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A Comparison of Models to Forecast Annual Average Potato Prices in Utah

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A COMPARISON OF MODELS TO FORECAST ANNUAL AVERAGE

POTATO PRICES IN UTAH

by

Glade R. Erikson

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Glade R. Erikson

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ABSTRACT

A Comparison of Models to Forecast Annual Average

Potato Prices in Utah

by

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Utah State University, 1993

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Department: Economics

Potatoes are a capital-intensive crop. A farmer who is considering expanding his potato acreage must carefully consider revenue requirements to offset the high costs of raising the crop. A method to forecast annual farm potato prices would be useful not only to the farmer, who is considering potato acreage expansion (or contraction), but also to the potato buyers.

Seven forecasting models were considered: (1) a simultaneous equation model (with five equations); (2) a Box-Jenkins type ARIMA model; (3) an exponential smoothing model; (4) a moving-average model; (5) a trend model; (6) an "opposite" model; and (7) a current, or naive, model.

The results reveal the following three things: (1) The "best" model was the trend model. This model gave the most accurate one-period out-of-sample forecasts of the models tested (as measured by the mean absolute error (MAE), the root

mean squared error (RMSE), and Theil's U_2 statistics). The simultaneous equation model could be considered as the next best model. (2) The forecast for the average Utah farm potato price for 1992 was about \$5.40 per cwt. (3) The average Utah farm potato price for 1993 should be in the \$5.51 to \$5.95 range (the forecasts from the trend and simultaneous equation models, respectively).

(73 pages)

CHAPTER 1

INTRODUCTION

In the United States, the per capita consumption of potatoes was just over 130 pounds in 1991, the highest per capita consumption of any vegetable (USDA, ERS July 1992). Figure 1 shows that per capita consumption of potatoes has increased since the early 1980s. As shown in figure 2, the value of U.S. potato sales exceeded \$2.2 billion in 1990. Figure 2 also shows the total production of U.S. potatoes. Both the value of sales and the total production of potatoes have increased since the 1970s (USDA, ERS July 1992).

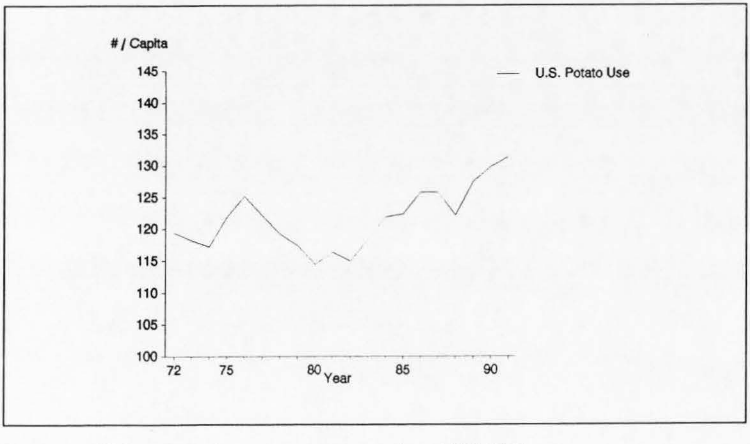

Figure 1. U.S. per capita potato consumption, 1972-1991

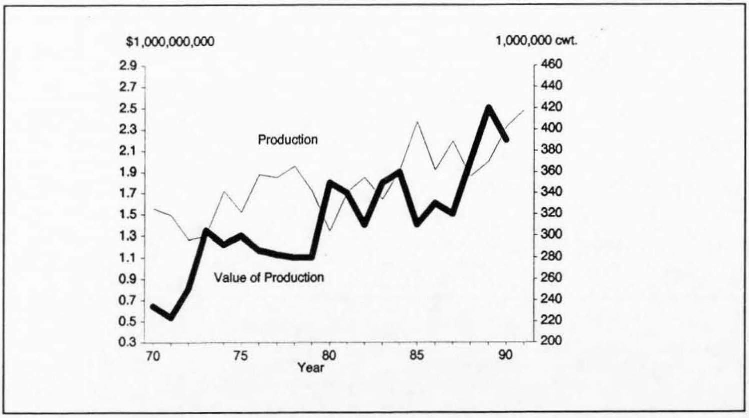

Figure 2. U.S. potato production and value of production, 1970-1990

In Utah, potatoes are also a valuable crop. *Utah Agricultural Statistics* (UDA) reports that Utah potato production was worth over $8.2 million in 1991. Utah production over the past five years has been around 1,600,000 cwt. and has been planted on about 6,500 acres. Figure 3 shows the production and value of production of Utah's potato crop since 1970.

On a per-acre basis, potatoes are one of Utah's most capital-intensive crops. A 1990 estimate suggests that total purchases, operation costs, and interest charges were over $1,300 per acre for a potato crop. In comparison, alfalfa, corn silage, winter wheat, and dry onion costs (1991) were $424, $351, $194, and $2,292 per acre, respectively (UDA).

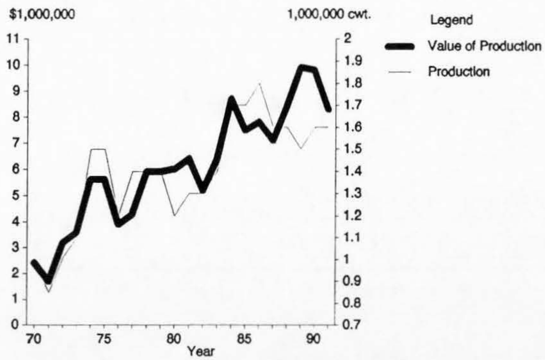

Figure 3. Utah potato production and value of production, 1970-1990

Justification and Discussion

As shown in figures 2 and 3, potato production in the U.S. has grown rather constantly since the 1970s, while production in Utah increased early in the 1970s and has remained about constant in recent years. One reason farmers may be hesitant to increase production is the risk associated with the large amounts of capital required to produce potatoes. This added risk may be partially offset by a good forecast for potato prices.

Research shows that the acreage adjustment by farmers in response to price is very minimal (Estes, Blakeslee, and Mittelhammer). Estes, Blakeslee, and Mittelhammer found that a 1% increase in expected price would only increase acreage by .26% in the Pacific Northwest growing area. The low acreage adjustment is partially explained by the high amount of fixed costs incurred by the high-value crop and the lack of suitable alternative high value crops.

The demand for potatoes is very price-inelastic, which can cause wide changes in price with small changes in supply (Estes, Blakeslee, and Mittelhammer). The high production costs associated with potatoes and the inelastic demand make it critical that the first year of a new or expanding potato production enterprise is supported by good prices.

Even though acreage adjustment may be small, the capital-intensive nature of potato production makes it very important (especially to the individual farmer). A new or expanding potato farmer must be able to harvest and market his/her crop at a good price in order to survive. As an example, an Upper Snake River (Idaho) dryland small grain producer decided to start a seed potato operation. He had his land paid for and several years' worth of grain in storage. Three consecutive potato marketing failures (because of frost, low prices, etc.) forced him to bankruptcy (Erikson).

A price forecast for potatoes not only will help farmers manage their present risk levels and plan acreage expansion (or contraction) strategies but will also be of benefit to potato buyers.

Discussion

Some potato producers (notably potato seed growers) suggest that when the price of potato seed is high, acreage should be reduced; and when the price of seed potatoes is low, potato production acreage should be increased (Romrell). This may seem logical because high potato seed demand (which causes high seed prices) suggests a lot of potatoes will be planted (and harvested) next year, which should depress prices.

Since seed potato prices and potato prices are often correlated, this statement is an example of an "opposite" naive expectation model (Heady). An "opposite" model suggests that if prices are high this year, they will be low next year. Heady suggests the "opposite" model may be reasonable for a farmer if a large number of other producers base their price expectations on current prices (a "current" price expectation model).

Other naive expectation models include: the mean yield and price, the modal yield and price, and the extension of a linear trend. Some expectation models are more valid in different situations than others. For example, a trend expectation model will not be efficient for yield predictions when yield is influenced by random weather patterns. Heady examined several naive expectation models for potato prices in the early 1950s and found the expectation of next year's price to be the same as the current year's price, given the lowest error of the models examined.

There are three broad categories of forecasting models: extrapolative, explanatory, and a mixture of the two (Skaggs and Snyder). The above naive forecasting models are extrapolative techniques. Other extrapolative techniques include vector autoregressive (VAR) models, autoregressive-integrated-moving average (ARIMA), and exponential smoothing models (Skaggs and Snyder).

Explanatory techniques are also used in forecasting (Skaggs and Snyder). The techniques include simple single-equation models or more complex simultaneous equation models. Estes, Blakeslee, and Mittelhammer used a 46-equation econometric model to model the U.S. potato industry. However, a model this complicated is beyond the capabilities of most farmers to utilize.

Objectives

The purpose of this research is to develop and compare usable models to predict short-term potato prices for Utah producers (and buyers). Models to be developed and compared include an econometric model and various naive expectation models.

There are three objectives:

1. Forecast Utah yearly average potato prices using several models (i.e., simultaneous equation, ARIMA, exponential smoothing, opposite, current (referred to later as naive), and trend).
2. Compare the forecasting models by forecasting one period out-of-sample over the 1986-1991 season and measure model accuracy using the mean

absolute error (MAE), the root mean square error (RMSE), and Theil's U_2 statistics.

3. Use the models to forecast prices for the 1992 and 1993 seasons.

Methods

Objective 1

This first objective was to forecast Utah's annual average potato prices using several models, i.e., (1) simultaneous equation, (2) ARIMA, (3) exponential smoothing, (4) moving-average, (5) trend, (6) opposite, and (7) naive (current). The objective was accomplished by:

a. Gathering data on annual average potato prices; income; prices of substitutes and complements; potato production, yield, and acreage; population; etc.

b. Including supply and demand functions in the econometric model with such variables as price of seed potatoes, potato stock, weather data, potato consumption, population, prices of other crops, etc. Then an estimate was made of the simultaneous equations using two-stage least squares (TSLS).

c. Estimating the extrapolative models.

Objective 2

The second objective was to compare the forecasting models by forecasting one year out-of-sample (one step ahead) over the 1986-1991 seasons and to compare the accuracy of the models using the mean absolute error (MAE), root mean square error (RMSE), and Theil's U_2 statistics. This was accomplished by:

a. Forecasting six years of potato prices out-of-sample and by re-estimating each model after each year.

b. Calculating the accuracy of the models using measures such as the mean absolute error (MAE), the root mean squared error (RMSE), and Theil's U_2 statistics.

Objective 3

In the third objective, models were used to forecast prices for the 1992 and 1993 seasons. After the models have been estimated, make a one- and a two-year out-of-sample forecast (for the 1992 and 1993 seasons). The 1992 forecast will be a one-step-ahead forecast. The 1993 forecast will be a two-step-ahead forecast. Data that are needed to run the models for the 1993 forecasts will be forecasted, if not available (for example, the 1992 Utah farm potato price).

CHAPTER 2

LITERATURE REVIEW

Potatoes

Demand

Traditionally, potatoes have been used as an example of an inferior good (Miller). That is, as income increases the quantity of potatoes demanded decreases $\left(\frac{\%\Delta Q_d}{\%\Delta I} < 0\right)$. In a time-series analysis, Hee (1967) found the income elasticity of farm potatoes demanded for food with respect to income to be not significantly different from zero. Hee suggests that cross-sectional analysis may separate the effects of time and income and allow income elasticities to be measured.

The wide number of potato uses may also be partially responsible for the inconclusive income effects on farm potato demand. For instance, French fries may be a luxury good while fresh potatoes may, in fact, be an inferior good. Estes, Blakeslee, and Mittelhammer found the income elasticity of quantity demanded for fresh potatoes to be lower than the income elasticity of demand for processed potatoes (0.11 and 0.67, respectively).

Recent potato consumption trends seem to support these findings. Since the early 1970s, per capita consumption of fresh potatoes has fallen by 19%. However, the increase in per capita consumption of frozen potatoes has more than made up the difference to give an overall 7% increase in per capita consumption of potatoes (USDA).

The own-price elasticity of demand for farm potatoes has usually been found to be in the inelastic region (less than 1 in absolute value elasticity terms) (Estes, Blakeslee, and Mittelhammer; Hee 1967). For example, Hee found late spring, early summer, and fall potatoes to have own-price elasticities of -0.6, -0.7, and -0.2, respectively. However, winter and early spring potatoes' own-price elasticity was found to be -2.6 (elastic) because of competition from stored fall potatoes. Estes, Blakeslee, and Mittelhammer estimated own-price elasticities of -0.12, -0.24, and -0.89 for fresh potatoes, processed potatoes, and feed potatoes, respectively.

Both the use of the potatoes and the season in which they are produced affects the own-price elasticities. Generally, however, potato demand can be considered quite price-inelastic (including pre-World War II periods) (Hee 1967). This suggests that a large potato crop will be worth far less than a small potato crop (shown graphically in figure 2, section I) and that rapid expansion of potato production would depress revenues for the whole production industry (Hee 1967; Estes, Blakeslee, and Mittelhammer).

The elasticity of demand for fresh and processed potatoes, with respect to the percentage of women in the U.S. labor force, was found to be -1.1 and 4.7, respectively, in 1982 (Estes, Blakeslee, and Mittelhammer). This demand for convenient food may partially explain the recent increase in demand for processed potatoes and the decline in demand for fresh potatoes.

More recently, a survey by McCraken and Marotz found that consumers may be reversing the trend by increasing their consumption of fresh potatoes and decreasing their consumption of processed potatoes. The concern over calorie intake was cited as the major reason for the reversal. The survey also found that consumers were responsive to potato quality, packaging, and price. Rice was mentioned as the most popular substitute for potatoes. The survey reported that Washington consumers were not influenced by origin or point-of-sale advertisements.

Goodwin et al., however, found that state-of-origin is important to determine prices for certain potato types. Idaho ten-ounce russet potatoes were priced superior to other states-of-origin. The red round potato, the russet 80-count (generally considered the premium potato), and the unsized russet (usually considered to be the lowest quality russet) had very minimal price premiums for state-of-origin. Goodwin et al. also suggest that package type is an important determinant of terminal market potato prices.

Supply

The supply of crops consists of yield and acreage factors. A "cobweb" model (see "cobweb" section below) has sometimes been used to explain the acreage planting decisions of potato farmers (Waugh). The cobweb model suggests that the planting decision for this year is influenced inversely by the last year's price. Guenthner and Chapman suggest that Idaho potato acreage can be predicted by last year's potato price, acreage last year, and last year's prices of competing crops (such as wheat, barley, sugarbeets, and hay).

Estes, Blakeslee, and Mittelhammer estimated the expected own-price short-run supply (acreage planted) elasticities to be less than one in every potato producing area, except the California region. This may be as expected, since California has a greater variety of substitutable crops than other areas. The long-run supply elasticities were also estimated. As expected, supply was more elastic in the long run than in the short run. However, in some regions, supply was elastic (Maine, California, Colorado, and other states), while in others (Pacific Northwest, Red River Valley, and the North Central States) supply was inelastic in the long run.

Estes, Blakeslee, and Mittelhammer also found the short-run elasticity, with respect to risk (the variance of expected price), was found to range from -0.005 to -0.085. Cross-expected price (price of competing crops) supply elasticities were generally found inelastic, again with the California and Colorado regions being the exceptions.

A survey of Idaho farmers by Guenthner and Chapman found that contract price and availability, crop rotation, U.S. acreage projections, price outlook, price of previous potato crop, other crop prices, cost of production, and lender advice (in that order) were important for acreage planting decisions.

Potato yield has been increasing, both in Utah and in the United States, since the 1950s (figure 4). As shown in figure 4, Utah potato yields have historically been below the national average. As one would expect, Utah yield data are considerably more variable than aggregate national yield data.

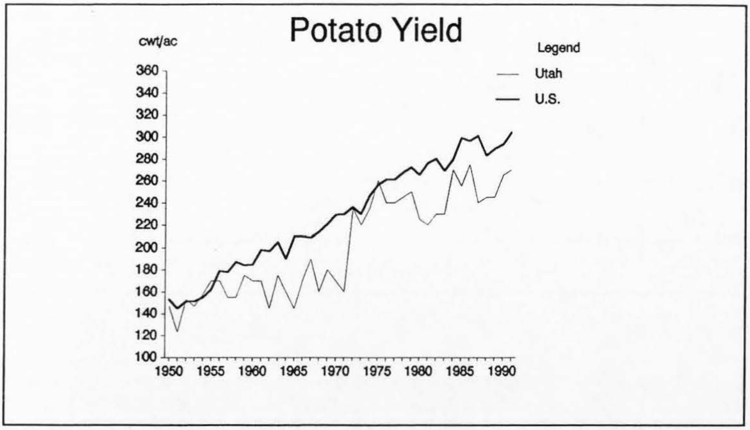

Figure 4. Potato yield in Utah and the U.S., 1950-1991

Imports and exports of potatoes have had a small impact on domestic potato supply. For instance, about 2% of production was exported in 1991. Imports were also about 2% of production (USDA, NASS).

Typically, 91% of potato production is sold. These sales include table stock, processed potatoes, feed, and seed. Of the 9% that is not sold, the majority is loss and shrinkage. Loss and shrinkage have been approximately 7% of total production recently. The remainder of the nonsales portion is consumed on-farm or used for seed on-farm (USDA, NASS).

Market Structure

Figures 5 and 6 were proposed by Hee (1967) (with some modification here) as a basic representation of the potato economy. The circles primarily represent economic variables, the squares represent physical variables, the arrows are the directions of influence, the dashed lines are interrelated physical quantities, the dotted lines are decision making relationships, and the solid lines are jointly determined variables. Figure 5 shows that acreage and yield determine production, and there are several variables that influence acreage and yield. Last year's potato

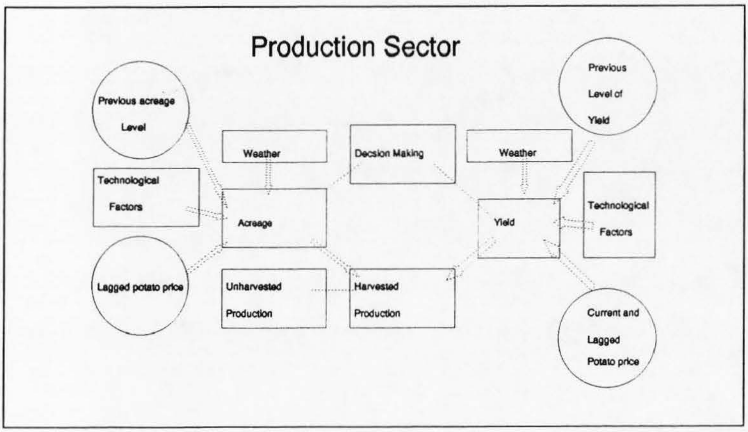

Figure 5. Production sector of the potato economy
Source: Hee (1967).

price, technology, and weather influence both acreage and yield. Previous acreage and yield levels influence acreage and yield (in this year), respectively.

Figure 6 suggests that the price of substitutes, last year's food consumption, income, tastes and preferences, and the retail price of potatoes influence the amount of potatoes consumed for food. Potatoes used for food are separated into fresh and processed uses. Marketing costs influence the retail price and the farm price. Farm prices influence the other uses of potatoes.

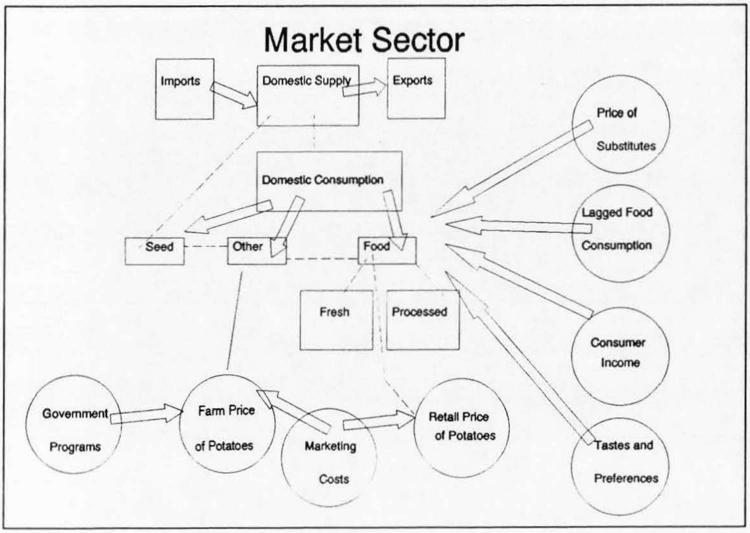

Figure 6. Market sector of the potato economy
Source: Hee (1967)

Forecasting

Simultaneous Equation Models

Using relationships of an economy (potato), like the ones presented in figures 5 and 6, one can set up a system of equations to estimate the relationships in the economy. Since some of the variables are jointly determined (X depends on Y, and Y depends on X), the equations are simultaneously related. Simultaneous equations may not be estimated without taking into account the information provided in the other equations (Gujarati).

Estimating single equations within a system of equations by least squares often causes simultaneous equation bias. Simultaneous equation bias is caused when one or more of the explanatory variables is correlated with the disturbance term. To overcome problems of simultaneity bias, special procedures must be used (Gujarati).

Given that the system is not underidentified, some of the appropriate procedures are two-stage least squares (2SLS), three-stage least squares (3SLS), indirect least squares (ILS), instrumental variables (IV), limited information maximum likelihood (LIML), and full information maximum likelihood (FIML) (Greene). Underidentified systems cannot be estimated.

Two conditions must be met for identification. The order condition is a necessary but not sufficient condition for identification (Greene). The order condition states that "the number of exogenous variables excluded from equation j must be at least as large as the number of endogenous variables included in equation j" (Greene, p. 606). The sufficient condition is the rank condition, which insures that there is one solution for the system (Greene).

Simultaneous equation models have been used in several instances to model potato supply and/or demand (Hee 1967; Hee 1966; Estes, Blakeslee, and Mittelhammer). Such models are very useful to determine the relationships among past economic and physical variables. The value of econometric simultaneous equations for forecasting is not clear. Generally, it is concluded that judgmental forecasting approaches are not any more accurate than objective ones; causal econometric models are not any more accurate than time-series models; and more complex models are not more accurate than simple models (McIntosh and Dorfman).

Extrapolative Techniques

There are three basic kinds of techniques used for forecasting: explanatory, extrapolative, and mixed (Skaggs and Snyder). Explanatory techniques "are based on the assumption that the future can be predicted by factors that explain past variations" (Skaggs and Snyder, p. 3). Simultaneous equation models are examples of explanatory techniques. Extrapolative techniques make forecasts using only the past data. These techniques include ARIMA and mechanical forecasting methods.

ARIMA. ARIMA (auto regressive integrated moving-average) procedures have been found to be quite useful for forecasting. For example, Bourke found that the Box-Jenkins (ARIMA) technique forecasted beef prices slightly better than simultaneous econometric equation techniques.

The Box-Jenkins procedure to ARIMA modeling consists of identification, estimation, and diagnostic steps. The steps are repeated until a satisfactory model is found (Bourke). For ARIMA modeling, the data must be stationary (constant mean and variance). The identification and diagnostic steps of the Box-Jenkins procedure check for stationarity and provide initial estimates of the appropriate model. If identification and diagnostics suggest that the data are not stationary, stationarity can often be achieved by taking a first or second difference of the data. A dth order difference can be written as follows (Makridakis, Wheelwright, and McGee):

(2-1) $$(1 - B)^d X_t = e_t ,$$

where B is the backwards shift operator--$BX_t = X_{t-1}$, and e_t is the error term.

A pth order autoregressive process in ARIMA modeling can be denoted as follows (Makridakis, Wheelwright, and McGee):

(2-2) $$X_t = \mu' + \phi_1 X_{x-1} + \phi_2 X_{x-2} + \dots + X_{t-p} E e_t ,$$

where μ' is the constant term, ϕ_j is the jth autoregressive parameter, and e_t is the error term at time t.

A qth order moving average process can be written (Makridakis, Wheelwright, and McGee):

$$X_t = \mu + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \ldots - \theta_q e_{t-q} , \tag{2-3}$$

where μ is the constant term, θ_q is the qth moving average parameter, and e_t is the error term in time t.

The ARIMA (p, d, q) notation follows the convention of designating the AR (autoregressive) order as p, the differencing order as d, and the MA (moving-average) order as q.

Like other extrapolative forecasts, ARIMA modeling lacks the rich economic theory of the explanatory models. This causes some forecasters to shy away from extrapolative techniques, though they may be more accurate than the explanatory techniques.

Naive and mechanical forecasting. "A naive method is defined as an unsophisticated and unscientific projection based on guesses or mechanical extrapolations of current prices" (Miller and Jelinek, p. 22). The current naive model is frequently used in forecasting as a baseline for forecast effectiveness. In the current forecasting model, the forecast is the current value. There are other kinds of mechanical models. Some researchers (Darcovich and Heady; Heady) have used expectations based on the mean, random outcomes, opposite, modal, moving-average, and linear trend models to make forecasts.

Darcovich and Heady found that in data series with some imperfect degree of autocorrelation, farmers should use the current-year model or the weighted moving-average model. For greater accuracy in large price changes, the "outlook model" was recommended (the outlook model was based on outlook reports of various state and federal agencies). For series (yield series) that were approximately random, they recommended the five-year moving-average model. Darcovich and Heady examined potato prices in their paper and found that the weighted moving-average and the outlook price forecasts were the most accurate.

Evaluation

Accuracy in most forecasting papers is measured by mathematical means. For example, McIntosh and Dorfman use the mean-squared forecast error, the Henriksson-Merton test, and the mean absolute percentage error in a price forecasting competition. Other researchers have used the root mean squared error (RMSE), the root mean percentage error (RM%E), the turning point (TP), Theil's U_2 statistic, and the mean squared error (MSE) as criteria for forecast evaluation (Brandt; Miller and Jelinek; Zapata and Garcia).

The statistics used in the paper are given in the following equations (Makridakis, Wheelwright, and McGee):

(2-4) $$\textit{mean absolute error}\,(MAE) = \sum_{i=1}^{n} |e_i| / n$$

(2-5) $$\textit{root mean squared error (RMSE)} = \sqrt{\sum_{i=1}^{n} e_1^2 / n}$$

(2-6) $$\textit{Theil's } U_2(U_2) = \sqrt{\frac{\sum_{1=1}^{n-1}\left(\frac{F_{i+1}-X_{i+1}}{X_i}\right)^2}{\sum_{i=1}^{n-1}\left(\frac{X_{i+1}-X_i}{X_i}\right)^2}}$$

Value of Forecast Information

Miller and Jelinek suggest that there probably is a tradeoff between forecast accuracy and increasing costs to obtain accuracy. They also suggest that large companies may be more willing and able to bear the costs of developing consistent forecasting models than would individual farmers. Farmers have financial limitations, time limitations, and application problems with respect to price forecasting (Miller and Jelinek). For a forecasting tool to have any value for a farmer, it must at least meet his/her financial and time limitations and be applicable.

Bradford and Kelejian's theoretical work concludes naive forecasters will receive higher gains from improved information than will sophisticated forecasters. This makes sense because naive forecasters should be able to make larger gains in information quality. If one assumes that farmers use more naive forecasts than large companies, it may be concluded that farmers will gain more than companies with better information (from better forecasts).

"Returns to management are premiums in income which accrue from correct anticipation of the future" (Heady, p. 467). Research suggests that correct expectations (forecasts) will increase not only the farm manager's welfare but also society's welfare (Freebairn; Heady). Freebairn found the costs of incorrect forecasts "are proportional to the square of the price forecast error with the proportional factor being greater the greater the demand and supply elasticities and the less opportunities for supply adjustment to current price" (p. 203). The distribution of the gains from forecasting depends on supply and demand elasticities. Producers gain (with improving forecast accuracy) relative to society the more elastic the demand curve and the less elastic the supply curve (Freebairn). Since the welfare of society increases with better information, and farmers are likely to receive a larger share of this increase in welfare, it seems that accurate forecasting would be one of a land-grant university's top priorities.

Forecasts can also help control risk. Brandt and other workers have found that by using futures markets and forecasting, risk can be managed.

Expectations

One of management's roles is to function as a coordinating unit. The tasks in coordination include expectations, plans, actions, and acceptance of consequences. If future events are known with certainty, initial plans will include provisions for those events and management will simply be required to supervise (Heady).

All managers form expectations in order to plan economic behavior. Prices are among the variables a manager has expectations about. "Expected price can be defined as a current opinion or forecast of a future period's cash market price" (Miller and Jelinek, p. 35). Darcovich and Heady suggest that simple mechanical expectation models are employed by most farmers.

The study of price and yield expectations has evolved from the simple naive model (where expectations are merely an extension of last year's actual) to extrapolative, adaptive, and rational expectation hypotheses (King). The adaptive and rational expectation hypotheses have received the most attention. Researchers often use the adaptive expectations model in agricultural applications (King).

Griliches (King) makes an important distinction between the adaptive expectations model and the partial adjustment model. "The adaptive expectations model attributes the lags to uncertainty and the discounting of current information. The partial adjustment model attributes the same lags to technological and psychological inertia and to the rising cost of rapid change" (p. 168).

If expectations are formed in the adaptive way, adjustments to expectations are based on the error of the last expectation. Conversely, rational expectations are forward looking. One who forms expectations in the rational manner identifies variables that will affect the variable of concern (i.e., price). He/she then anticipates those variables and adjusts his/her expectations accordingly. For example, a farmer may anticipate changes in governmental policy regarding farm exports and adjust expectations accordingly (Byrns and Stone).

Studies of expectation data suggest that average expectations are more accurate than naive models and as accurate as equation systems, and that expectations are generally conservative (underestimate the change that actually occurs) (Muth).

Economic Theory

Economic theory suggests that there will be an equilibrium price at the intersection of the supply and demand curves at a particular place and time (Miller and Jelinek). Forecasters may try to estimate future supply and demand in order to predict the price of the commodity. Figure 7 shows two possible expectation paths from t-4 to t_0 and the supply and demand curves to determine the price in t_0.

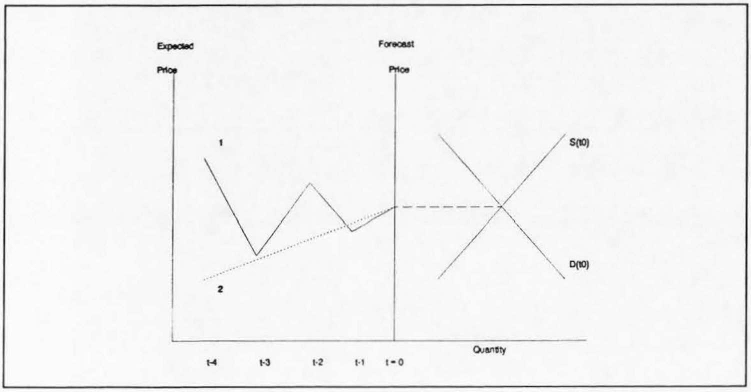

Figure 7. Forecast convergence on cash price
Source: (Miller and Jelinek)

Potatoes may follow the cobweb model (Waugh; Muth). The cobweb model suggests that this year's supply is a function of last year's price. When a shock to the system takes the system from equilibrium, prices and quantities oscillate with each production cycle (year). Figure 8 gives an example of a converging cobweb model. Suppose quantity produced in year 1 was below equilibrium at Q1. Price would then be P1. Producers, assuming that P1 will be the price in year 2, produce Q2, and prices fall to P2. The same cycle repeats for year 3 and continues until another shock occurs or until equilibrium is reached (Waugh; Samuelson).

A flatter (more elastic) supply curve may produce an exploding cobweb model in which price and quantity oscillations grow larger instead of smaller. Various other supply and demand curves may lead to persistent oscillations or nonlinear oscillations (Waugh; Samuelson).

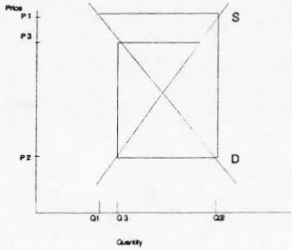

Figure 8. Converging cobweb model

CHAPTER 3

DESCRIPTION OF FORECASTING MODELS

Forecasting requires careful selection of models to create an accurate and useful forecast. The forecasting models used to predict Utah's potato prices are developed and described below.

Simultaneous Equation Model

When modifying the relationships in figures 5 and 6, the United States' potato economy may be described by five equations (3-1 through 3-5):

(3-1) $$AH_t = f\left(AH_{t-1},\ P_{p_{t-1}},\ P_{w_{t-1}}\right),$$

(3-2) $$YD_t = f\left(W_t,\ T\right),$$

(3-3) $$D_t = f\left(P_{p_{t-1}},\ P_p,\ DPI_t\right),$$

(3-4) $$S_t = f\left(AH_t,\ YD_t\right),$$

(3-5) $$S_t = D_t,$$

where AH is the acres of potatoes planted in the U.S. (in time t), YD is the yearly average U.S. potato yield, D is the yearly demand for U.S. potatoes (domestic), S is the yearly supply of U.S. potatoes (domestic production), P_p is the real yearly average U.S. farm price of potatoes, P_w is the real yearly average U.S. farm price of wheat, T is time, W is weather, and DPI is the U.S. Disposable Personal Income.

Assuming the functions are linear, the weather is unpredictable (and, therefore, useless in a forecasting model), and by using the inverse demand function (where price is a function of quantity demanded (= supplied) and other variables, instead of where quantity demanded is a function of price and other variables), the equations may be represented as below.

$$(3\text{-}6) \qquad AH_t = a_1 + c_{11}AH_{t-1} + c_{12}P_{pf_{t-1}} + c_{13}P_{sb_{t-1}} ,$$

$$(3\text{-}7) \qquad YD_t = a_2 + c_{21}T ,$$

$$(3\text{-}8) \qquad UtPp_t = a_3 + b_{31}D_t + c_{31}NDI + c_{32}P_{pf_{t-1}} ,$$

$$(3\text{-}9) \qquad S_t = AH_t * YD_t ,$$

$$(3\text{-}10) \qquad S_t = D_t ,$$

where a's are the constant terms, b's are the coefficients on the endogenous variables, c's are the coefficients on the predetermined variables, UtPp is the nominal farm price for Utah potatoes, and other variables are as described above.

The farm prices for potatoes are state averages for Utah while farm prices for other commodities are national averages. Supply, demand, population, income, yield, acres harvested, and yield are all national statistics. The data, data sources, and data units of measurement are shown in the appendix.

The predetermined (exogenous) variables in the system are AH_{t-1}, $UtPp_{t-1}$, $P_{w_{t-1}}$, T, Pp_{t-1}, and NDI_t. The endogenous variables are AH_t, YD_t, D_t, S_t, and $UtPp_t$. Table 1 shows that the equation system is overidentified.

Table 1. Identification of the Simultaneous Equation Model

Equation	Number of excluded exogenous	Number of included endogenous -1	Identification
(1)	6-3 = 3	1-1 = 0	over
(2)	6-1 = 5	1-1 = 0	over
(3)	6-2 = 4	2-1 = 1	over
(4)	Identity		
(5)	Identity		

Assuming that there is a high degree of correlation between Utah farm prices and U.S. farm prices, the price for Utah potatoes can be substituted for the U.S. potato price. This may be reasonable given that Utah potato farmers are basically price takers, and that the national potato market dictates what Utah farmers can get for their potatoes. This gives a model that predicts Utah prices from national supply and demand equations. The relationship between Utah prices and the national potato market is shown in figure 9. Figure 10 shows the actual farm prices in Utah and the United States over the past 40 years.

ARIMA Model

Figures 11 and 12 show the first step in the identification stage of the Box-Jenkins process. The trend (nonconstant mean) illustrated in figure 11 suggests that the data (nominal average Utah potato prices) are not stationary. Figure 12 shows linearly decreasing autocorrelations, also a sign of nonstationarity.

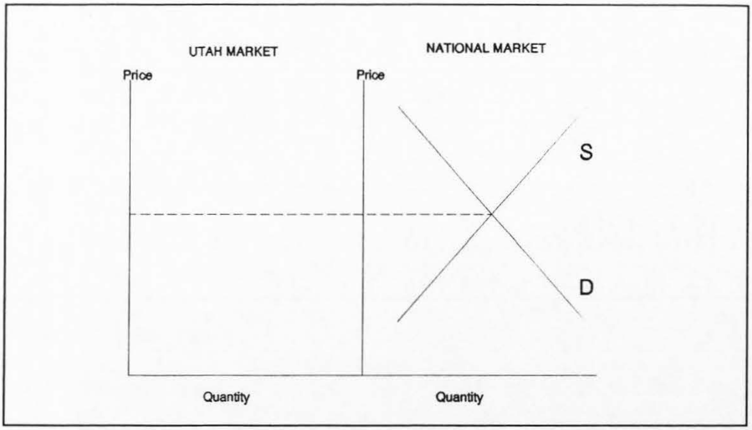

Figure 9. The relationship between the national potato market and Utah's potato price

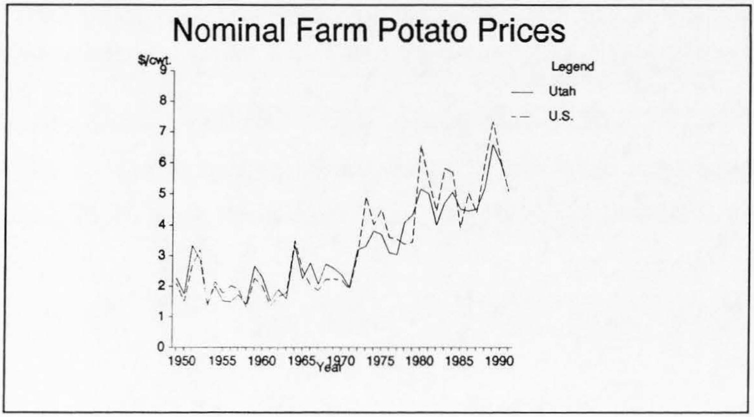

Figure 10. Nominal farm potato prices in Utah and the U.S., 1949-1991

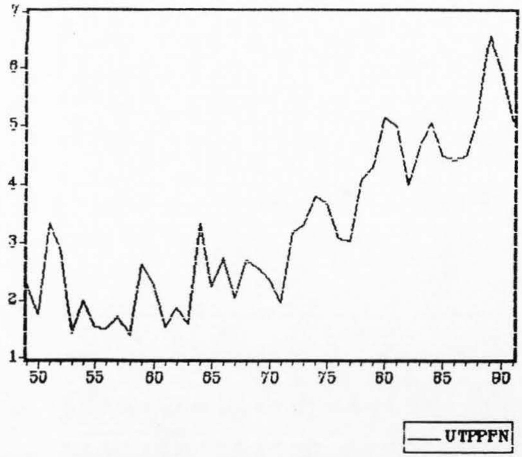

Figure 11. Nominal Utah potato prices

```
IDENT UTPPFN
Date: 11-13-1992 / Time: 15:48
SMPL range: 1949  -  1991
Number of observations: 43
=========================================================================
      Autocorrelations          Partial Autocorrelations        ac     pac
=========================================================================
:        .   |************  :        .   |***********  :  1  0.825  0.825
:        .   |**********    :        .   |*   .        :  2  0.707  0.082
:        .   |*********     :        .   |*   .        :  3  0.622  0.061
:        .   |*********     :        .   |**  .        :  4  0.595  0.162
:        .   |*********     :        .   |**  .        :  5  0.589  0.125
:        .   |********      :        .  *|    .        :  6  0.535 -0.082
:        .   |*******       :        .  *|    .        :  7  0.453 -0.101
:        .   |*******       :        .   |**  .        :  8  0.429  0.128
:        .   |******        :        . **|    .        :  9  0.359 -0.165
:        .   |*****         :        .  *|    .        : 10  0.294 -0.099
:        .   |***.          :        . **|    .        : 11  0.195 -0.150
:        .   |*   .         :        .  *|    .        : 12  0.111 -0.072
:        .   |*   .         :        .  *|    .        : 13  0.053 -0.074
:        .   |    .         :        .   |    .        : 14  0.018 -0.002
:        .   |    .         :        .   |*   .        : 15  0.004  0.105
:        .  *|    .         :        .  *|    .        : 16 -0.039 -0.068
:        . **|    .         :        .  *|    .        : 17 -0.117 -0.103
:        .***|    .         :        . **|    .        : 18 -0.202 -0.123
:        .***|    .         :        .   |    .        : 19 -0.248  0.026
:        .***|    .         :        .   |    .        : 20 -0.259  0.008
:        .***|    .         :        .   |*   .        : 21 -0.245  0.083
:        ****|    .         :        .  *|    .        : 22 -0.290 -0.115
=========================================================================
 Q-Statistic (22 lags)  152.233              S.E. of Correlations  0.152
=========================================================================
```

Figure 12. Partial and autocorrelations of nominal Utah potato prices

Figure 13 shows the first difference ($X'_t = X_t - X_{t-1}$, where X' is the first difference) of the average nominal Utah potato price; and figure 14 plots the autocorrelations and partial autocorrelations. Figure 13 shows no noticeable trend in the data--the data should be stationary in mean. However, figure 13 shows there may be fluctuations in the variance of the data, which suggests that the data may be nonstationary in variance. Figure 14 shows the autocorrelations dampening off exponentially, which suggests stationarity.

Figures 15 and 16 plot the data, the autocorrelations, and partial autocorrelations of the second first difference ($X''_t = X'_t - X'_{t-1}$). Figures 15 and 16 show no appreciable improvement in the stationarity of the data with a second differencing.

Figures 11 through 16 imply that one difference is needed for stationarity (ARIMA (p, 1, q)). By examining the autocorrelations and the partial autocorrelations in figure 14, a preliminary model can found. Spikes in the autocorrelations loosely correlate with the moving-average order, and spikes in the partials correlate with the autoregressive orders. A preliminary model may have a fourth order autoregressive parameter and no moving-average parameters.

After further diagnostics, the ARIMA model used for forecasting was as follows:

$$(1 - B)X_t = \mu' + \phi_1 X_{t-1} + \phi_2 X_{t-2} + \phi_3 X_{t-3} + \phi_4 X_{t-4} + \phi_7 X_{t-7} + e_t - \theta_5 e_{t-5} - \theta_6 e_{t-6} - \theta_7 e_{t-7} - \theta_8 e_{t-8} \; . \tag{3-11}$$

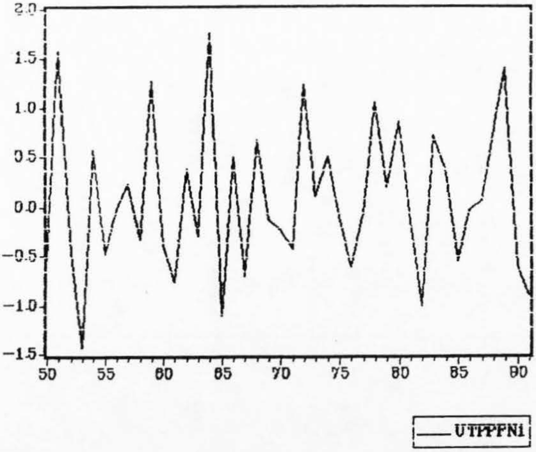

Figure 13. First difference of nominal Utah potato prices

```
IDENT UTPPFN1
Date: 11-13-1992 / Time: 15:42
SMPL range: 1950  -  1991
Number of observations: 42
==========================================================================
      Autocorrelations          Partial Autocorrelations        ac     pac
==========================================================================
:          ****:    .      :          ****:    .      :  1 -0.300 -0.300
:         .   *:    .      :         .***:    .      :  2 -0.109 -0.218
:         .   *:    .      :         .***:    .      :  3 -0.110 -0.248
:         .   *:    .      :         ****:    .      :  4 -0.086 -0.295
:         .    :**  .      :         .   *:    .      :  5  0.186 -0.039
:         .    :*   .      :         .    :*   .      :  6  0.062  0.043
:         .***:    .      :          ****:    .      :  7 -0.257 -0.277
:         .    :**  .      :         .    :*   .      :  8  0.186  0.040
:         .    :    .      :         .    :*   .      :  9  0.016  0.098
:         .    :*   .      :         .    :**  .      : 10  0.080  0.138
:         .   *:    .      :         .    :    .      : 11 -0.089  0.001
:         .   *:    .      :         .    :*   .      : 12 -0.061  0.088
:         .   *:    .      :         .   *:    .      : 13 -0.057 -0.039
:         .    :    .      :         .***:    .      : 14 -0.008 -0.214
:         .    :**  .      :         .    :*   .      : 15  0.164  0.076
:         .    :    .      :         .    :*   .      : 16  0.020  0.091
:         .    :    .      :         .    :**  .      : 17  0.032  0.145
:         .  **:    .      :         .   *:    .      : 18 -0.130 -0.055
:         .   *:    .      :         .   *:    .      : 19 -0.087 -0.045
:         .    :    .      :         .  **:    .      : 20  0.003 -0.159
:         .    :**  .      :         .    :    .      : 21  0.155  0.014
:         .   *:    .      :         .   *:    .      : 22 -0.102 -0.066
==========================================================================
Q-Statistic (22 lags)    15.499          S.E. of Correlations   0.154
==========================================================================
```

Figure 14. Partial and autocorrelations of the first difference of nominal Utah potato prices

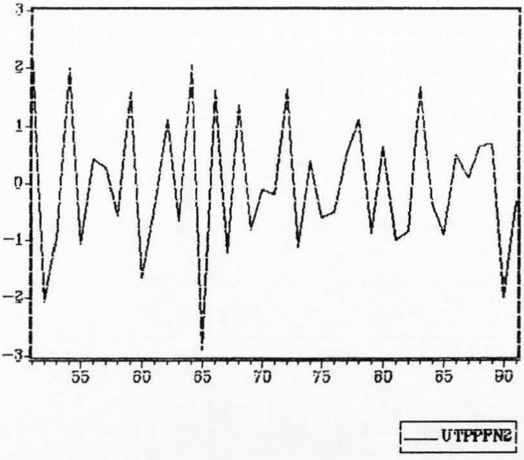

Figure 15. Second first difference of nominal Utah potato prices

```
IDENT UTPPFN2
Date: 11-13-1992 / Time: 15:52
SMPL range: 1951  -  1991
Number of observations: 41
==========================================================================
      Autocorrelations           Partial Autocorrelations        ac     pac
==========================================================================
:        *******:   .    :        *******:   .    :  1 -0.560 -0.560
:           .   :*  .    :           ****:   .    :  2  0.088 -0.330
:           .   :   .    :           .***:   .    :  3 -0.031 -0.245
:           .  *:   .    :          *****:   .    :  4 -0.088 -0.358
:           .   :** .    :           .***:   .    :  5  0.144 -0.222
:           .   :*  .    :           .   :*  .    :  6  0.073  0.099
:           ****:   .    :           .***:   .    :  7 -0.282 -0.224
:           .   :***.    :           .  *:   .    :  8  0.241 -0.095
:           .  *:   .    :           .   :   .    :  9 -0.103 -0.013
:           .   :*  .    :           .   :*  .    : 10  0.089  0.098
:           .  *:   .    :           .   :   .    : 11 -0.065 -0.007
:           .   :   .    :           .   :*  .    : 12  0.010  0.093
:           .   :   .    :           .   :** .    : 13 -0.010  0.137
:           .  *:   .    :           . **:   .    : 14 -0.046 -0.134
:           .   :*  .    :           .   :   .    : 15  0.087 -0.034
:           .   :   .    :           .   :   .    : 16 -0.037 -0.007
:           .   :*  .    :           .   :** .    : 17  0.067  0.137
:           .  *:   .    :           .   :   .    : 18 -0.074  0.023
:           .   :   .    :           .   :*  .    : 19 -0.008  0.061
:           .  *:   .    :           . **:   .    : 20 -0.052 -0.126
:           .   :** .    :           .   :   .    : 21  0.161 -0.002
:           .  *:   .    :           .   :   .    : 22 -0.109  0.025
==========================================================================
Q-Statistic (22 lags)   23.708            S.E. of Correlations   0.156
==========================================================================
```

Figure 16. Partial and autocorrelations of the second first difference of nominal Utah potato prices

Using the backward shift notation (B) and rearranging terms, the ARIMA model may be presented as follows:

$$(3\text{-}12) \qquad \begin{aligned}&(1 - \phi_1 B - \phi_2 B^2 - \phi_3 B^3 - \phi_4 B^4 - \phi_7 B^7)(1 - B)X_t \\ &= \mu' + (1 - \theta_5 B^5 - \theta_6 B^6 - \theta_7 B^7 - \theta_8 B^8)e_t \ .\end{aligned}$$

Simplifying, the first difference of Utah annual potato prices is a function of the prices in years t-1, 2, 3, 4, and 7, and the error terms in years t-5, 6, 7, and 8.

Exponential Smoothing

In the basic exponential smoothing model, the errors of past observations are incorporated into the forecast for the future. In equation (3-13), X is the actual data, F is the forecast, and α is the smoothing parameter. Alpha (α) is a constant between zero and 1 and determines the weights on past observations. The weights for $\alpha < 1$ decrease exponentially; when $\alpha = 1$, the forecast is the naive forecast (last observed value) (Makridakis, Wheelwright, and McGee).

$$(3\text{-}13) \qquad F_{t+1} = \alpha X_t + (1 - \alpha)F_t \ .$$

The negative feedback mechanism can be illustrated more clearly in equation (3-14), where X_t - F_t is the error term, and alpha is the weight on the error term:

$$(3\text{-}14) \qquad F_{t+1} = F_t + \alpha (X_t - F_t) \ .$$

Holt's (Makridakis, Wheelwright, and McGee) two-parameter double exponential is used as the exponential smoothing model because it provides a way to deal with the trend component separately. The model is given in equations (3-15) through (3-17):

(3-15) $$S_t = \alpha X_t + (1 - \alpha)(S_{t-1} + b_{t-1}) ,$$

(3-16) $$b_t = \gamma(S_t - S_{t-1}) + (1 - \gamma)b_{t-1} ,$$

(3-17) $$F_{t+m} = S_t + b_t m .$$

Equation (3-17) is the forecast for t + m periods ahead. S is the smoothed data, b is the trend component of the smoothed data, alpha (α) is the first smoothing constant, and gamma (γ) is the second smoothing constant (where $0 \leq \alpha, \gamma \leq 1$) (Makridakis, Wheelwright, and McGee). For the exponential forecasting model, forecasts were made with $\alpha = 0.1$ and $\gamma = 0.3$. The values for α and γ were chosen to minimize the Theil U_2 statistic.

Moving-Average

The mean of all data is not an appropriate model for these data because of the trend in the data. A moving average model does not handle a trend very well either but better than a mean model (Makridakis, Wheelwright, and McGee). The shorter the moving-average, the more closely the forecast follows the latest data. A moving-average of order 1 is the naive forecast where $F_{t+1} = X_t$. The general formula for a moving-average forecast is as follows:

(3-18) $$F_{T+m} = \frac{\sum_{i=m}^{T+(m-1)} X_i}{T}$$

where T is the order of the moving-average, and m is the number of periods ahead to forecast. When m is 1, the formula is as follows:

(3-19) $$F_{T+1} = \frac{\sum_{i=1}^{T} X_i}{T}$$

The order of the moving-average (T) was three for the forecasts presented here. That is, the fourth period forecast was the average of the three previous periods.

Trend

The trend model simply extrapolates the historical trend line into the future to make the forecast. The basic model is as follows:

(3-20) $$F_t = a + bt$$

The relationship between time and price (X_t) is described by b with intercept a. A forecast for time t is made by substituting the time unit for t.

Opposite

The intuitive basis for the use of the opposite model lies within the cobweb framework. The cobweb model suggests that prices and quantities fluctuate up and down. In an economy that follows the cobweb model, low prices this year suggest that the prices will rebound next year.

In this model, the trend is used as the expected value and the difference between the trend line and the actual data is added to the trend line for the forecast in the next period as follows:

(3-21) $$F_{t+1} = (T_t - X_t) + (a + bt_{t+1})$$

where T is the trend line in time t. The intercept a and the slope b coefficients are the same for this model as the trend model. The difference is the adjustment for the cobweb supply effects.

Current (Naive)

The final model examined here is the simplest of the models. The last observed value is used for a forecast of the next year's value. The equation is:

(3-22) $$F_{t+1} = X_t \;.$$

CHAPTER 4

RESULTS

The Utah potato price forecast results for the 1993 crop year and the statistical measures of accuracy are shown below in table 2.

Table 2. Utah Potato Price Forecasts for 1993, 1992, and One-Period Out-Of-Sample Evaluation Results (rankings are in superscripts)

	Simul-taneous	ARIMA	Ex. smooth	Moving-average	Trend	Oppo-site	Naive
MAE	$.531^{2}$	$.648^{5}$	$.572^{3}$	$.719^{6}$	$.471^{1}$	$.935^{7}$	$.592^{4}$
RMSE	$.670^{2}$	$.818^{5}$	$.676^{3}$	$.910^{6}$	$.633^{1}$	1.29^{7}	$.750^{4}$
U_2	$.898^{4}$	$.895^{3}$	$.861^{2}$	1.22^{6}	$.834^{1}$	1.57^{7}	1.00^{5}
Frcst 1992	5.43	5.30	6.08	5.95	5.40	5.53	5.25
1993	5.95	5.69	6.27	5.73	5.51	5.47	5.25

The mean absolute error (MAE) and the root mean squared error (RMSE) are absolute measures of accuracy while the Theil's U_2 statistic is a relative measure of accuracy. As table 2 shows, the trend model gave the lowest relative error though the period 1986-1991 (inclusive) as measured by the mean absolute error. As measured by the MAE statistic, several models (the opposite, ARIMA, and moving-average) had larger absolute errors than the naive model.

The root mean error statistic puts relatively greater emphasis on large errors than the MAE, because the errors are squared in the RMSE statistic. Again, the trend model provided the forecast with the smallest absolute error as measured by the RMSE. The RMSE gave the same ranking of the accuracy of the models as the

MAE statistic. The ARIMA, moving-average, and opposite models, again, all scored worse than the naive model in the RMSE statistic.

Theil's U_2 statistic measures the relative accuracy of the forecast as compared to the naive forecast. The trend model scored better than the rest of the models, with the exponential model next, and ARIMA and simultaneous models coming in third and fourth. Naive models score one by Theil's U_2 statistic. Less than one indicates that the model is relatively better than the naive model, and greater than one indicates a relatively worse (than naive) forecast. The moving-average and opposite model forecasts scored greater than one in Theil's U_2 statistic.

Table 2 also shows the 1992 and 1993 forecasts for Utah potato prices. The forecasts for 1993 ranged from $5.25/cwt in the naive forecast to $6.27 in the exponentially smoothed forecast. Since the 1992 crop year prices have yet to be released, the models used their own predicted value of the 1992 crop to make the forecast.

If the opposite model and the naive model are excluded (on the basis of poor performance), the prediction for 1993 potato prices will be between $5.51 and $6.27. The trend model gives a price forecast at the lower end of this range. Since other models give a higher forecast, stronger farm prices for Utah than the trend may be likely.

The forecast data used to calculate the MAE, the RMSE, and Theil's U_2 statistics are shown below in table 3 (the 1986-1991 data). Table 3 gives the one period out-of-sample forecasts from 1986 to 1992, the 1993 forecast, and the actual average farm potato prices in Utah.

Table 3. Actual Utah Potato Prices, One-Period Out-of-Sample Forecasts for Seven Forecasting Models from 1986-1992 and the 1993 Forecasts ($/cwt)

	Actual	Simul-taneous	ARIMA	Ex. Smooth	Moving-Average	Trend	Oppo-site	Naive
1986	4.45	4.72	5.14	5.01	4.75	4.56	4.53	4.50
1987	4.50	5.04	4.46	5.14	4.67	4.63	4.72	4.45
1988	5.20	4.99	5.55	5.25	4.48	4.70	4.81	4.50
1989	6.60	5.19	5.69	5.41	4.72	4.88	4.47	5.20
1990	6.00	5.52	4.42	5.73	5.43	5.25	3.80	6.60
1991	5.25	5.53	4.94	5.96	5.93	5.38	4.66	6.00
1992	N/A	5.43	5.30	6.08	5.95	5.40	5.45	5.25
1993	N/A	5.95	5.69	6.27	5.73	5.51	5.47	5.25

Simultaneous Equation Model

Four equations were estimated for each yearly out-of-sample forecast. The national supply of potatoes was estimated in two parts. Yield (YD) was simply regressed on time. Acreage harvested (AH) was estimated as a function of last year's acreage harvested (AH_{t-1}), the national real farm price of potatoes last year (Pp_{t-1}), and the national real farm price of wheat last year ($P_{w_{t-1}}$) by two-stage least squares. Yield and harvested acreage were then used as the supply (= demand) in the inverse demand equation. Real disposable personal income (DPI) was regressed on time, estimated one period ahead, and used in the inverse demand equation.

The inverse demand equation was estimated with two-stage least squares. The nominal price of Utah potatoes (UtPp) was regressed on national potato demand (D), last year's price ($UtPp_{t-1}$), and the national real disposable personal income (DPI). The exogenous variables in the system were a constant, lagged acreage harvested (AH_{t-1}), lagged real national farm potato prices (Pp_{t-1}), lagged real national farm wheat prices (Pw_{t-1}), time, real national disposable personal income (DPI), and nominal Utah farm potato prices ($UtPp_{t-1}$) and time (year).

The equation coefficients, F-statistic, and the Durbin-Watson statistic are shown in tables 4, 5, 6, and 7. The t-statistics are shown in parentheses. Table 4 contains the data for the yield equations over the years 1985-1992. For each estimation, the data series started at 1950 and ended at the year indicated in the left-hand column of the table. The equation was then used to predict the dependent variable for the following year. For example, the 1992 yield equation presented in the first row of table 4 has 43 observations (from 1950-1992) and was used to predict the 1993 yield. The equation labeled 1991 has 42 observations. Tables 5, 6, and 7 give the acreage harvested equations, the disposable personal income equations, and the inverse demand equations, respectively.

The yield equations were found to be significantly different from zero as indicated by the F-statistics. The DW-statistics were also acceptable. Individual t-statistics suggest the constant and trend components are significantly different from zero. The AR(1) column is the "rho" coefficient associated with the

Table 4. Yield Equations, 1985-1992 (t-statistics are in parentheses)

Sample 1950-	Yield (YD) (cwt/ac, national average) C	Year (#, A.D.)	AR(1)	F	DW
1992	-7556	3.970	0.3143	1024	1.96
	(-26.7)	(27.5)	(2.23)		
1991	-7524	3.935	0.3233	934	1.98
	(-28.2)	(29.1)	(.152)		
1990	-7544	3.945	0.3131	856	1.93
	(-27.3)	(28.2)	(1.94)		
1989	-7662	4.004	0.2332	833	1.87
	(-30.1)	(31.0)	(1.37)		
1988	-7806	4.078	0.08474	839	1.74
	(-35.9)	(37.0)	(0.456)		
1987	-7972	4.163	0.1101	993	1.91
	(-38.6)	(39.7)	(0.658)		
1986	-7955	4.154	0.1079	889	1.91
	(-36.6)	(37.6)	(0.635)		
1985	-7945	4.149	0.1019	792	1.85
	(-34.8)	(35.8)	(0.573)		

Cochrane-Orcutt technique of first-order autoregressive correction. The coefficients indicate that there is weak positive first-order serial correlation. Although the t-statistic indicates the coefficient may not be significantly different from zero, the autoregressive correction is used because earlier regressions (without the autoregressive correction) gave borderline Durbin-Watson statistics.

Table 5 shows that all coefficients are significantly different from zero at alpha = 0.05. The F-statistics also indicate the models are different from zero. Note that the coefficients are all fairly stable (do not change much from year to

Table 5. Acreage Harvested Equations, 1985-1992 (t-statistics are in parentheses)

Sample	Acreage Harvested (AH) (1000 ac, national)					
1950-	C	AH_{t-1}	Pp_{t-1}	Pw_{t-1}	F	DW
1992	370.8	0.6281	30.28	-16.38	28.9	1.96
	(3.10)	(7.06)	(6.25)	(-3.02)		
1991	369.5	0.6308	30.21	-16.62	27.9	1.96
	(3.05)	(6.95)	(6.16)	(-2.99)		
1990	373.2	0.6262	30.11	-16.16	27.3	1.95
	(3.03)	(6.74)	(6.05)	(-2.77)		
1989	368.7	0.6279	29.81	-15.38	27.3	1.99
	(2.98)	(6.72)	(5.95)	(-2.60)		
1988	367.0	0.6277	29.84	-15.34	26.0	1.99
	(2.90)	(6.61)	(5.87)	(-2.55)		
1987	369.3	0.6274	29.75	-15.50	24.3	1.96
	(2.86)	(6.52)	(5.75)	(-2.52)		
1986	350.1	0.6363	29.97	-14.84	23.8	1.88
	(2.65)	(6.53)	(5.75)	(-2.37)		
1985	358.9	0.6410	29.10	-15.88	22.8	1.89
	(2.74)	(6.64)	(5.59)	(-2.54)		

year) as each successive observation is added. (In using the models to make predictions, all digits reported by the software were used to be as precise as possible, whereas the numbers are rounded in tables 5, 6, and 7.)

The $\delta AH/\delta Pp_{t-1}$ is > 0 as expected, a \$1 increase in last year's U.S. real potato price will decrease U.S. harvested potato acreage this year by about 30,000 acres. The $\delta AH/\delta Pw_{t-1}$ is < 0 as expected, a \$1 increase in real wheat prices will increase harvested acreage in this year by about 15,000 acres. The wheat price variable was included to be a substitute in the supply function, and the sign of the coefficient agrees.

Table 6. Disposable Personal Income Equations, 1985-1992 (t-statistics are in parentheses)

Sample 1950-	C	Year (#, A.D.)	AR(1)	F	DW
	Disposable Personal Income (DPI)($B, national)				
1992	-156221	80.22	0.9225	4550	2.04
	(-4.39)	(4.49)	(12.9)		
1991	-138117	71.09	0.8905	4530	1.82
	(-8.42)	(8.59)	(12.8)		
1990	-164605	84.42	0.9379	4420	2.01
	(-3.19)	(25.9)	(13.0)		
1989	-183082	93.66	0.9521	3890	2.04
	(-1.65)	(1.69)	(11.9)		
1988	-174393	89.32	0.9463	3370	1.98
	(-1.70)	(1.74)	(10.3)		
1987	-135601	69.31	0.8843	3130	1.95
	(-5.70)	(5.81)	(9.08)		
1986	-128801	66.38	0.8613	2730	1.92
	(-6.69)	(6.82)	(7.94)		
1985	-121091	62.42	0.8144	2430	1.88
	(-9.73)	(9.90)	(6.84)		

Table 6 shows fairly large fluctuations in the coefficients associated with time and the in-the-constant term, which illustrates the need to re-estimate the equations for each period. The rho coefficient indicates extreme positive serial autocorrelation for all of the disposable personal income models. The Cochrane-Orcutt technique allows the autocorrelation to be corrected without violating the assumptions of ordinary least squares.

Table 7 shows the inverse demand models to be significant. All the coefficients are significant at alpha = 0.05, except the 1985 and 1986 lagged Utah potato prices. They are significant at alpha = 0.10.

Table 7. Inverse Demand Equations, 1985-1992 (t-statistics are in parentheses)

Sample	Nominal Utah potato price (UtPp) ($/cwt)					
1950-	C	D (=S) (Kcwt)	$UtPp_{t-1}$ (same)	DPI ($B)	F	DW
1992	2.405	-1.504E-5	0.2737	2.233E-3	116	2.02
	(2.90)	(-3.12)	(2.40)	(5.81)		
1991	2.420	-1.512E-5	0.2737	2.239E-3	104	2.01
	(2.90)	(-3.11)	(2.36)	(5.69)		
1990	2.378	-1.504E-5	0.2845	2.233E-3	96.3	2.05
	(2.78)	(-3.05)	(2.40)	(5.61)		
1989	2.378	-1.505E-5	0.2859	2.234E-3	82.5	2.00
	(2.77)	(-3.05)	(2.25)	(5.58)		
1988	2.063	-1.259E-5	0.2820	2.012E-3	66.2	1.96
	(2.34)	(-2.41)	(2.22)	(4.72)		
1987	2.344	-1.472E-5	0.2638	2.232E-3	61.4	1.95
	(2.47)	(-2.52)	(2.08)	(4.45)		
1986	2.492	-1.606E-5	0.2490	2.394E-3	58.9	1.95
	(2.75)	(-2.88)	(1.96)	(4.87)		
1985	2.876	-1.949E-5	0.2251	2.777E-3	62.3	1.96
	(3.22)	(-3.43)	(1.85)	(5.40)		

The coefficients of the inverse demand functions have the appropriate signs. The $\delta UtPp/\delta D$ is less than zero, which is expected for a downward sloping demand curve. An increase in U.S. quantity supplied (= quantity demanded) by 100 million sacks (cwt) will decrease Utah prices by about $1.50 per sack. The $\delta UtPp/\delta UtPp_{t-1}$ is greater than zero, which indicates some positive autoregression in the farm price of potatoes.

Table 8 shows the price flexibility of Utah potato prices on national demand (Tomek and Robinson, p. 48). The price flexibility in 1991 (the last year with solid Utah price data) is -1.2. This suggests that a 1% increase in the quantity of potatoes supplied nationally (= quantity demanded) will decrease Utah average prices by 1.2%.

The elasticity of demand (national demand on Utah prices) is also shown in table 8. The elasticity is in the inelastic range (absolute value less than one) for most of the years represented. The inelastic price elasticity is consistent with other studies. Unfortunately, in this case, the price elasticity makes little sense, because a 1% change decrease in Utah potato prices will not increase demand 0.8%.

The explanation for the anomalies in 1989 and 1988 may be easier from the price flexibility side. In those years, drought reduced potato production in some states. The decrease in the availability of substitutes for Utah potatoes may have contributed to the anomalies in those two years.

Table 8. Price Flexibilities and Price Elasticities for Utah Potatoes, 1986-1992

Year	Price flexibility $\%\delta UtPp_t/\%\delta D_t$	Price elasticity $\%\delta D_t/\%\delta UtPp_t$
1992	-1.14	-0.877
1991	-1.20	-0.833
1990	-1.01	-0.990
1989	-0.845	-1.18
1988	-0.863	-1.16
1987	-1.27	-0.787
1986	-1.31	-0.763
1985	-1.79	-0.568

With respect to disposable personal income, the δUtPp/δDPI is greater than zero. At first, this may appear contradictory to previous studies that have shown that potatoes are inferior goods, or at least that the income effect on potato demand is not different from zero. However, the DPI variable contains both the elements of U.S. population and U.S. per capita income. That is, the real U.S. disposable personal income is per capita income multiplied by population.

While potatoes may be an inferior good, potato demand is also positively correlated with population. In this instance, the effect of the population seems to outweigh the effect of per capita income.

Confidence Interval for 1993 Forecast

Given that the explanatory variables are as forecasted for 1993, a confidence interval for the Utah farm potato price can be created for the 1993 price forecast. A confidence interval can be expressed as follows:

$$(4\text{-}1) \qquad c.i.:\ y = \hat{y} \pm (t_{d.f.,\alpha/2})(\sigma_{\hat{y}})$$

where $\hat{y}$ is the estimated forecast, t is the t-statistic with appropriate degrees of freedom and level of significance, and $\sigma_{\hat{y}}$ is standard deviation of the forecast.

According to Kmenta (p. 427), the forecast standard deviation is as follows:

$$(4\text{-}2) \qquad \sigma_{\hat{y}}^2 = \sigma^2\left[1 + \frac{1}{n} + \underline{X}'_0(\underline{X}'\,\underline{X})^{-1}\underline{X}_0\right],$$

where σ^2 is the variance of the regression, n is the number of observations, and k is the number of parameters.

$$\underline{X_0} = \begin{bmatrix} X_{02} - \bar{X}_2 \\ X_{03} - \bar{X}_3 \\ \cdot \\ \cdot \\ \cdot \\ X_{0K} - \bar{X}_k \end{bmatrix}$$

$$(1 \ x \ k - 1)$$

$$\underline{X} = \begin{bmatrix} X_{12} \cdot \ . \ . \ X_{1k} \\ X_{22} \cdot \ . \ . \ X_{2k} \\ \cdot \\ \cdot \\ \cdot \\ X_{n2} \cdot \ . \ . \ X_{nk} \end{bmatrix}$$

$$(n \ x \ k - 1) \ .$$

A 10% confidence interval with degrees of freedom = 30 gives a t-value of 1.697. The standard error of the forecast is 0.4991. The forecast is $5.95/cwt for 1993. Accordingly, the confidence interval around the 1993 forecast is as follows:

(4-3) $\quad$ UtPp = \$5.92 $\pm$ (1.697 * 0.4991) (d.f. = 30, α = 10%)

(4-4) $\quad$ \$5.10 $\leq$ UtPp $\leq$ \$6.80 .

ARIMA Model

As explained in chapter 3, the time-series of Utah nominal potato prices was differenced and modeled with the Box-Jenkins procedure. Table 9 gives the results.

As in the simultaneous equation results section, the equation estimated from the 1957-1992 data (number of observation = 36) was used for the 1993 forecast.

Since no 1992 data were available, the ARIMA forecast for 1992 was used as a proxy.

The ARIMA models were significantly different from zero at alpha = 0.05. However, adjusted R^2 values were, at best, in the low 60%s and fell below 50% in one model. Individual t-statistics (reported in parentheses) indicated some coefficients reported below were not significant from zero. The critical t-value for 21 degrees of freedom (the 1985 model) is 2.08 for alpha = 0.05 and 1.721 for alpha = 0.10.

The trend component of the time-series was estimated over the 1950-1992 time period. The equations for the trend component are shown in the trend model section below. Using the equations in table 9 (equations for the fitted value), the one year out-of-sample forecasts were made, as shown in table 10.

Trend Model

Following the same reporting conventions used in the simultaneous and ARIMA sections above, the trend equations are shown in table 11.

The confidence interval on the trend model can be calculated from the following equations:

$$\text{(4-5)} \qquad c.i.: \ y = \hat{y} \pm (t_{d.f., \alpha/2})(\sigma_{\hat{y}}) \ ,$$

where $\hat{y}$ is the estimated forecast, t is the t-statistic with appropriate degrees of freedom and level of significance, and $\sigma_{\hat{y}}$ is the standard deviation of the forecast.

Table 9. ARIMA Model Equations, 1985-1992 (t-statistics in brackets)

Sample 1957-	C	MA(7)	MA(8)	AR(1)	AR(2)
1992	0.105	-0.437	0.590	-0.272	-0.421
	(3.96)	(-2.11)	(2.78)	(-1.70)	(-3.09)
1991	0.106	-0.434	0.571	-0.245	-0.446
	(3.69)	(-1.97)	(2.57)	(-1.45)	(-3.12)
1990	0.109	-0.449	0.547	-0.201	-0.426
	(3.51)	(-2.00)	(2.40)	(-1.16)	(-2.72)
1989	0.106	-0.423	0.589	-0.224	-0.444
	(3.42)	(-1.83)	(2.55)	(-1.17)	(-2.70)
1988	0.0997	-0.480	0.553	-0.430	-0.364
	(3.13)	(-1.63)	(2.14)	(-2.45)	(-3.90)
1987	0.0993	-0.532	0.566	-0.417	-0.354
	(3.05)	(-1.79)	(1.99)	(-2.31)	(-2.05)
1986	0.0955	-0.601	0.475	-0.421	-0.306
	(2.84)	(1.85)	(1.53)	(-2.31)	(-1.63)
1985	0.104	-0.444	0.601	-0.461	-0.348
	(3.17)	(-1.40)	(1.79)	(-2.53)	(-1.80)

Sample 1957-	AR(3)	AR(4)	AR(7)	F	Adj. R^2
1992	-0.700	-0.313	-0.0534	9.07	0.617
	(-5.42)	(-2.28)	(-0.431)		
1991	-0.672	-0.304	-0.0530	8.12	0.594
	(-4.74)	(-2.09)	(-0.401)		
1990	-0.618	-0.284	-0.0569	7.32	0.573
	(-4.09)	(-1.92)	(-0.423)		
1989	-0.638	-0.283	-0.0675	7.10	0.572
	(-4.16)	(-1.85)	(-0.494)		
1988	-0.644	-0.352	0.0391	5.31	0.493
	(-3.90)	(-2.40)	(0.221)		
1987	-0.632	-0.351	0.0563	5.36	0.505
	(-3.65)	(-2.38)	(0.319)		
1986	-0.613	-0.405	0.0475	5.32	0.511
	(-3.47)	(-2.72)	(0.260)		
1985	-0.631	-0.435	-0.0348	5.18	0.511
	(-3.50)	(-2.84)	(-0.215)		

Table 10. ARIMA One Year Out-of-Sample Forecast

Sample	Forecast year	Trend component	Fitted value	Forecast ($/cwt)
1957-1992	1993	5.51	0.179	5.69
1957-1991	1992	5.40	-0.102	5.30
1957-1990	1991	5.38	-0.443	4.94
1957-1989	1990	5.25	-0.827	4.42
1957-1988	1989	4.88	0.812	5.69
1957-1987	1988	4.70	0.850	5.55
1957-1986	1987	4.63	-0.172	4.46
1957-1985	1986	4.56	0.583	5.14

Table 11. Trend Equations, 1985-1992

Year 1950-	C	Year	AR(1)	F	Adj. R_2
1992	-196.35	0.1013	0.4245	84.5	0.800
	(-7.35)	(7.47)	(3.07)		
1991	-196.12	0.1012	0.4244	77.0	0.787
	(-7.00)	(7.12)	(3.03)		
1990	-202.12	0.1042	0.4432	71.1	0.778
	(-6.54)	(6.64)	(3.08)		
1989	-200.24	0.1033	0.4335	60.0	0.752
	(-6.13)	(6.23)	(2.74)		
1988	-178.84	0.09237	0.3868	54.3	0.737
	(-6.33)	(6.44)	(2.57)		
1987	-172.39	0.08908	0.08908	47.9	0.717
	(-5.83)	(5.93)	(2.57)		
1986	-173.60	0.08970	0.3883	43.7	0.703
	(-5.56)	(5.66)	(2.54)		
1985	-175.21	0.09052	0.3891	39.6	0.689
	(-5.30)	(5.39)	(2.50)		

(4-6) $$\sigma_{\hat{y}} = \sigma \sqrt{1 + \frac{1}{n} + \frac{(X_0 - \bar{X})^2}{\Sigma(X_i - \bar{X})^2}}$$

where σ is the standard deviation of the regression, n is the number of observations, X^0 is the X value for the forecast (1993), and $\bar{X}$ is the mean of the X values (= 1971).

The above equations give the same results for a two-explanatory variable model as the confidence interval equations in the simultaneous equation model sections. Using the above equations, the confidence interval for the trend model is as follows:

(4-7) $$UtPp = \$5.51 \pm (1.697 * 0.6653) \quad (d.f. = 30, \alpha = 0.10)$$

$$4.38 \leq UtPp \leq 6.64$$

Notice that the confidence interval is narrower for the simultaneous equation model than for the trend model (standard deviation of the forecast was 0.4991 for the simultaneous equation model and 0.6653 for the trend model), even though the trend model scored better in the accuracy statistics. A partial explanation for this may lie in the fact that the confidence interval for the forecast gets wider as you move away from the mean of the explanatory variables. Since the trend model is based on time only, the explanatory variables are far from the mean to make forecast.

Opposite Model

Using the results from the trend model, the opposite model was developed. The opposite model results are shown in table 12. The in-sample trend column in table 12 comes from the trend equations presented in table 11. The trend forecast column comes from the corresponding equations extended one year out-of-sample (exactly the same forecast as the trend model).

Subtracting the trend from the actual (in time t) and adding to the trend forecast (time t + 1) gave the opposite forecast (time t + 1) as shown in the last column of table 12.

Table 12. Opposite Model Results

	$Actual_t$ (1)	$Trend_t$ (in sample) (2)	Forecast year	Trend forecast (3)	Opposite forecast (2-1)+3
1992	5.45[1]	5.406	1993	5.51	5.47
1991	5.25	5.301	1992	5.40	5.45
1990	6.00	5.275	1991	5.38	4.66
1989	6.60	5.148	1990	5.25	3.80
1988	5.20	4.786	1989	4.88	4.47
1987	4.50	4.614	1988	4.70	4.81
1986	4.45	4.539	1987	4.63	4.72
1985	4.50	4.468	1986	4.56	4.53

[1]1992 forecast.

Exponential Smoothing, Moving-Average, and Naive Models

The exponential smoothing model consisted of two parameters, alpha and gamma (see chapter 3). The exponential smoothing forecasts were made with alpha = 0.10 and gamma = 0.30. The moving-average model was a three-period moving average. The naive model used last period's actual as this period's forecast. The exponential smoothing, moving-average, and naive model results are shown in table 2 at the beginning of this chapter.

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Utah farmers adjust crop acreage continuously. For example, in 1989, 6,300 acres of potatoes were planted in Utah, down from 6,800 acres the previous year (UDA).

One factor to consider when adjusting crop acreage is the expected price of the crop. The high costs in potato production make the first year critical to the success or failure of the farmer. A workable model to predict short-term potato prices would be useful for the decision maker who is considering increasing potato acreage, decreasing acreage, or buying potatoes.

Of the forecasting models tested, the trend model is the model of choice. The trend model seems to be the most simple, accurate, and easy-to-apply forecasting model of the models tested. The model consists of intercept and time trend components. The trend model gave the lowest absolute error in one-period out-of-sample forecasts over the 1986-1991 period, as measured by the RMSE and the MAE. The trend model also had the best performance of the models tested in a relative measure of accuracy--Theil's U_2 statistic. The trend gave a 16.5% improvement over the naive model, as measured by Theil's U_2 statistic. A decision maker can easily apply the trend model by graphical means or through the use of least squares regression analysis.

The two-parameter exponential smoothing model or the simultaneous equation model may be the next best choice. A potato price forecaster who wants to use more than one forecasting model may select one of these models to be used in combination with the trend model. The simultaneous equation model gave slightly lower absolute errors and slightly higher relative errors than the exponential smoothing model.

Estimation of the simultaneous equation model not only requires some econometric skill but also is rather data-intensive. Much of the difficulty in using the simultaneous model for Utah potato price forecasting has been overcome by the model presented here. The data requirements and sources have been identified. The variables have been identified and the basic relationships documented. Even with these problems worked out, many people in industry and on the farm may have difficulty using the model to find a 1994 forecast.

The exponential smoothing model was not the easiest model to estimate yet was much easier than the simultaneous equation model. The most difficult part of the exponential smoothing model may be setting up the statistics to measure the accuracy of the model in order to find the best values for the parameters--alpha and gamma. Given that the parameters of the exponential smoothing model have been estimated and the coefficients of the simultaneous equation model have been estimated, the models may be equally easy to employ.

The data requirements of the simultaneous equation model are greater than the exponential smoothing model, yet the simultaneous model allows a confidence interval to be calculated for the forecast. The confidence interval feature is valuable for the decision maker, so perhaps the simultaneous model should be a forecaster's second model choice (over the exponential smoothing model). The exponential smoothing model forecast for 1993 was considerably higher ($6.27) than all of the other forecasts, which suggests that the 1993 forecast for that model may not be that viable.

The ARIMA model scored worse than the naive model in the absolute error statistics yet better than the simultaneous model in Theil's U_2 statistic. However, the ARIMA model developed here would be difficult to use even after the relationships have been developed. Because of the difficulty in using the ARIMA model and its marginal value, this model is not a top choice for further use.

The naive model, though not as accurate as other models, provides a useful benchmark forecast. Since the trend model is easy to use, comparing the results of it or a simultaneous equation model to last year's price may be helpful in making a decision. One problem with the naive model is that since the latest data available are the 1991 crop year price, the naive model forecast is quite "old" (i.e., the 1993 forecast is the 1991 price).

The opposite and the moving-average model scored worse than the naive model in both absolute and relative measures. Though both are fairly easy to use, the poor accuracy provided by the models leaves much to be desired. The opposite model was a particularly dismal failure. Since the intuitive basis for the opposite model rested on the cobweb supply model, either the cobweb theory does not apply to potato supply, or it is cancelled out by some other market force(s).

The average 1993 Utah farm potato price should be between \$5.51 and \$5.95/cwt (forecasts from the trend and simultaneous models, the two models with the lowest absolute errors in a one-year out-of-sample forecast). The models indicate that the average 1992 Utah farm potato price as the marketing is completed will be about \$5.40/cwt (trend forecast = \$5.40 and simultaneous equation forecast = \$5.43).

The forecasting tools and results provided here will perhaps benefit the decision makers--in the production decisions of the farmer, and in the contract negotiations of the buyer.

Information is valuable, and price forecasting will be valuable as long as the marginal benefits of the information exceeds the marginal cost. The following research recommendations are along the same theme as this paper.

1. Forecasting models could be developed to provide more information for farmers who grow other crops. Hay, wheat, barley, and onions are all grown in Utah. Hay is Utah's largest cash crop. However, since hay is a long-lived crop, a four- to five-year out-of-sample forecast would be necessary to provide information for planting strategies.

   Wheat and barley have the added complexities of the futures or cross-futures markets. The futures market gives another method for forecasting prices. Since small grains are given so much attention nationally, onions may be a good candidate for a study similar to this one.

2. A monthly or quarterly forecasting model to predict potato prices would complement this study well. The farmer (buyer) has models to predict yearly average prices for production (input) decisions provided by this study. A monthly or quarterly price forecasting mechanism would facilitate marketing (or buying) the crop after it has been planted.

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APPENDIX

Table 13. Data Used for Forecasting Models

(1) Year (T)	(2) AH (g)	(3) YD (c,f)	(4) S(D)(c,f)	(5) Pp(c,e)	(6) Pw(d)	(7) NDI (b)	(8) UtPp (c)	(9) Deflator (a)	(10) Real Pp	(11) Real Pw	(12) Real NDI (h)
1948	1981	136	269,937		1.98	188.3		20.33		9.74	926.1
1949	1755	137	240,950	2.10	1.88	186.4	2.28	20.25	10.39	9.29	920.7
1950	1698	153	259,112	1.50	2.00	206.9	1.75	20.59	7.28	9.71	1,004.8
1951	1349	145	195,776	2.68	2.11	226.1	3.33	21.62	12.41	9.76	1,045.6
1952	1397	151	211,095	3.21	2.09	236.7	2.86	21.97	14.62	9.51	1,077.4
1953	1536	151	231,679	1.31	2.04	250.4	1.43	22.31	5.87	9.14	1,122.2
1954	1413	155	219,547	2.15	2.12	254.8	2.00	22.66	9.50	9.36	1,124.5
1955	1405	162	227,696	1.77	1.99	275.3	1.52	23.43	7.57	8.49	1,174.8
1956	1371	179	245,792	2.02	1.97	290.4	1.49	24.21	8.36	8.14	1,199.6
1957	1359	178	242,522	1.91	1.93	305.1	1.73	25.07	7.62	7.70	1,217.0
1958	1428	187	266,897	1.31	1.75	311.6	1.40	25.59	5.13	6.84	1,217.8
1959	1331	184	245,272	2.27	1.76	337.1	2.67	25.60	8.87	6.88	1,316.8
1960	1386	185	257,104	2.00	1.74	352.0	2.28	26.00	7.70	6.69	1,353.8
1961	1480	198	293,166	1.36	1.83	364.7	1.52	26.30	5.17	6.96	1,386.7
1962	1347	197	264,810	1.67	2.04	384.6	1.89	26.80	6.22	7.61	1,435.1
1963	1323	205	271,158	1.78	1.85	402.5	1.59	27.20	6.54	6.80	1,479.8
1964	1272	190	241,076	3.50	1.37	431.8	3.35	27.70	12.63	4.95	1,558.8
1965	1383	210	291,109	2.53	1.35	475.8	2.25	28.40	8.92	4.75	1,675.4
1966	1462	210	307,242	2.04	1.63	508.8	2.76	29.40	6.93	5.54	1,730.6
1967	1460	209	305,766	1.87	1.39	544.7	2.06	30.30	6.16	4.59	1,797.7
1968	1383	214	295,401	2.23	1.24	591.0	2.73	31.70	7.05	3.91	1,864.4
1969	1416	221	312,578	2.24	1.25	634.2	2.60	33.30	6.72	3.75	1,904.5
1970	1421	229	325,716	2.21	1.33	695.3	2.38	35.10	6.30	3.79	1,980.9
1971	1391	230	319,329	1.90	1.34	741.3	1.96	37.00	5.14	3.62	2,003.5
1972	1256	236	296,359	3.02	1.76	801.3	3.20	38.80	7.77	4.54	2,065.2
1973	1307	230	300,013	4.90	3.95	901.7	3.30	41.30	11.86	9.56	2,183.3
1974	1392	246	342,395	4.01	4.09	982.9	3.80	44.90	8.92	9.11	2,189.1
1975	1260	256	321,978	4.48	3.55	1096.1	3.70	49.20	9.10	7.22	2,227.8
1976	1371	261	357,666	3.59	2.73	1194.4	3.10	52.30	6.87	5.22	2,283.7
1977	1360	261	355,334	3.55	2.33	1311.5	3.04	55.90	6.35	4.17	2,346.2
1978	1375	267	366,314	3.38	2.97	1474.0	4.10	60.30	5.60	4.93	2,444.4
1979	1258	272	342,447	3.44	3.80	1650.2	4.30	65.50	5.24	5.80	2,519.4
1980	1148	265	303,905	6.55	3.99	1918.0	5.15	71.70	9.13	5.56	2,675.0
1981	1232	276	340,623	5.42	3.69	2041.7	5.00	78.90	6.87	4.68	2,587.7
1982	1267	280	355,131	4.45	3.45	2180.5	4.00	83.80	5.32	4.12	2,602.0
1983	1242	269	333,726	5.82	3.51	2340.1	4.70	87.20	6.67	4.03	2,683.6
1984	1298	279	362,039	5.69	3.39	2668.6	5.05	91.00	6.25	3.73	2,932.5
1985	1359	299	406,609	3.92	3.08	2838.7	4.50	94.40	4.15	3.26	3,007.1
1986	1220	296	361,743	5.03	2.42	3013.3	4.45	96.90	5.19	2.50	3,109.7
1987	1293	301	389,320	4.38	2.57	3194.7	4.50	100.00	4.38	2.57	3,194.7
1988	1259	283	356,438	6.02	3.72	3479.2	5.20	103.90	5.79	3.58	3,348.6
1989	1282	289	370,444	7.36	3.72	3725.5	6.60	108.40	6.79	3.43	3,436.8
1990	1371	293	402,110	6.08	2.61	3946.1	6.00	112.90	5.39	2.31	3,495.2
1991	1375	304	417,622	4.96	3.00	4058.2	5.25	117.00	4.24	2.56	3,468.5
1992	1305	315	411,200	5.50	3.00	4406.1		120.40	4.57	2.49	3,659.6
1993	1287.7	317.7	409,217								3,665.1

Notes:

(a) 1948-1958 adapted from GNP price deflator series. 1948-1958--**source**: USDC. 1959-1992--**source**: U.S. President.

(b) 1990-1992--**source**: USDC, BEA. 1991-1992--second quarter. 1948-1989--**source**: USDC.

(c) 1948-1989--**source**: USDA, ERS 1991. 1990-1991--**source**: USDA, NASS.

(d) 1948-1990--**source**: USDA. 1991-1992--**source**: USDA, ERS November 1992. 1992 estimated USDA, ERS November 1992 (midpoint of estimate range).

(e) 1992 U.S. potato price (midpoint of estimate) from USDA, ERS July and November 1992.

(f) 1992--**source**: USDA, ERS July and November 1992. 1993 estimated from model.

(g) 1948-1989--**source**: USDA, ERS 1991. 1990-1992--**source**: USDA, ERS July 1992. 1993 estimated from model.

(h) 1993 estimated from model.

Table 14. Variable Names and Units of Measurement for Data Used in Forecasting Models

Abbreviation	Variable name	Unit
AH	Real U.S. harvested potato acreage	1000 ac
YD	U.S. average potato yield	cwt./ac.
S(D)	U.S. potato production (demand)	1000 cwt
Pp	Real U.S. average farm potato price	$/cwt
Pw	Real U.S. average farm wheat price	$/bu
NDI	Real U.S. net disposable personal income	$ billion
Deflator	Gross domestic product deflator, 1987 = 100	%
UtPp	Nominal Utah average farm potato price	$/cwt