planting to bearing age.

4.2.3 Predictive Power

Because orchards are long term investments, involving biological lags in production, the supply response to loss of pesticide alternatives should be examined over a period of several years. The model equations (1)-(4) were used, in addition to several linking equations and identities, to formulate the forecasting model[5]. The forecasting model is then used to predict annual estimates of the endogenous variables to the year 2006. Prior to the forecasting exercise, the model was run over the historical period and an ex post forecast evaluation was conducted. The findings from this endeavor are presented below.

Ex Post Forecast Evaluation

In order to test the long range forecasting ability of the model, an *ex post* evaluation of the forecasting model was conducted. The model was run over the period from 1973 to 1994 and then compared with the actual data available from this time period. Graphs showing the *ex post* performance of the model are presented in Appendix 4.2. Several forecast evaluation statistics[6] were calculated to determine how well the forecasting model performed. These statistics are presented in the table below.

TABLE 4.2: *EX POST* FORECAST EVALUATION STATISTICS

Variable	Mean Percentage Error	Mean Absolute Percentage Error
PRICETC	-12.0	49.0
PMOVMT	-8.0	16.0
ACRE	4.0	5.0
YIELDTC	-4.0	15.0

[5] See Appendix 4.1 for the forecasting model and evaluation statistics edit file

One way to determine forecast accuracy is to examine forecast errors. Forecast errors are composed of both random and biased errors and several statistics are available to measure both types of errors (Ferris, 1994). For example, Mean Absolute Percentage Error (MAPE) is a measure of total error (random and bias) in forecasting. This value reflects the total errors as a percentage of actual values, for easy comparison among the various endogenous variables in the model (Ferris, 1994). The model was fairly accurate in predicting bearing acreage (ACRE) over the historical period, with only 5 percent total error. The model also performed well in predicting average yield per acre (YIELD) and per capita tart cherry movement (PMOVMT), with approximately 16 percent total errors in the predictions. The model was less accurate in predicting historical tart cherry prices received by growers. The MAPE of 49 percent for PRICETC indicates that the model's ability to forecast tart cherry price is somewhat questionable.

In addition to knowing the percentage of total errors, it is also important to assess whether the model is predicting values that are consistently over or under the actual variable values. One statistic that can reflect this sort of bias is the Mean Percentage Error (MPE). MPE takes the signs of the errors into account. By examining the MPE column in the table above, one can see that the model does appear to have some bias problems. The model has a tendency towards overestimation in the case of PRICETC, PMOVMT, and YIELDTC. On the other hand, the MPE value for ACRE indicates that the model tends to underestimate bearing tart cherry acreage. These biases should be kept in mind when examining the model's prediction for the forecast period.

Ex Ante Evaluation of the Forecasting Model

Since data from 1995 were not used in formulating the forecasting model, *ex ante* forecast evaluations were also conducted for some of the model's variables. *Ex ante* forecast evaluation allows one to see how well the model predicts outside of the sample used in formulating the model. This test is more rigorous than *ex post* evaluation. The results of the forecasting model for 1995 are compared with the actual values from 1995 in the table below.

TABLE 4.3: *EX ANTE* MODEL PERFORMANCE

Variable	Predicted Value for 1995	Actual Value for 1995
PRICETC	10.8 cents	6.1 cents
PMOVMT	0.87 lbs./capita	NA
ACRE	44691 acres	44175 acres
YIELD	6322 lbs./acre	8690 lbs./acre
QTY	282.5 million lbs.	384 million lbs.

As shown in the table above, the *ex ante* performance of the model is fairly good for tart cherry acreage, but the model underestimated production (QTY), yield, and grower price for 1995.

The Forecasting Model

After the model was successfully run over the historical period, it was used to estimate the supply response to pesticide loss over a twelve year forecasting period. In order to solve the forecasting model through the year 2006, predictions about the future values of the exogenous variables in the model are needed. Several methods were employed to arrive at these predictions or educated guesses. For example, population predictions were obtained from the U.S. Bureau of the Census. The CPI and AAP series were each regressed on TIME and then the regression results were used to extend each series as indicated in the edit file. Tart cherry abandonment (TCA), which has been relatively minor in the past, was assumed to be zero over the forecasting period. The negative yield effect of pesticide loss makes tart cherry abandonment even less likely in the future as tart cherry abandonment occurs when the prices received by growers are less than the costs the growers incur to sell the cherries. Tart cherry prices have fallen below these costs only in instances when tart cherry production has been unusually large. Fresh utilization of tart cherries has remained relatively stable over the historical period for which data were available. Thus, mean fresh utilization of 6.35 million pounds per year was assumed for the forecasting period. The pesticide dummy variables DDIFLOTAN and DFUNGINEX were assigned values of zero in the future (they were assumed to be unavailable for use). Since the future availability of Guthion™ is uncertain, the forecast model was run several times with varying assumptions about the availability of Guthion™. In the first scenario, Guthion™ is assumed to be available through 2006 . In the second, third, and fourth scenarios Guthion™ is assumed to be lost in 1997, 2000, and 2003, respectively. By running the model over these scenarios, the effect of different loss dates on tart cherry supply response can be analyzed.

The model predictions through 2006 should allow adequate examination of the longer term supply response while mitigating problems associated with long term forecasting. Longer forecasting periods were rejected due to the increasing uncertainty about future values of the exogenous variables. Even estimates within a decade are tenuous at best. It is difficult to know how population, apple prices, pesticide policy, damage control strategies, etc. will change over a long period of time. Consequently, the forecasting results must be viewed in light of the current policy and technological environment.

The last year in which historical data was available for all of the relevant variables in the model was 1994. Thus the forecasting model was employed to obtain annual projections of tart cherry yield, bearing acres, grower price, and tart cherry movement from 1995 to 2006. A synopsis of the model's predictions for each of the scenarios and an evaluation of the forecasts are presented below. The annual predicted values over the forecast period for the key variables are presented in Appendix 4.3.

Predictions From the Forecasting Model

Scenario One--Guthion™ Available Over the Forecast Period

In this scenario, price increases sharply in 1996, then increases from \$0.74/lb. in 1997 to \$0.14/lb. in 1999. From the year 2000 to 2006, grower price is predicted to be relatively stable between \$0.11 and \$0.14 per pound. Although Guthion™ is assumed to be available over the entire forecast period, the general predicted trend is a decline in production. Predicted production is 255.07 million lbs. in 1997 versus 156.37 million lbs. in 2006. This predicted decline in production can be attributed to both yield and acreage effects.

According to the model's predictions, bearing acreage will steadily decline over the forecast period--falling from 42,749 acres in 1997 to 32,318 acres in 2006. This decrease translates into a 25 percent decline in bearing acreage over the next decade. This decline is the result of the low (and even negative) gross margins predicted in the earlier portion of the forecasting period and the negative trend in bearing acreage over time.

The yield effect is not as pronounced as the acreage effect. Tart cherry yield per acre is predicted to fluctuate between approximately 6000 to 4000 lbs. per acre over the next decade. The fluctuations appear to taper off over the forecast period, with yields stabilizing around 4500 to 5000 lbs. per acre after the year 2000. One would expect yield to be relatively stable, excluding weather and vintage effects, given that Guthion™ is assumed to be available for damage control in this scenario.

Scenario Two--Guthion™ is lost in 1997

In Scenario Two, price again fluctuates, but falls towards $0.15 per lb. from 1999 to 2006. Production is predicted to be quite a bit lower than when it was assumed that Guthion™ was available. Predicted supply in 1997 is 150 million lbs., declining to 132 million lbs. in 2006. Once again, the acreage effect seems to outweigh the yield effect as the catalyst of the negative supply response.

Tart cherry acreage is estimated to steadily decline from approximately 42,500 acres in 1998 to 34,011 acres in 2006. The impetus of the negative acreage effect appears to be the steady decline of gross margins per acre (excluding one year) over the forecast period and declining trends in bearing acreage. Tart cherry yields are predicted to be relatively stable over the forecast period (approximately 3500-4500 lbs. per acre). Not surprisingly, these yield estimates are lower than in the scenario where Guthion™ is always available.

Scenario Three--Guthion™ is lost in 2000

In this scenario, prices received by tart cherry growers dip below $0.10/lb. in 1997 and 1998 before rising to approximately $0.20/lb. in 1999. From 2000 to 2006 tart cherry prices hover at or above $0.15 per lb.. Tart cherry production is predicted to decline from approximately 200 million lbs. annually to 100-150 million lbs./year after the loss of Guthion™ as a damage control input.

Again, the predicted trend in bearing acreage is that of continuous decline. Bearing acreage starts at 42749 acres in 1997 and declines to 32444 acres in 2006. Processed tart cherry movement (or tart cherry demand) experiences quite a decline over the forecast period. The predicted decline from over 0.80 lbs. per capita in 1997 to approximately 0.61 lbs. per capita in 2006 is quite pronounced.

Variable tart cherry yields are again predicted in this scenario. Tart cherry yield is estimated to be 5967 lbs. per acre in 1997 and then falls to 3030 lbs. per acre in 2000 (when Guthion™ is assumed to be lost). In the years following the loss of Guthion™, predicted yields fluctuate between 4379 and 3593 lbs. per acre.

Scenario Four--Guthion™ lost in 2003

In this scenario, tart cherry prices are predicted to increase over the forecast period. Predicted prices are as low as $0.08/lb. in 1997 before rising to a high of $0.22lb. in 2003 (the year Guthion™ is assumed lost). Production is relatively stable (approximately 200 million lbs. per year) in this scenario, until Guthion™ is lost. Production falls to 96.32 million pounds in 2003, before recovering to approximately 120 million pounds per year for 2004 through 2006.

Again, tart cherry demand is predicted to fall over the forecast period from 0.84 lbs./capita to 0.56 lbs./capita in 2006. This decline is driven by predicted price increases and is more pronounced than in the other scenarios. The acreage effect is similar to the predicted outcomes in the other scenarios. These similarities are due to the biological lags in tart cherry production. Although the price and yield effects vary across the scenarios, these effects do not impart much influence over bearing acreage (through the gross margin variables) until new plantings come into bearing (six years into the future at least).

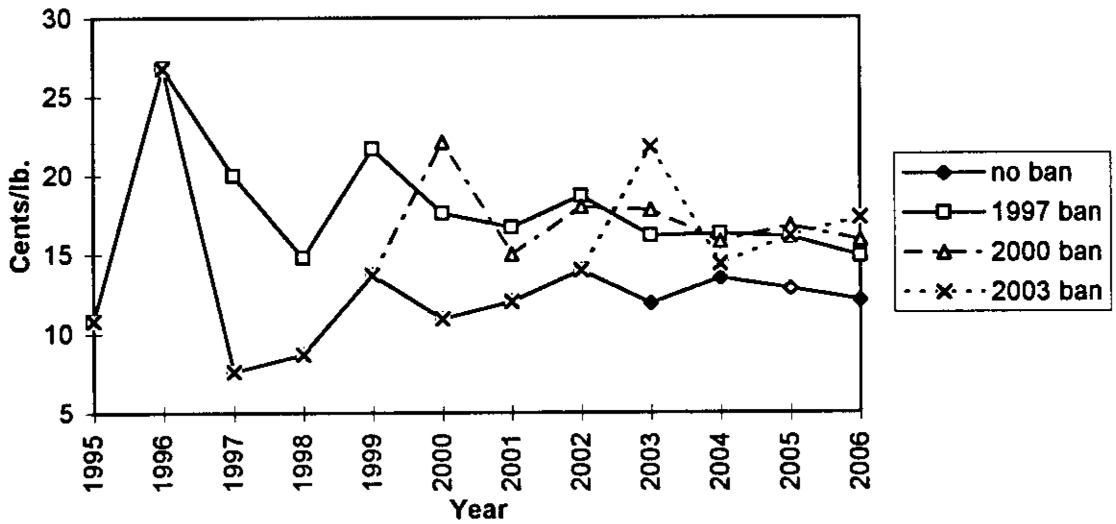
The yield effect in this scenario is quite variable, but has a general downward trend. Tart cherry yield is estimated to be almost 6000 lbs./acre in 1997 and then fluctuates, trending downward to 3424 lbs./acre in 2006. As expected, the yield effect in this scenario is not as pronounced as in the scenarios where Guthion™ was lost earlier.

CHAPTER FIVE: CONCLUSIONS

5.1 Summary and Conclusions

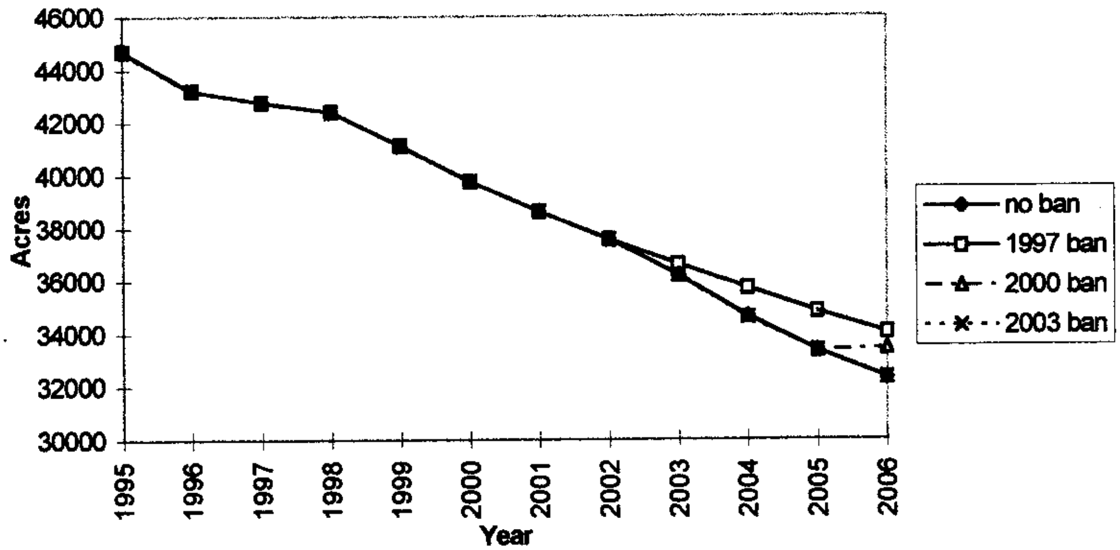
The forecast results indicate that there are some important changes on the horizon for the tart cherry industry. Some of these changes appear to be influenced or exacerbated by the loss of pesticide alternatives, while other trends seem inevitable regardless of pesticide availability. The predicted changes in real grower prices over the forecast period fall into the former category. There is a downward trend in grower prices over the forecast period, however, this decline may be overwhelmed by the positive relationship between production losses (due to yield and acreage effects) and grower price. As shown in Figure 5.1, real grower prices are predicted to be lowest when Guthion™ is assumed to be available over the entire forecast period. In this scenario, grower prices are predicted to be approximately 10-12 cents per pound. In scenarios where Guthion™ is assumed to be lost at some point over the forecasting period, grower prices are predicted to climb above 15 cents per pound over the next decade, with sharp increases predicted for the season in which Guthion™ is lost as a damage control input.

Figure 5.1: Predicted Real Grower Prices for Tart Cherries



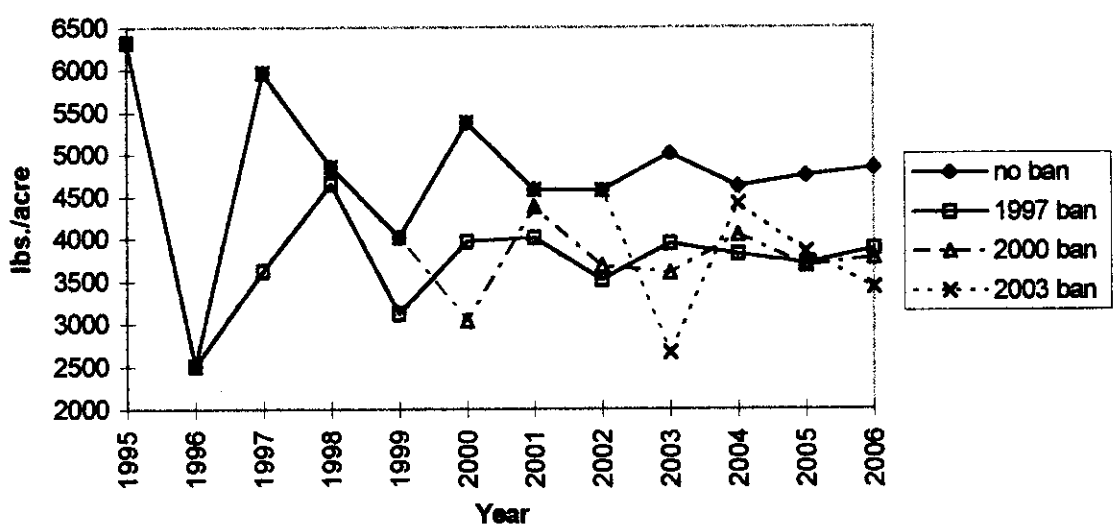
The model's acreage predictions for all four pesticide loss scenarios, show acreage falling steadily over the next decade. The decline in acreage over the forecast period is slightly greater the longer Guthion™ is available for use on tart cherry. When Guthion™ is assumed to be lost in 1997, acreage drops from approximately 45000 acres to 34011 acres over the forecast period. In contrast, when Guthion™ is assumed to be available for use over the entire forecast period, bearing acreage declines from 45000 acres to 32318 acres. Thus the disinvestment effect in tart cherry acreage appears to be slightly mitigated by the price increases associated with the loss of Guthion™. Disinvestment trends might be more perceivable if the model was run over a longer forecast period since there is a time lag before changes in grower price (through the gross margin per acre variable) influence bearing acreage.

Figure 5.2: Predicted Tart Cherry Bearing Acreage



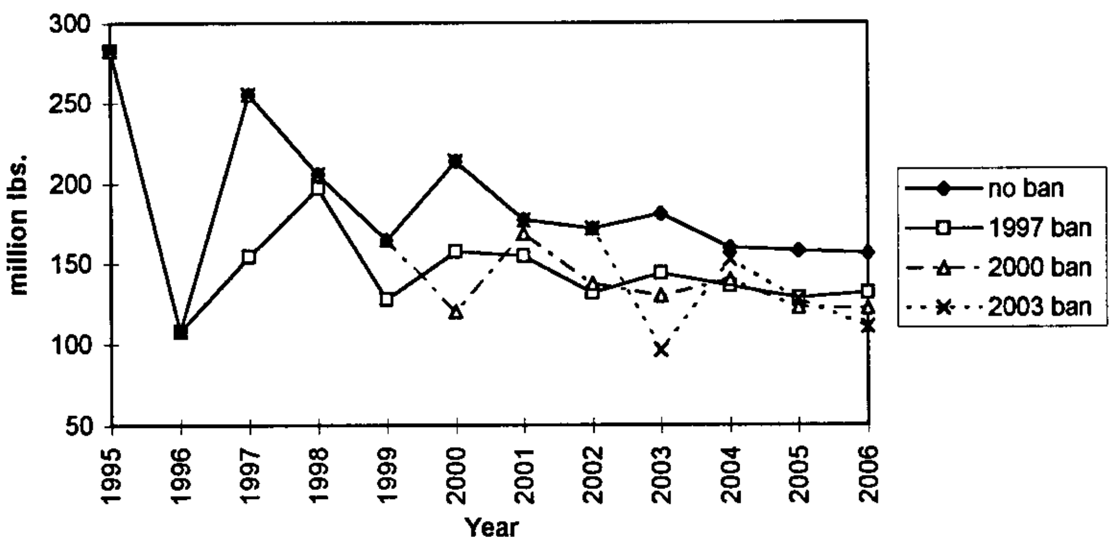
The yield predictions of course vary according to the assumptions about the availability of Guthion™ as a damage control input. Predicted yields are relatively stable, fluctuating between approximately 4000 and 5000 lbs. per acre when Guthion™ is assumed to be available for the entire forecasting period. In the other scenarios, yields drop dramatically in the year that Guthion™ is lost and then tend to remain around or below 4000 lbs. per acre for the rest of the forecasting period.

Figure 5.3: Predicted Tart Cherry Yields



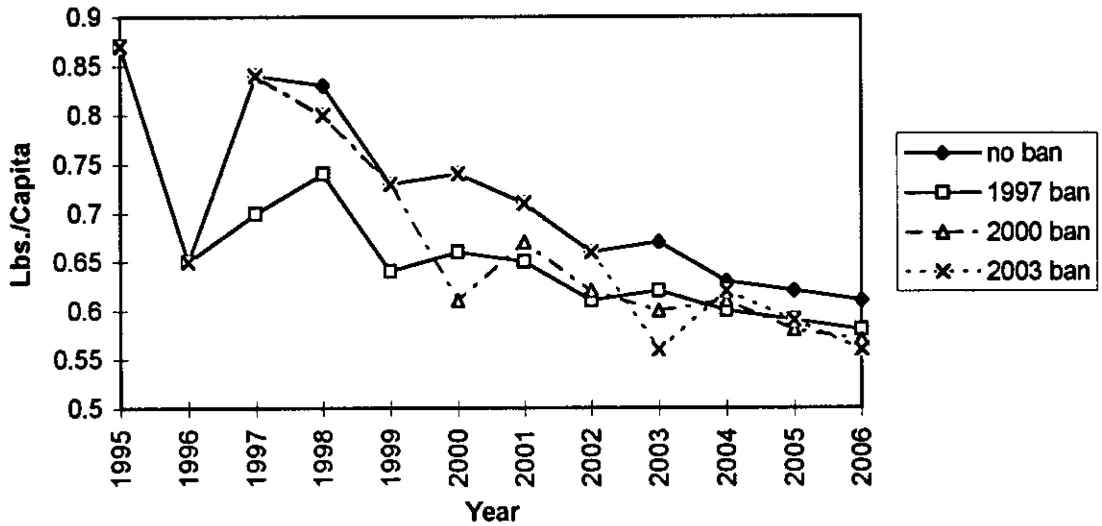
Because the predicted acreage and yield effects determine the predicted tart cherry supply, the trends in national production differ according to pesticide availability. There is a definite downward trend in tart cherry production (not surprising given the predicted decline in bearing acreage) in each of the estimated scenarios, however, production further declines in the scenarios where Guthion™ is lost. When Guthion™ is assumed to be available (so the negative yield effect is small), yield is predicted to decline by approximately 100 million pounds over the next decade. Thus, much of the supply response is due to the acreage effect (disinvestment). In the scenarios where Guthion™ is assumed lost, production drops more quickly and falls below 150 million pounds per year.

Figure 5.4: Predicted Tart Cherry Production



The predictions for tart cherry demand (per capita annual movement) are fairly consistent across the pesticide loss scenarios. Overall, tart cherry demand is predicted to decline from 0.85 lbs./capita to 0.55-0.60 lbs./capita over the next decade. Again, there are slight deviations in the speed and magnitude of the demand decline depending on when or if Guthion™ is assumed to be lost. The quantity demanded declines sooner the earlier Guthion™ is assumed to be lost due to the resulting price increase in tart cherry price.

Figure 5.5: Predicted Tart Cherry Movement



These findings provide some insight into the nature and the degree of the supply response in tart cherry to loss of Funginex™ and Guthion™. However, the accuracy of these results may be questioned on several grounds. First, one of the key equations in the forecasting model, the yield equation, likely suffers biases from omitted variables. As discussed in Chapter Four, the estimated coefficients on lagged yields are likely to be biased due to the omission of damage control input level, tree/orchard characteristics, and weather variables. More distressing is the fact that the overall direction of the bias is indeterminant given that both upward and downward biases are expected. On the other hand, it seems likely that the estimated coefficients on the pesticide dummy variables are upwardly biased due to omitted damage control input levels.

Second, the forecast evaluation statistics also invoke some concern about the accuracy of the forecasting model. According to these statistics, the model has a tendency to overestimate grower price, yield, and processor demand. Bearing acreage is likely to be underestimated by the model, given its performance in forecasting over the historical period. Consequently, the dramatic predicted decline in bearing acreage may be somewhat overstated.

Third, the model's predictions must always be interpreted in light of the assumptions made in the forecasting model. For example, the specification of the yield equation assumed no changes in production technology in response to the pesticide losses. In reality, growers are likely to adopt new chemicals or biological control methods, particularly over the long run, in response to pesticide losses. Thus the negative yield effect due to pesticide losses is likely to be overstated--instead of going from applying Guthion™ to applying no chemicals, growers are likely to adopt alternative chemical or non-chemical control means which may be relatively less effective, but certainly better than zero abatement effort. The pest complex was also assumed to remain the same over the forecasting period. There is also much uncertainty as to when and which chemicals will be lost due to regulations or economic considerations. Some of this uncertainty was incorporated into the model by running several pesticide loss scenarios. However, given the recent passage of the Food Quality Protection Act of 1996, the pesticide policy environment is likely to change in the near future. On the demand side, no changes in consumer preferences for tart cherries were assumed over the forecast period.

Finally, lack of econometric data for key variables limited the analysis that could be accomplished in this framework. Investment and disinvestment effects to pesticide loss could not be directly estimated due to data limitations. Inadequate data on specific pesticide applications also prevented estimation of yield effects through the abatement function.

5.2 Recommendations for Future Research

Future research on the supply response to loss of pesticide alternatives for tart cherry or other perennial fruits should strive to address the major limitations in this area: the *ex ante* nature of the loss of pesticide alternatives to the reregistration process and the lack of detailed data on pesticide applications and alternative damage control strategies.

As evident from this research endeavor and the supply response and pesticide literature, in order to realistically estimate the supply response to pesticide loss, the model must:

1) permit product and input substitutions to capture likely producer response to changes in production costs and expected profitability due to pesticide losses.
2) incorporate fruit quality changes due to pesticide loss, because fruit quality dictates whether the fruit is acceptable for sale, and if so, the price it fetches in fresh or processed markets.
3) incorporate heterogeneous production (at least at the regional level). While aggregate effects will influence market prices and production levels, inter-regional and intra-regional comparative advantage will dictate supply location shifts resulting from differential pest pressures, control needs, and viable alternative crops.
4) overcome data limitations due to the fact that the impending pesticide losses have not occurred in the past.

A promising approach might be to combine some of the econometric equations from the model with a mathematical programming model to more fully analyze the supply response. A dynamic mathematical programming model could explicitly model pesticide management technology, alternative production enterprises, fruit quality considerations, and inter-regional production heterogeneity while econometric equations could endogenizes crop prices and facilitate the updating of producer price expectations.

APPENDICES

Appendix 3.1: Data Sources, Data Tables, and Mean Values

Annual data series were collected from various sources in order to estimate the supply and demand model. *Note: Some of the variables in the following list have been altered from their original form (units have been changed, data has been deflated or transformed into per capita terms, etc.). In these instances, the indicated data sources contain the original series from which the derived series are based.*

Variable	Description
AAP[1]	= Average Grower Price for Apples, in cents/lb.
ACRE[5]	= Bearing Acres of Tart Cherries, in acres
ATCP[2]	= Average Grower Price for Tart Cherry (all utilizations), in cents/lb.
CPI[6]	= Consumer Price Index (1982-1984 = 1.0)
DDIFOLITAN[9]	= Dummy Variable for Years Difolitan Registered for Use on Tart Cherry (available = 1.0, not available = 0)
DFUNGINEX[9]	= Dummy Variable for Years Funginex Registered for Use on Tart Cherry (available = 1.0, not available = 0)
DGUTHION[9]	= Dummy Variable for Years Guthion Registered for Use on Tart Cherry (available = 1.0, not available = 0)
DOUT[8]	= Dummy Variable for Outlier observations
FRUTIL[2]	= Fresh Utilization of Tart Cherries, in millions of lbs.
MOVMT[2]	= Processed Tart Cherry Movement, in million lbs.
POP[2]	= U.S. Population, January, in millions
QTY[2]	= Tart Cherry Production, in million lbs.
STOCKSTC[2]	= Frozen and Canned Tart Cherry Stocks, in million lbs.
TCA[2]	= Tart Cherry Abandonment, in million lbs.

UTIL[1] = Utilized Tart Cherry Production, in million lbs.

VARCOST[4] = Deflated Variable Costs for Tart Cherry Production, in dollars/acre

Generated Variables

C = Constant

GMARGIN = {(PRICETC*YIELDTC)/100 - VCTC} gross margins for tart cherry, in $/acre

PFRUTIL = FRUTIL/POP (per capita fresh utilization of tart cherry), in lbs./person

PMOVMT = MOVMT/POP (per capita processed tart cherry movement), in lbs./person

PQTY = QTY/POP (per capita tart cherry production), in lbs./person

PRICEAP = AAP/CPI (deflated average apple price) in cents/lb.

PRICETC = ATCP/CPI (deflated average tart cherry price) in cents/lb.

PSTOCK = STOCKSTC/POP (per capita frozen & canned tart cherry stocks), in lbs./person

PSTOCK2 = PSTOCK^2 (per capita frozen & canned tart cherry stocks squared)

PTCA = TCA/POP (per capita tart cherry abandonment), in lbs./person

PUTIL = UTIL/POP (per capita utilization of tart cherry production), in lbs./person

TIME[8] = Time Trend where 1965 = 1, 1966 =2, ...

YIELDTC = (QTY/ACRE)*1,000,000 (average yield of tart cherries) in lbs./bearing acre

Where

(1) U.S. Department of Agriculture. "Fruit and Tree Nuts Situation and Outlook Report." Economic Research Service, USDA, various issues.

(2) "Red Tart Cherry Crop Statistics & Market Analysis." Michigan Red Tart Cherry Growers Marketing Committee and Michigan Agricultural Cooperative Marketing Association, Inc., various annual issues, 1990-1995.

(3) "Michigan Agricultural Statistics." Michigan Agricultural Statistic Service, Michigan Department of Agriculture, various issues.

(4) Woods, Timothy. "A Net Present Value Model of the Supply of Michigan Sweet Cherries." Unpublished paper, Department of Agricultural Economics, Michigan State University, August 1992.

(5) U.S. Department of Agriculture. "Fruits and Nuts Bearing Acreage, 1947-1983." National Agricultural Statistical Service, USDA, Statistical Bulletin Number 761, December 1987.

(6) Data were obtained from Dr. John Ferris, Department of Agricultural Economics, Michigan State University.

(7) Data were obtained from Dr. Alan Jones, Pesticide Research Center, Michigan State University.

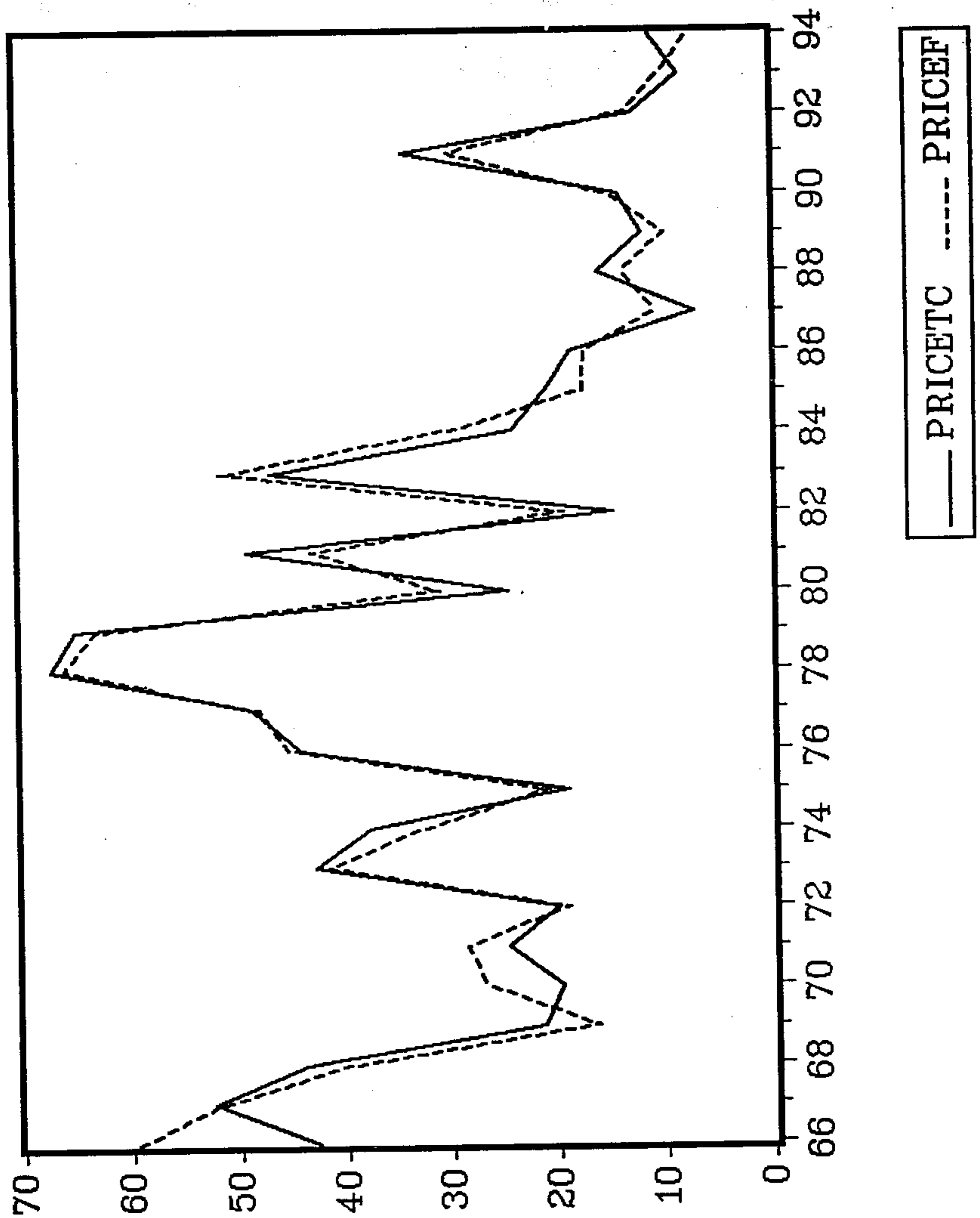
(8) Series was constructed from other cited series or is based on general information.

(9) Information was obtained from the National Pesticide Telecommunications Network, Oregon State University, 1-800-858-7378, July 1996.

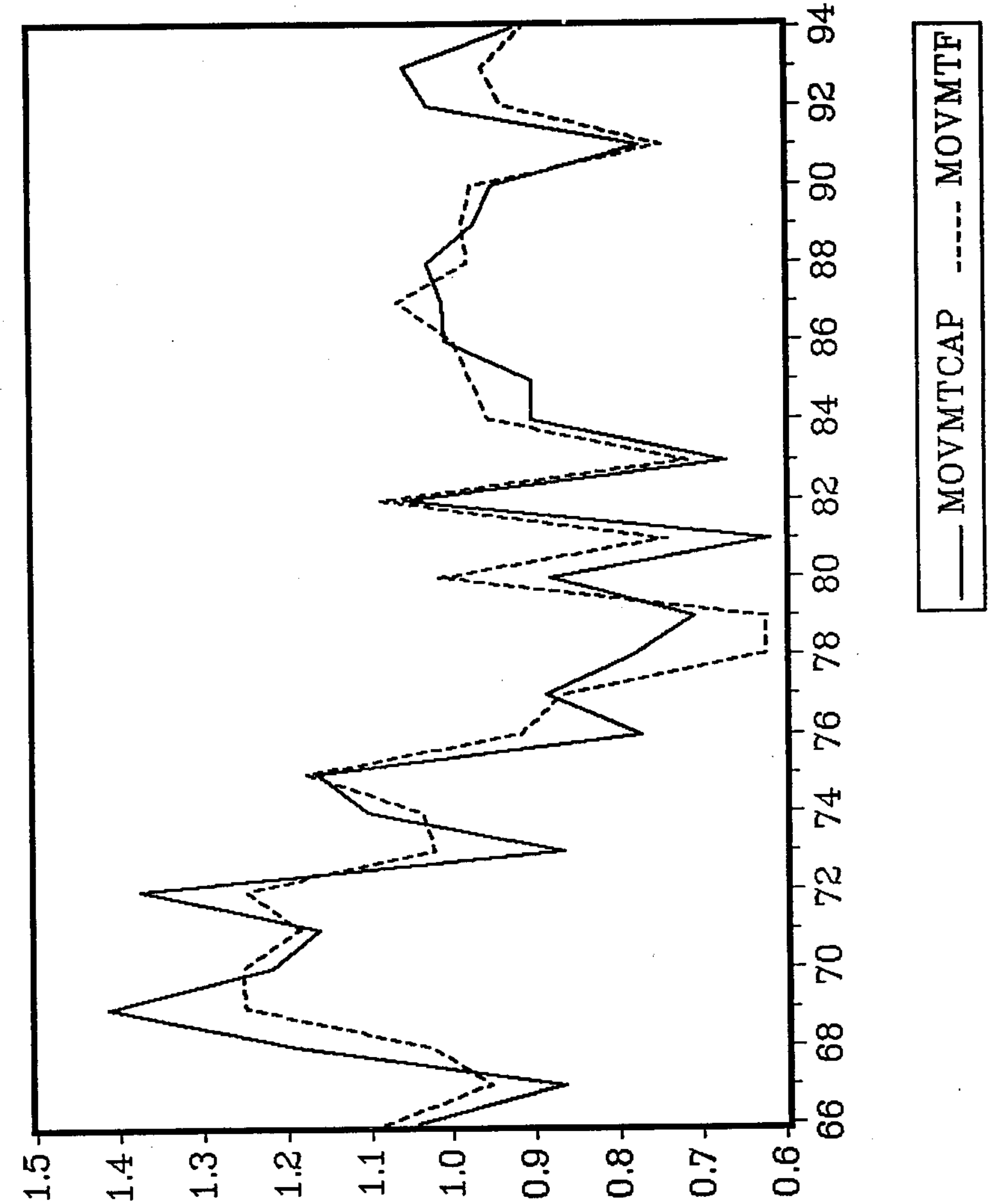
OBS	AAP	ACREBEAR	ATCP	CPI	DDIFOLITAN	DFUNGINEX	DGUTHION	DOUT	
1965	4.5	65000	NA	0.315	0	0	0	0	
1966	4.5	64200	13.8	0.324	0	0	0	0	
1967	4.5	62600	17.5	0.334	0	0	0	0	
1968	4.5	61400	15.2	0.348	0	0	0	0	
1969	4.2	60600	7.8	0.367	0	0	0	0	
1970	4.5	59300	7.6	0.388	1	0	0	0	
1971	4.9	56100	10.0	0.405	1	0	0	0	
1972	6.4	54200	8.3	0.418	1	0	0	0	
1973	8.8	52900	19.0	0.444	1	0	0	0	
1974	8.4	51600	18.5	0.493	1	0	0	0	
1975	6.5	49700	10.2	0.538	1	0	0	0	
1976	9.1	45000	25.1	0.569	1	0	0	0	
1977	10.6	42900	29.4	0.606	1	0	0	0	
1978	10.4	40800	43.8	0.652	1	0	0	1	
1979	10.9	40800	47.2	0.726	1	0	0	1	
1980	8.7	42000	20.2	0.824	1	0	0	0	
1981	11.1	40800	44.5	0.909	1	0	0	0	
1982	10.0	40340	14.1	0.965	1	0	1	0	
1983	10.5	40940	46.6	0.996	1	0	1	0	
1984	11.1	43700	25.0	1.039	1	0	1	0	
1985	11.7	46730	22.4	1.076	1	0	1	0	
1986	13.4	48930	20.3	1.096	1	0	1	0	
1987	8.6	50050	7.8	1.136	1	0	1	0	
1988	12.7	49280	18.7	1.183	1	0	1	0	
1989	10.4	49290	14.5	1.240	1	0	1	0	
1990	15.1	48790	18.1	1.307	0	0	1	0	
1991	17.9	49590	46.4	1.362	0	0	1	0	
1992	13.6	48450	17.6	1.403	0	0	1	0	
1993	12.9	47250	11.8	1.445	0	1	1	0	
1994	12.8	46175	15.9	1.457	0	1	1	0	
1995	16.7	44175	6.1	NA	0	1	1	0	
OBS	FRUTIL	GMARGIN	MOVMT	POP	STOCKSTC	TCA	TIME	UTIL	YIELD
1965	NA	NA	346.3	193.5000	92.4	31.0	1	309.8	5443
1966	NA	534.40	204.0	195.9000	55.9	1.0	2	165.8	2804
1967	NA	106.07	171.1	197.7000	17.7	0.0	3	168.7	2843
1968	NA	730.63	237.3	199.7000	15.2	0.2	4	263.8	4488
1969	NA	25.05	285.1	201.8000	41.7	12.5	5	293.1	5231
1970	NA	-187.40	248.0	203.8490	49.6	15.2	6	226.0	4233
1971	5.2	-34.64	239.6	206.4660	27.6	3.7	7	307.3	4988
1972	5.2	313.15	287.0	208.9170	55.3	43.0	8	262.2	5751
1973	5.2	516.68	182.3	210.9850	30.5	1.2	9	173.4	3313
1974	4.4	1,048.56	234.5	212.9320	18.1	0.3	10	264.6	5134
1975	7.2	334.94	249.9	214.9610	43.8	44.4	11	246.1	5845
1976	4.4	467.80	167.7	217.0950	32.8	0.0	12	146.6	3235
1977	6.1	1,487.81	193.7	219.1790	5.8	0.0	13	210.9	4916
1978	5.0	2,207.63	172.8	221.4770	16.9	0.0	14	181.2	4441
1979	4.3	2,080.23	158.2	223.8650	20.3	0.0	15	170.4	4176
1980	6.3	636.48	199.1	226.4510	28.2	5.7	16	216.2	5193
1981	4.0	1,108.49	140.9	228.9370	39.0	0.4	17	132.8	3265
1982	7.4	489.95	243.9	231.1570	26.9	66.0	18	244.9	7710
1983	5.3	1,331.47	155.7	233.3220	20.5	1.0	19	153.6	3760
1984	8.0	933.21	211.9	235.3850	13.1	16.6	20	255.9	6220
1985	7.6	719.34	213.8	237.4680	48.7	7.2	21	280.2	6120
1986	5.5	374.04	240.8	239.6380	106.9	5.7	22	218.4	4580
1987	9.1	-26.27	243.6	241.7840	79.0	73.0	23	286.0	7170
1988	5.0	301.92	250.4	243.9810	87.7	2.7	24	233.5	4790
1989	6.7	202.54	238.6	246.2240	65.8	21.1	25	243.0	5360
1990	5.1	197.95	235.5	248.6590	63.5	5.9	26	202.9	4280
1991	3.7	851.36	193.9	251.3670	25.8	0.2	27	189.7	3830
1992	8.8	414.65	260.0	254.0760	17.9	22.1	28	313.0	6920
1993	5.2	105.13	270.5	256.9640	62.1	66.8	29	256.6	6840
1994	3.5	231.90	239.2	259.6810	43.0	7.9	30	279.9	6280
1995	2.7	NA	NA	262.0730	82.6	84.4	31	NA	8690

VARIABLE	MEAN	STD. DEV.	MAX	MIN
ACREBEAR	49462	7,057.00	64,200.00	40,340.00
ATCP	21	13.00	47.00	8.00
GMTC	606	593.00	2,208.00	-187.00
MOVMT	220	40.00	287.00	141.00
POP	227	19.00	260.00	196.00
PRICETC	30	17.00	67.00	7.00
QTY	243	63.00	359.00	133.00
UTIL	227	51.00	313.00	133.00
UTILCAP	1	0.23	1.48	0.58
YIELD	4956	1,321.00	7,710.00	2,804.00

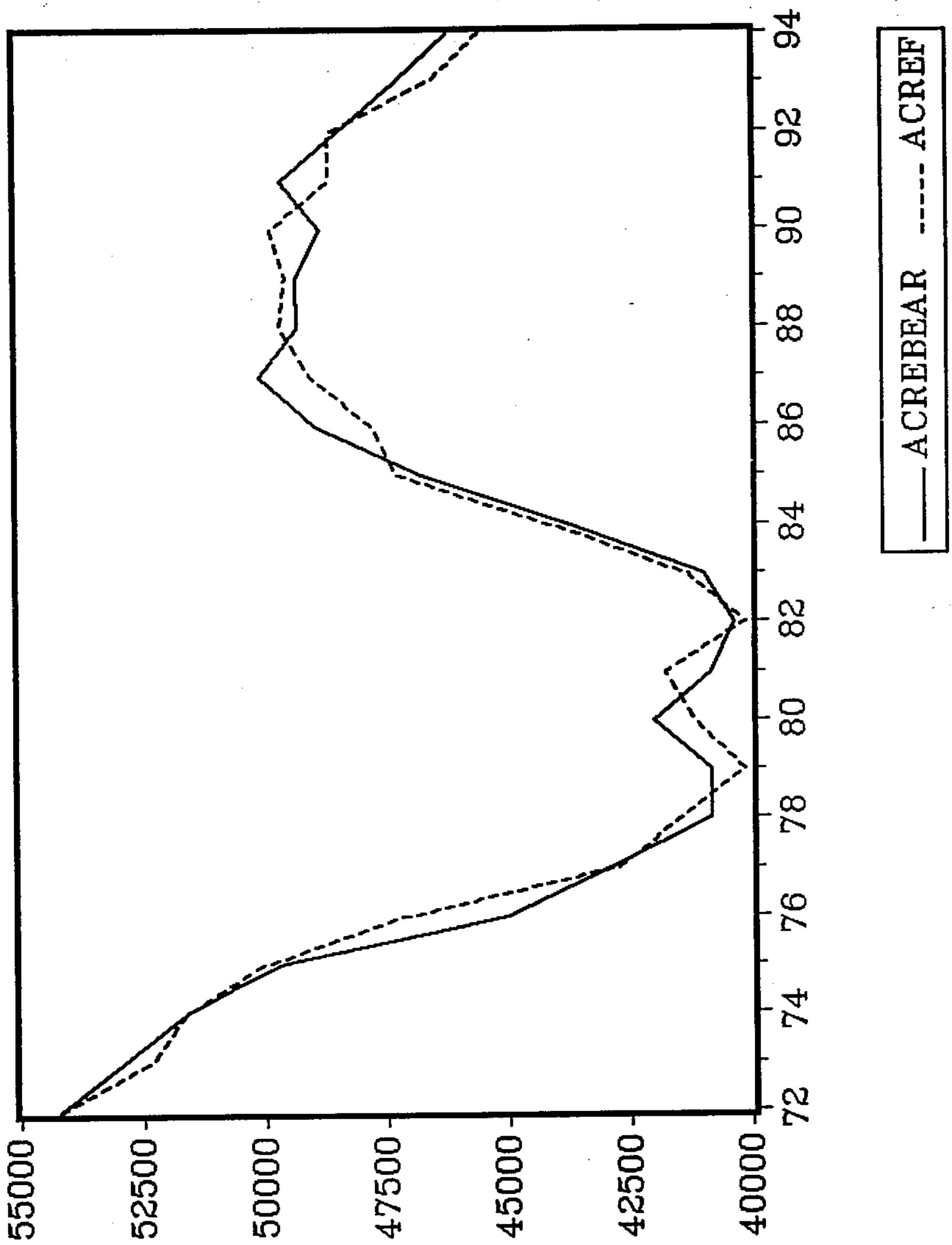
Appendix 3.2: Actual and Predicted Real Grower Prices



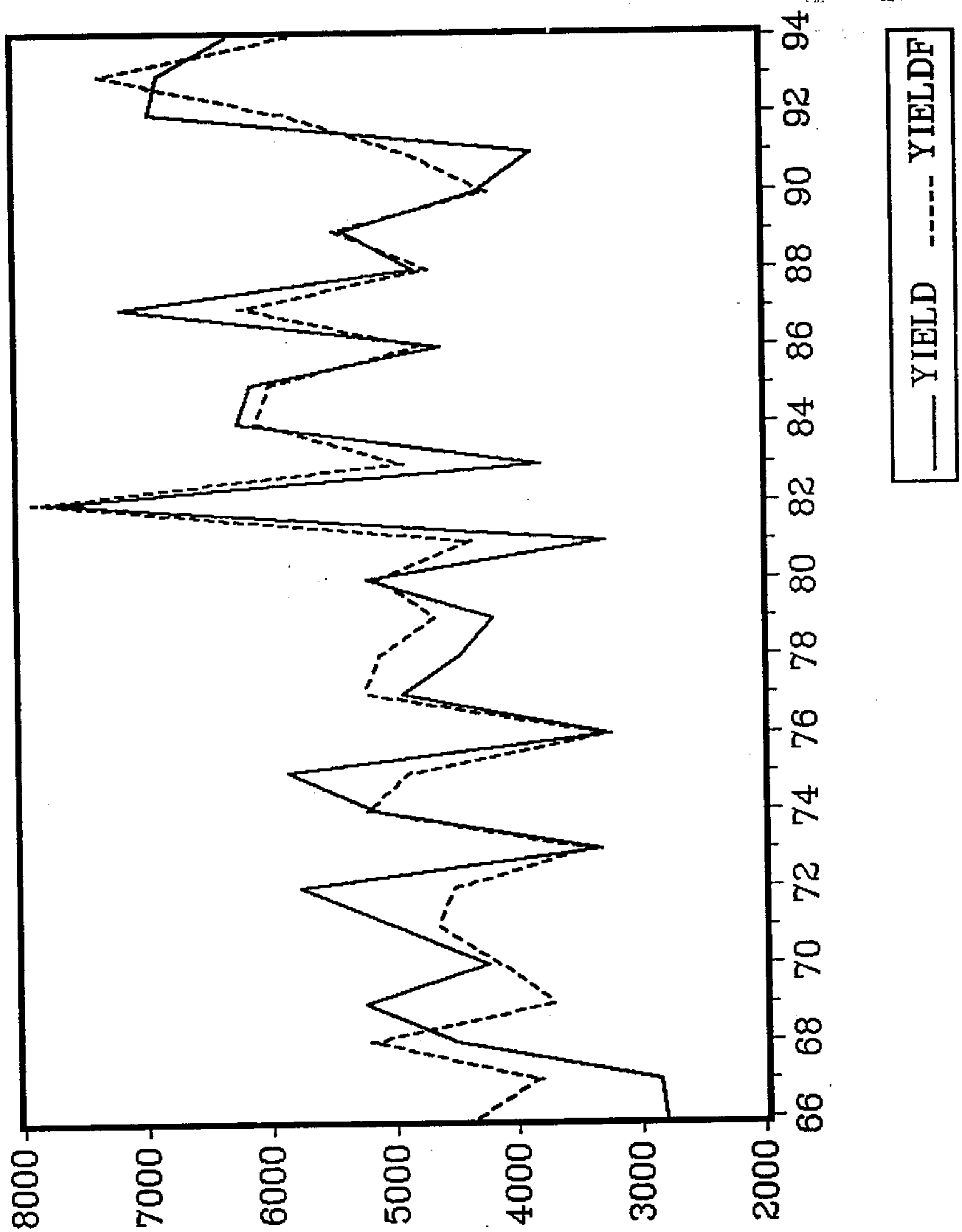
Appendix 3.3: Actual and Predicted Per Capita Movement



Appendix 3.4: Actual and Predicted Bearing Acreage



Appendix 3.5: Actual and Predicted Tart Cherry Yields



Appendix 4.1: Forecast Model and Evaluation Statistics

```
1: PRICETCf=100.2871-1.078077*TIME-32.94856*putilf-203.8497*pstock+343.1837*
pstock2f+20.80333*DOUT+[AR(1) = -.7072544]
2: putilf=pqtyf=ptcaf
3: pqtyf=qtyf/pop
4: qtyf=(acref*yieldf)/1000000
5: ptcaf=tca/pop
6: pstockf=(putilf(-1)+pstockf(-1)-pfrutilf(-1)-pmovmtf(-1))*((putilf(-1)+pstockf(-1)-
pfrutilf(-1)-pmovmtf(-1))>0.1749)+0.1749*(( putilf(-1)+pstockf(-1)-pfrutilf(-1)-
pmovmtf(-1))<=0.1749)
7: pfrutilf=frutil/pop
8: pmovmtf=1.461476-1.717766D-02*TIME-1.122872D-02*PRICETCf+9.7658D-03*
PRICEAPf
9: priceapf=aap/cpi
10: ACREf=680.4399+.9394257*ACREf(-1)+1.513746*GMARGINf(-6)+1.077875*
GMARGINf(-7)
11: gmarginf=(pricetcf*yieldf/100)-varcost
12: YIELDf=9297.236-.9128376*YIELDF(-1)-.5363512*YIELDf(-2)
+2018.954*DDIFOLOT+4078.224*DFUNGINE+2347.749*DGUTHION
13: pstock2f=pstockf^2
14: aap=aap*(time<32)+(aap(-1)+0.37)*(time=>32)
15: tca=tca*(time<32)+(0)*(time=>32)
16: cpi=cpi*(time<31)+(cpi(-1)+0.02609*time+0.00058*time2)*(time=>31)
17: time2=time^2
18: qty2f=qtyf^2
19: frutil=frutil*(time<32)+(frutil(-1)+0.0555)*(time=>32)
```

```
1: @ calculate the error term
2: a=pmovmt
3: f=pmovmtf
4: e=a-f
5: @ calculate variables for mean negative and positive percent errors
6: nege=e*(e<=0)+na*(e>0)
7: pose=e*(e>0)+na*(e=<0)
8: nega=a*(e=<0)+na(e>0)
9: posa=a*(e>0)+na(e=<0)
10: rnege=nege/nega
11: rpose=pose/posa
12: @ calculate variables for mean absolute percentage error
13: abse=-e(e=<0)+e*(e>0)
14: abspe=abse/a
15: @ calculate variables for adjusted mean absolute percentage error
16: abspea=abse/(.5*(a+f))
17: @ calculate variables for root mean squared percentage error
18: esq=e^2
19: @ calculate variable for mean percentage error
20: rea=e/a
```

Formulas for Calculating the Forecast Evaluation Statistics

Mean Absolute Percentage Error (MAPE)

$$MAPE \equiv \{1 / n \sum_{t=1}^{n} (|E_t| \ / \ A_t)] * 100$$

Mean Percentage Error (MPE)

$$MPE \equiv [1 / n \sum_{t=1}^{n} (E_t \ / \ A_t)] * 100$$

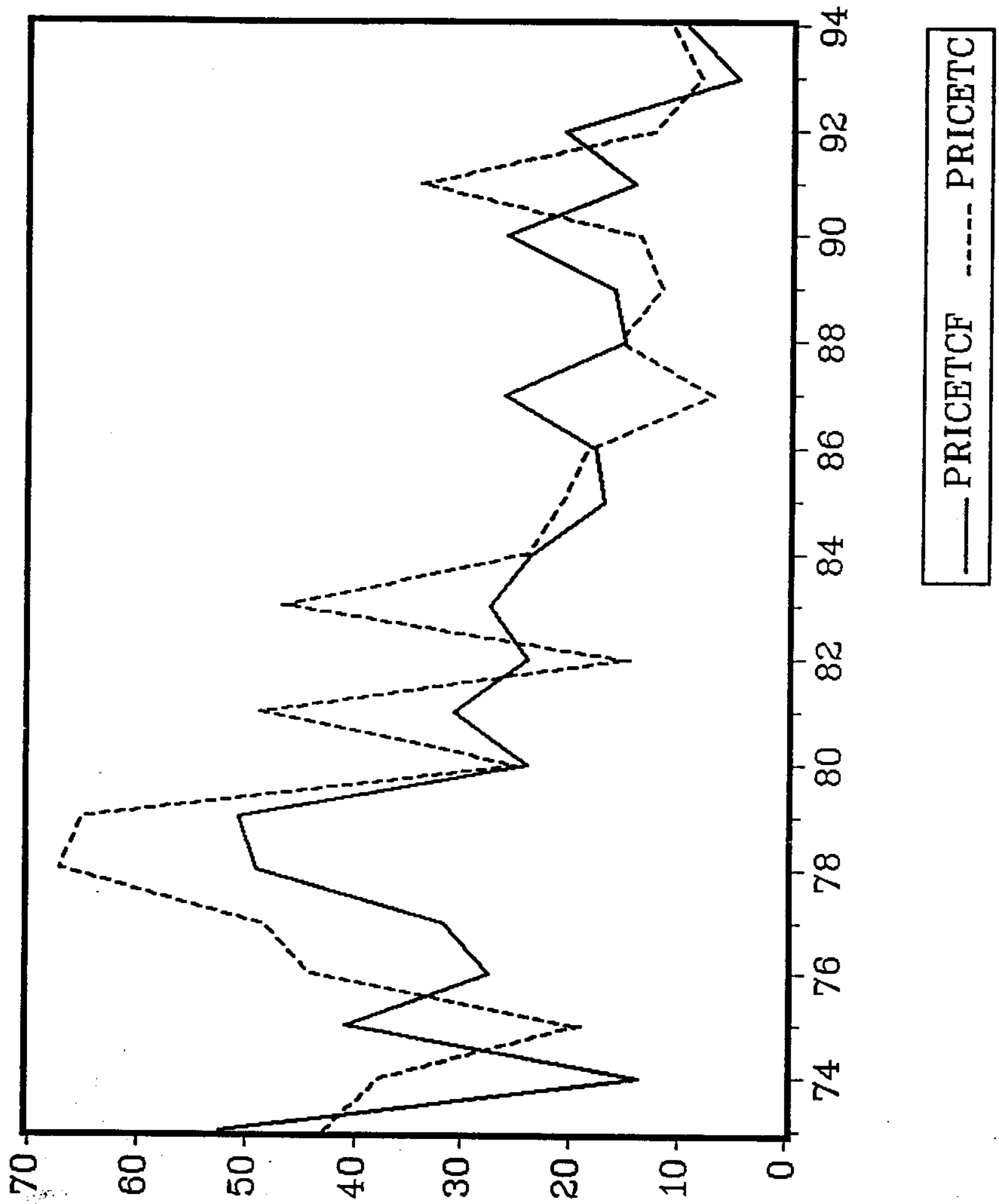
Where
E = Error= Actual Value - Forecast Value

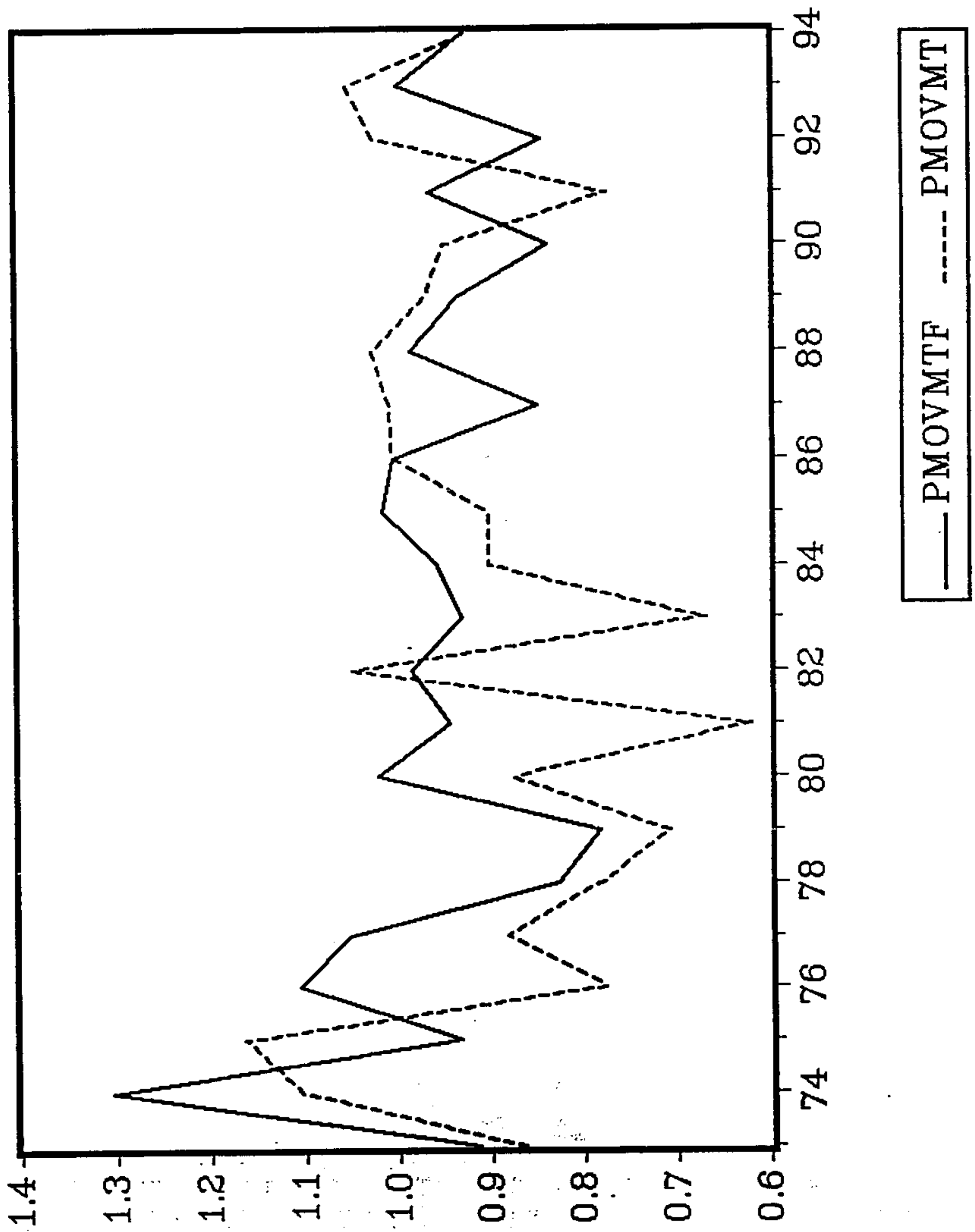
A = Actual Value

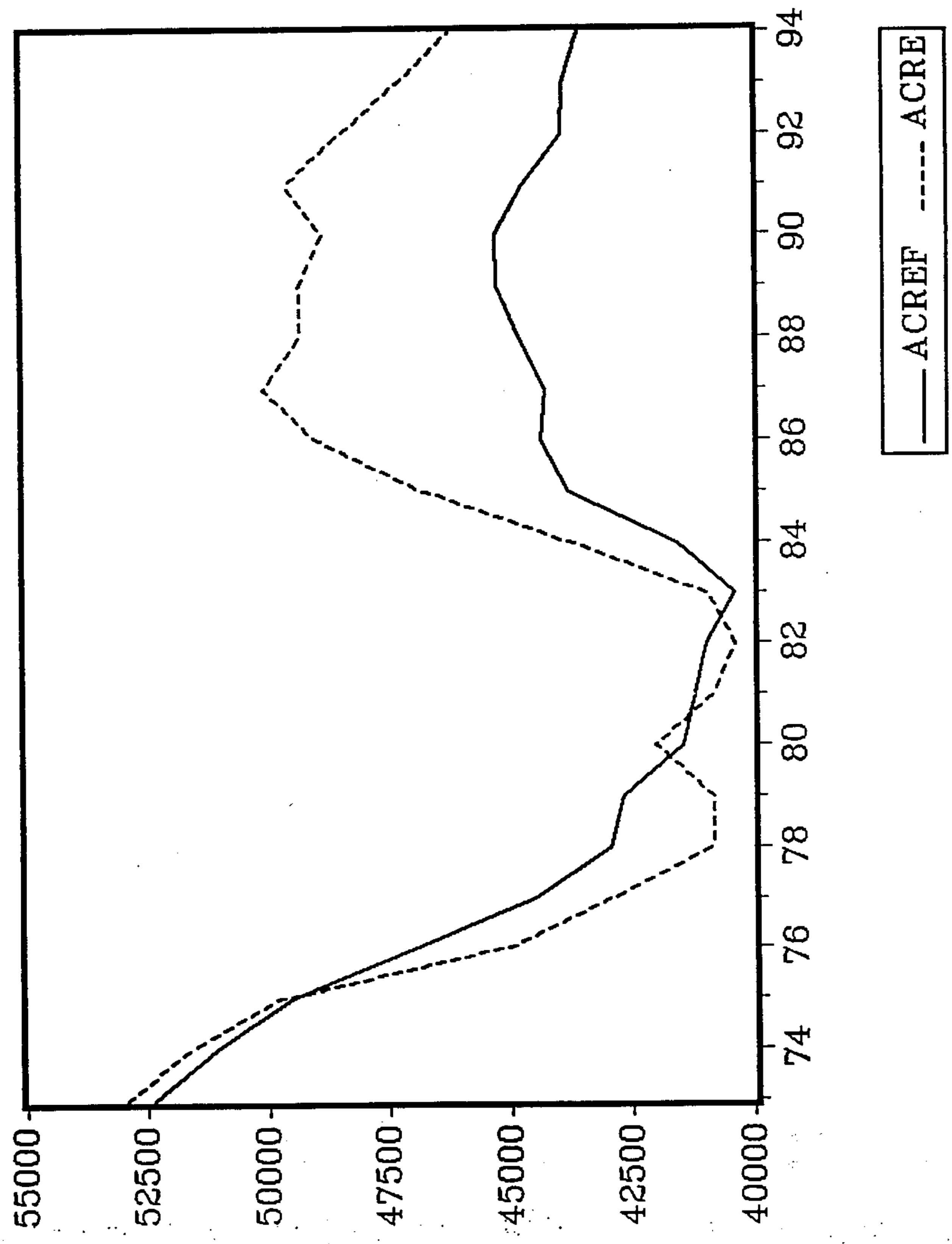
t = observation

n = number of observations

Appendix 4.2: Ex Post Forecast Evaluations




PMOVMTF
PMOVMT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50000
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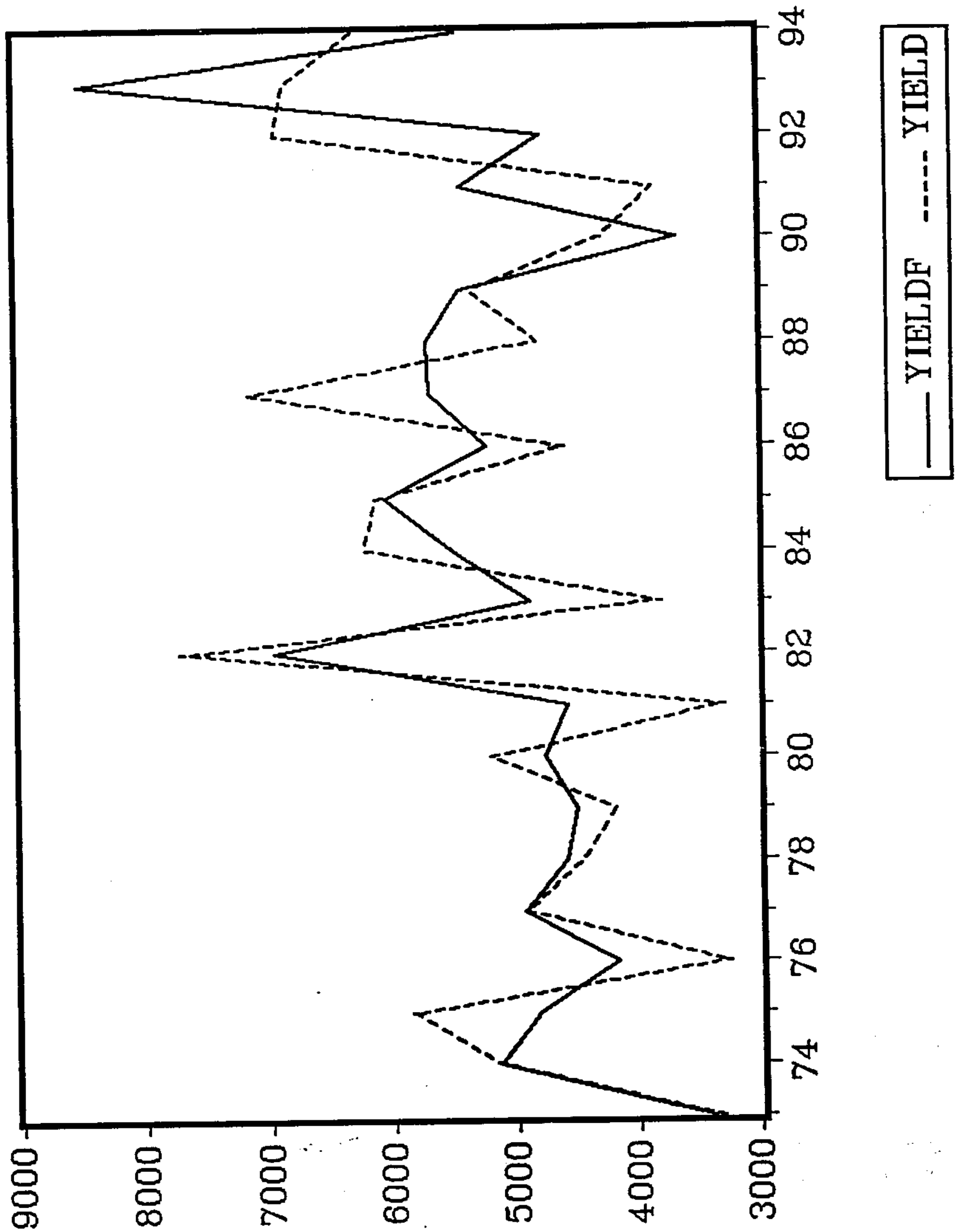
74
76
78
80
82
84
86
88
90
92
94
ACREF
ACRE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8000
7000
6000
5000
4000
3000
74
76
78
80
82
84
86
88
90
92
94
YIELDF
YIELD

Appendix 4.3: Annual Forecast Predictions By Variable

Real Grower Price for Tart Cherries

Year	Scenario One Guthion available	Scenario Two Guthion lost in 1997	Scenario Three Guthion lost in 2000	Scenario Four Guthion lost in 2003
1995	10.8	10.8	10.8	10.8
1996	26.8	26.8	26.8	26.8
1997	7.6	20.0	7.6	7.6
1998	8.7	14.8	8.7	8.7
1999	13.7	21.7	13.7	13.7
2000	10.9	17.6	22.1	10.9
2001	12.0	16.7	15.0	12.0
2002	14.0	18.7	18.0	14.0
2003	11.9	16.2	17.8	21.8
2004	13.5	16.3	15.8	14.4
2005	12.8	16.1	16.8	16.2
2006	12.1	14.9	15.9	17.3

National Tart Cherry Production

Year	**Scenario One** Guthion available	**Scenario Two** Guthion lost in 1997	**Scenario Three** Guthion lost in 2000	**Scenario Four** Guthion lost in 2003
1995	282.53	282.53	282.53	282.53
1996	108.20	108.20	108.20	108.20
1997	255.07	154.71	255.07	255.07
1998	205.75	197.07	205.75	205.75
1999	164.97	127.91	164.97	164.97
2000	213.81	157.56	120.47	213.81
2001	177.04	154.93	169.14	177.04
2002	171.85	131.81	137.99	171.84
2003	181.30	144.27	130.09	96.32
2004	159.99	136.31	140.15	152.90
2005	158.17	128.83	122.61	128.10
2006	156.37	131.73	122.35	110.65

Annual Per Capita Tart Cherry Movement (Proxy for Demand)

Year	**Scenario One** Guthion available	**Scenario Two** Guthion lost in 1997	**Scenario Three** Guthion lost in 2000	**Scenario Four** Guthion lost in 2003
1995	0.87	0.87	0.87	0.87
1996	0.65	0.65	0.65	0.65
1997	0.84	0.70	0.84	0.84
1998	0.83	0.74	0.80	0.80
1999	0.73	0.64	0.73	0.73
2000	0.74	0.66	0.61	0.74
2001	0.71	0.65	0.67	0.71
2002	0.66	0.61	0.62	0.66
2003	0.67	0.62	0.60	0.56
2004	0.63	0.60	0.61	0.62
2005	0.62	0.59	0.58	0.59
2006	0.61	0.58	0.57	0.56

Tart Cherry Acreage

Year	Scenario One Guthion available	Scenario Two Guthion lost in 1997	Scenario Three Guthion lost in 2000	Scenario Four Guthion lost in 2003
1995	44690	44690	44690	44690
1996	43182	43182	43182	43182
1997	42749	42749	42749	42749
1998	42385	42385	42385	42385
1999	41104	41104	41104	41104
2000	39759	39759	39759	39759
2001	38628	38628	38628	38628
2002	37547	37547	37547	37547
2003	36197	36603	36197	36197
2004	34645	35716	34645	34645
2005	33347	34825	33347	33347
2006	32318	34011	33444	32318

Tart Cherry Yields

Year	Scenario One Guthion available	Scenario Two Guthion lost in 1997	Scenario Three Guthion lost in 2000	Scenario Four Guthion lost in 2003
1995	6322	6322	6322	6322
1996	2506	2506	2506	2506
1997	5967	3619	5967	5967
1998	4854	4650	4854	4854
1999	4014	3112	4014	4014
2000	5378	3963	3030	5378
2001	4583	4011	4379	4583
2002	4577	3511	3675	4577
2003	5009	3941	3594	2661
2004	4618	3816	4045	4413
2005	4743	3699	3677	3841
2006	4839	3873	3771	3424

Gross Margins per acre of Tart Cherry

Year	**Scenario One** Guthion available	**Scenario Two** Guthion lost in 1997	**Scenario Three** Guthion lost in 2000	**Scenario Four** Guthion lost in 2003
1995	229.10	229.10	229.10	229.10
1996	219.34	219.34	219.34	219.34
1997	4.52	272.71	4.52	4.52
1998	-29.21	235.39	-29.21	-29.21
1999	100.22	223.65	100.22	100.22
2000	133.53	246.74	217.05	133.53
2001	97.68	219.42	207.05	97.68
2002	190.39	206.33	210.43	190.39
2003	143.00	186.71	189.93	128.35
2004	173.75	169.85	189.12	182.26
2005	153.30	144.80	167.41	170.91
2006	132.97	125.02	150.09	140.29

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