DISSERTATION

ECONOMETRICS OF MARKET AND NON-MARKET GOODS

Submitted by

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In partial fulfillment of the requirements

For the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Fall 2014

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ABSTRACT

ECONOMETRICS OF MARKET AND NON-MARKET GOODS

This dissertation illustrates how different econometric methods can be applied to market and non-market goods. The first essay focuses on forecasting cheddar cheese prices by utilizing time series models from the simplest model autoregressive order 2 AR (2) model, to more complex models such as second order vector autoregressive (VAR(2)) or second order vector error correction models (VECM(2)). One-to twelve month ahead forecast horizons for cheddar cheese levels and difference models were calculated for each forecasting methods for the out of sample time period of January 1990 to December 2013. The forecasts' accuracy was diagnosed by using root mean squared error (RMSE), and Diebold-Mariano (D-M) tests and comparing the forecasted cheddar cheese prices to existing USDA National Agricultural Statistics Service (NASS) cheddar cheese prices, and Futures. The D-M test is comparable to the RMSE test for forecasting price level, AR (2) forecasting method has lower forecasted error in January and February, and VAR (2) is more accurate from March onward. VAR (2) has the lowest RMSE for forecasting price level. In the forecasting model of price differences AR (2) forecasting method results are more accurate from January to April and VAR (2) has more accurate results from May onwards, and VECM (2) were never better than simpler forecasting methods in both forecasting price levels and price differences models.

In the second essay, Colorado households' non-market values for two forest management options for reducing intensity of future wildfires and associated non-market environmental effects of wildfires has been calculated. The first policy is the traditional harvesting of pine beetle killed trees and burn on-site. The second policy also involves harvesting trees but involves

moving the trees offsite and converting them into biochar, thus reducing some of the environmental effects associated with burning on-site. A contingent valuation method mail survey was implemented to evaluate these two management options. The survey achieved a 47% response rate. I used a non-parametric Turnbull estimator to calculate the willingness to pay (WTP) for burn on-site and off-site biochar conversion. The calculated WTP for burn on-site and off-site biochar conversion is $411 per household, and $470, respectively.

In the third essay, household's non-market values for forest management options for avoiding forest fires in Larimer County have been calculated using a different stated preference survey design. A thousand surveys were mailed that asked respondents to rank the management options (including their costs to households) from best to worst. We used rank ordered and conditional logit models to calculate the WTP for burn on-site and biochar option. The rank ordered model outperformed the conditional logit in terms of consistency with economic theory. However even the rank ordered logit had insignificant cost coefficient for the burn on site option. The annual willingness to pay (WTP) for the biochar option, in rank-ordered logit model is $508 per household.

AKNOWLEDGMENTS

I am honored to have the opportunity to work with Dr. John Loomis as my adviser in the Department of Agricultural and Resource Economics at Colorado State University. Dr. Loomis has been a great resource to me in designing surveys, and mentoring me along my journey toward a doctorate in resource economics. I would like to thank him for his guidance since the beginning of my time at Colorado State University.

I would like to thank Dr. Koontz for mentoring me and providing useful feedback throughout my dissertation. This research would not have been possible if not for the funding provided by Dan McCollum. I also need to thank Terrence Iverson for providing useful comments and feedback.

I also would like to thank my former advisor Thomas Stevens for believing in my potential to join a doctorate program and for his non-stop support through my career. I would like to send my sincere and warm thanks to my parents, my lovely sisters, brothers, and Parnia who have been supporting me from the beginning of my journey 7 years ago when I left Iran to pursue my Ph.D. Finally I would like to thank my dear husband, Ben who has sacrificed a lot in the last three years of being apart so I can pursue my dream.

Funding for this research project is provided by the U.S. Forest Service and Colorado State University. I am responsible for any mistakes or inaccuracies in this dissertation.

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CHAPTER ONE
Introduction

The purpose of this dissertation is to study a wide range of econometric models and apply them to both market and non-market goods. The first section involves forecasting cheddar cheese prices, and the second section evaluates the willingness to pay (WTP) for different forest fire management options that triggered by pine beetle infestation.

Agri-business firms face a great deal of volatility and risk in agricultural commodity prices, and having accurate forecasting methods helps them manage this risk. Cheese prices are important determinants of mountain west farm-gate milk prices. And forecasts of cheese prices are of interest to dairy producers and extension educators. Forecasts of cheese prices are useful in developing price expectations and implementing dairy risk management plans.

Chapter 2 includes time series modeling of cheddar cheese prices, and the purpose of the study is to figure out whether to use a simple model such as an autoregressive order 2 AR (2) model, or a more complex model such as second order vector autoregressive (VAR(2)) or second order vector error correction models (VECM (2)). A diagnostic test was performed to test which model we should adopt based on the accuracy of the forecasted data compared to the NASS USDA cheddar cheese price, and futures markets over the forecast horizon January 2010 through December 2013.

The second section of this dissertation (Chapters 3, and 4) focuses on the important and destructive issue of forest fires in the state of Colorado. People have lost their houses, experienced polluted and smoky air and have faced restrictions on their access to the use of recreational areas as a consequence of forest fires. One of the contributing factors to the intensity and spread of forest fires is the distribution of pine beetle killed trees. One approach to deal with forest fires is to remove the pine beetle killed trees. Three different color-mail surveys have been sent to a random sample of 1500 residents of Larimer County to ask them about different management options regarding forest fires in the state of Colorado in order to evaluate the risk of catastrophic forest fires due to pine beetle killed trees for two different forest fire management options. Those suggested management options under which the pine beetle killed trees could be managed properly are “Burn on Site”, and “Move Offsite and Convert to Biochar”. In “Burn on Site” dead and dying trees must be collected and a controlled burn is executed during the spring when it is safe to avoid spreading the fire. In the “Move offsite and Convert to Biochar” option, the collected dead and dying trees will be moved out of the forest in an assembly to convert into a new product called “Biochar”.

I. THE NATURE OF THE DATA

The data in chapter 2 for cheddar cheese price, total milk supply, cheddar cheese production, and American cheese stock, are derived from NASS USDA and total dairy exports are derived from USDA Agricultural Marketing Services (AMS) monthly. The data covers the period from January 1990-December 2013. Our dependent variable is quantitative, and continuous. This secondary data is used to derive out of sample forecast for cheddar cheese price. It is time series data.

To collect primary data for the forest fires study which is discussed in chapters 3, and 4 we sent three different color-mail surveys based on Dillman repeated mailing method (Dillman and Sallant, 1994) to residents in Larimer County. In these chapters the nature of our dependent variable is qualitative which describes the choice of an individual and whether they choose alternative management options versus current management option or not. The respondents say yes or no to the suggested management options versus the current management option of dealing with forest fires. In order to use econometric techniques we have to quantify our dependent variable by treating the dependent variable as a dummy variable which takes one of two values 0, and 1. For example, in our CVM survey if a respondent selected the burn on site management option versus the current management option, we assign value of 1 to our dependent variable and 0 otherwise.

II. EVALUATING WTP USING FULLY PARAMETRIC OR NON-PARAMETRIC MODELS

Non-market valuation of public goods typically relies upon a cross section of data from individual surveys. Since (Bishop and Heberlein, 1979) first introduced discrete choice models into stated preference analyses, the data has been analyzed using parametric models such as logit and non-parametric models. The WTP depends on parameters that must be estimated. Thus in order to calculate WTP the analyst is interested in modeling the unknown population parameters $\beta's$ & σ^2. We have to make an estimate by analyzing the data, and finding the function that provides us with an appropriate estimate of the unknown parameters. The assumptions that we make about the form of the relationship between the dependent variable and independent variables (explanatory variables), and assumptions about the exact probability density function (PDF) of the dependent variable affect the type of estimator that we use to make inferences about population parameters. Our assumptions about the form of the conditional mean of the dependent variable and the PDF of the dependent variable determine where we fall in the spectrum of parametric to non-parametric models. Once we assign specific values to unknown parameters of the model, we can then define a unique (PDF) on a fully defined probability distribution. In this scenario we have a fully parametric model. Where we don't make any assumptions about PDF nor the conditional mean of dependent variable we used a non-parametric model. In moving from a fully-parametric model to a non-parametric model less priori information is provided. The advantage of the non-parametric model is that the data provides an empirical distribution, rather than a distribution imposed by the researcher in parametric functions (Mushinksi, 2012, Department of Economics, Colorado State University, Fort Collins, CO, 80525).

In order to estimate a dollar value on forest fires and consequences associated with fire, we utilize both non-parametric models such as Turnbull estimator (Haab and McConnell, 2003) for repeated contingent valuation survey data and parametric maximum likelihood models such as rank-ordered logit and conditional logit models for best-worst stated preferences survey data to calculate the WTP.

CHAPTER TWO
Using Time Series Econometrics for Forecasting Dairy Product Prices: Cheese Prices Over Alternative Forecast Horizons

I. INTRODUCTION

Predicting the demand for dairy products is essential for farmers when making decisions on how much to produce for upcoming seasons. Price forecasting reduces the risk of making a wrong decision on the production side. Farmers need to consider that future prices should be consistent with basic economics. One of the most obvious allocation purposes is fluid milk before being processed into other products such as cheddar cheese, butter, and non-fat dry milk (NFDM). Class III dairy products (cheese) and class IV products (butter and non-fat dry milk) are produced when the supply of milk exceeds demand.

Cheese sales have more than doubled in the past 30 years in the United States. The calcium content in the cheese that has been retained from the original milk product is an essential part of one's everyday nutritional requirements. The substantial increase in sales is attributed to an increased variation of cheese, using more cheese in fast food restaurants and an increase in demand from the ethnic food industry (Blayney, Davis, Dong, Johnson, & Stefanova, 2010).

The approach used was to build an error correction vector autoregression (EC-VAR) of cheese prices (See Bozic and Fortenbery; Fortenbery and Zapata; and Thraen and Petrov). Milk production, cheese production and stocks, and cheese prices were found to be closely related. Monthly USDA National Agricultural Statistics Service (NASS) production and price data were used. Cheddar cheese information was used as that is the largest market. Total dairy product exports in metric tons are derived from USDA AMS monthly data. The dairy export data represents a combination of dairy products including milk & cream, whey & solids, and cheese.

The in-sample period was 1990 through 2009 and the out-of-sample forecast period was 2010 through 2013. One-to-twelve month ahead forecast horizons were used.

Lag 2 has been chosen based on a lag test for all the forecasting methods. This VECM (2) model is compared against a second order vector autoregressive (VAR (2)) and against an autoregressive order 2 (AR (2)) model of cheese prices. These two model types are progressively more simple and easy to use. Comparisons are performed by examining root mean squared error test (RMSE) over the different forecast horizons and using Diebold-Mariano (D-M) tests to examine if the difference in performance across forecasting models is statistically significant.

Milk production, dairy product production and inventories display strong autoregressive properties, strong seasonality, and strong deterministic trends. Cheese production and inventories are relatively predictable due to predictable milk production. Cheese prices are less predictable, from the perspective of any forecast evaluation measure, but the forecast performance does not deteriorate at long forecast horizons as quickly as other livestock product prices (See Sanders and Manfredo 2003 and 2007).

We specifically examined periods of large forecast error – where the VECM (2) cheese price forecasts are the most different from actual cheese prices. The domestic demand shocks – domestic consumption relative to price – and trade shocks – large month-to-month and year-on-year changes in exports are the cause of divergence between the forecasted price and actual cheese prices. Thus, increasing the forecasting performance of price levels and differences VECM(2) models appears to require information that would be rather unobserved or need to focus on rapid unanticipated changes in cheese stocks which would be difficult with public data.

We can divide the literature review into three sections of structural models which focuses on forecasting, and analysis of market changes, time series modeling which focuses on price-volatility and class III milk price forecasting, and the final section covers futures, options, hedging and basis studies.

Structural Time Series Models

Mosheim (2012) applied various forecasting methods such as OLS; two-stage least squares (2SLS); three-stage least squares (3SLS); seemingly unrelated regression (SURE); restricted vector autoregression (VAR); and unconstrained vector autoregression (VARX) to forecast the price of US dairy sector by using quarterly data 1998 to 2009 and then evaluate the precision of those forecasting methods. He concluded that the unconstrained vector autoregressive model with exogenous variables is more accurate than other models, and it predicts price well when compared with actual milk prices.

Blayney et al. (2010) used three different methods to analyze United States cheese consumption in the last three decades from 1975 to 2008. They applied supply and AIDS methods to Nielsen 2005 Home scanner data to estimate the demand of cheese, the demand elasticity, and distinguish the socio-demographic and economic factors that affect cheese demand. Consumer income, race and ethnicity, regional population and age contributed significantly to an increase in cheese consumption. Also, annual income in the U.S. increased over the past eight years, which raised the total consumption of cheese per capita. Race and ethnicity was major factor, where whites were found to buy more cheese than other ethnicities. The overall population rate is increasing faster than the population rate for the white Americans however, which indicates a possible expected decrease in per capita cheese consumption in future. On the other hand the northeast and south regions increase in population will also affect cheese consumption since they have higher consumption rates of cheese compared to other regions in the U.S. Age also affects cheese consumption where older people consume more cheese. Increases in cheese consumption increase the need for milk production which is something that the dairy industry should consider when attempting to meet market demand. The second part of the literature focuses on cash and futures price applications to cheddar cheese prices, where the research focus is on commodity hedging in order to reduce the risk associated with price fluctuation, which assures lower loss rate for the dairy cooperatives.

Awokuse and Bessler (2003) used the directed acyclic graphs (DAG) by using Tetrad II to analyze relationship among Sim's 1986 model of US economy. The use of DAG which is a data based method is preferred to theoretical structural VAR model that Sim used to distinguish the relationship between income, investment, price, money, unemployment and interest rate. The process they adopt is based on the correlation matrix. They graphed the DAG and using Choleski factorization they study the relationship among variables at various confidence levels from 5% to 30%, while structural VAR models that Sim used rely on prior information to identify the relationship between variables based on Choleski factorization process. So, by using DAG Awokuse and Bessler (2003) were able to use the DAG (data-based approach) which can be used for policy implications whereas VAR models are good for forecasting purposes (zero-restriction) and specification issues remain unsolved regarding the number of lags to choose.

Non- Structural Time Series Models

Dong et al (2011) studied class III milk price volatility by using VAR analysis. They discovered that corn futures markets, financial markets, seasonality, demand and supply conditions of cheese, and changes in US exchange rate affect the volatility of milk price in the market.

Mckenzie et al (2009), used forecast error variance decompositions (FEVDS) to check whether targeted forecasted variables are endogenous or exogenous. Their hypothesis is that

VAR models would be preferred to AR models when forecasted target variables are endogenous and vice-versa. They used wholesale chicken cut prices such as monthly average of daily prices of boneless skinless chicken breast tender out, broiler wings, bulk leg quarters, and whole broilers without giblets from January 1989 to June 2007.

Jesse and Schuelke (2002) provided a user-friendly method to forecast Class III and Class IV prices by adopting a two-step forecasting process. The first stage involved calculating the U.S. milk supply forecasts using milk cow numbers and milk production figures per cows. Then they distribute the total milk supply to Class III and IV products such as butter, cheddar cheese, non- fat dry milk, and dry whey. The second stage involved forecasting Class III and IV product prices by regressing product prices on production, stock prices, and demand-related variables.

Futures Options and Basis Studies

Thraen (1999) compared cash and futures markets for cheddar cheese to allow the dairy industry to manage the risk involved with price fluctuations. He believes that using risk management tools decreases the need for government subsidies and minimum price support. The data included weekly cheese spot prices, the Friday futures price and a weekly interest rate series from July 1993 through October 1997. He used unit roots to test for the nonstationary nature of the cheese market using three alternative tests: i) the Augmented Dickey-Fuller (ADF) test, (ii) the non-parametric Phillips-Perron (PP) test, and (iii) the stationarity test developed by Kwaitkowski, et al. (KPSS). All tests suggested I (1), where the first difference becomes stationary. Then the Johansen method was used to test for the presence of a cointegrating relationship between the logarithms of cash, futures, and interest rates. They ran a third order-vector autoregressive model (VAR (3)) to discover a convergence between cash and future markets in long-run equilibrium. He concluded that there is a flow of information between two markets and recommended the use of cheese future price discovery as a risk management tool for the dairy industry.

Haden and VanTassell (1988) applied VAR to the dairy industry to analyze several dynamic relationships within the dairy industry such as response of the dairy sector to a change in milk prices. Milk production increases through time and then decrease after an increase in the price of milk.

The model by Jesse and Schuelke (2002) was adopted in this study to forecast monthly cheddar cheese price production. They chose total milk supply, commercial American cheese stocks, monthly dummy variables, and annual trend variable as explanatory variables to estimate monthly cheddar cheese price production. We added cheese exports which will be helpful in explaining the forecast errors.

II. DATA

Factors that are expected to influence production of cheddar cheese as used by Jesse and Schuelke (2002) are total milk supply (million lbs.), American cheese stocks (thousand lbs.) which includes Colby and Monterrey jack varieties, and cheddar-style cheese, cheese exports (metric tons), monthly dummy variables, and annual trend variable. Data for cheddar cheese price ($ per lb.) is available monthly from 1990 to 2013. The data for monthly prices and production is derived from USDA NASS, and total dairy product export data is derived from USDA AMS monthly. The total dairy product export data is in metric tons (MT) and is a combination of milk & cream, whey & solids, and cheese exports. Our in sample data is from January 1990 to December 2009 and out of sample data is from January 2010 through December 2013. Please see Table 2.1 for summary statistics. (All Tables are presented at the end of chapter).

Figure 2.1, Figure 2.2,Figure 2.3, Figure 2.4, and Figure 2.5 are graphs of these series. The cheese price series appears stationary. Cheddar cheese production, American cheese stocks, total milk supply, and cheese exports appear nonstationary with deterministic trends, seasonality, and structural breaks. Also three XY graphs of production of cheddar cheese versus total milk supply, American cheese stocks versus total milk supply, production of cheddar cheese versus American cheese stocks have been presented inFigure 2.6,Figure 2.7, andFigure 2.8. The XY graphs are at the core of the cointegration testing as evidence for the existence of a unit root. Based on the XY graphs, if the results are scattered in a graph, there will not be a relationship among variables of interests (no conintegration equation exists), otherwise there will be a positive (upward line), or a negative (downward line) among the variables of interest, which is a statement that a unit root test exists. (All figures are presented at the end of chapter).

III. RESULTS AND DISCUSSION

Data Testing Results (Stationarity-Tests)

The purpose is to forecast the monthly cheddar cheese spot price for January 2010 to December of 2013 using the cheddar cheese production function, American cheese stocks, and total milk supply, and its price lags. Both stationary and non-stationary structures were tested in the data. The null hypothesis is that these data are non-stationary, as opposed to the alternative hypothesis of stationary data. First, each variable was plotted against time, and then the Augmented-Dickey Fuller (ADF) test was used to test for a unit root. In cases where the error term, u_t was unlikely to be white noise, the ADF test was used to test the residual of each variable and check whether mean and variance fluctuate over time. The ADF test includes a lagged dependent variable such as y_{t-1},y_{t-2},..y_{t-i}, where i=1,...p. In the model $\Delta y_t = y_t - y_{t-1}$, is represented as a difference in dependent variable. We also have time trends, t as well as an intercept term α_0 .

$$\Delta y_t = \alpha_0 + \gamma y_{t-1} + \alpha_2 t + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + u_t \qquad \text{Equation 2-1}$$

The cheese price was stationary, while cheese production, American cheese stocks and total milk supply were non-stationary (random walk). The results of the ADF are presented in Table 2.2. If the absolute value of ADF is less than the absolute value of critical values at different level of significance, then the null hypothesis of a unit root is rejected and it is concluded that the underlying variable is stationary. In the opposite case, non-stationary data is corrected for by the first difference method.

The cheddar cheese price, cheddar cheese production, stock of American cheese, total milk supply, and cheese export is graphed against time to check the trend over time. The figures are presented in Figure 2.1, Figure 2.2,Figure 2.3,Figure 2.4, and Figure 2.5. In doing so, the price of cheddar cheese appears stationary, production of cheddar cheese is non-stationary, and stock of American cheese has a trend whereas the total milk supply has two structural breaks, one in June of 1993 and the other in January of 2005. We add trend variables and structural breaks in our VAR (2) and VECM (2) models to account for that.

In order to make sure that cheddar cheese price is stationary, we created a variable called "New" which is a difference between total milk supply divided by 100 and price of cheddar cheese multiplied by 10. We test the ADF and discover that the difference is stationary which gives us confidence that price of cheddar cheese is stationary.

We also graph the price multiplied by 10 against total milk supply divided by 100 (to put them in the same scale on order of magnitude) to check whether the cheddar cheese price and total milk supply are related or not. There is not a relationship between cheddar cheese price and total milk supplied, so unit root does not exists and cheddar cheese price is stationary.

IV. FORECASTING MODELS

Auto-Regressive Model

An autoregressive model (AR) is a common model for time series. This model is a basic forecasting model and we compare the results from the AR (2) model with other forecasting methods such as VAR (2) and VECM (2). AR (2) is autoregressive of order 2 in which the dependent variable is a linear weighted sum of lagged values of dependent variable, seasonality, trend and an error term.

$$p_t = \sum_{i=1}^{N} \rho_i p_{t-i} + D + trend + \varepsilon_t \quad \text{Equation 2-2}$$

$$= \rho_1\, p_{t-1} + \rho_2 p_{t-2} + D + trend + \varepsilon_t$$

Where p_t is the current cheddar cheese price, p_{t-i} is the lagged cheddar cheese price, i is the number of lags which is 2 in our study, D is the dummy variable for seasonality, ρ is the weight associated with autoregression coefficient, and ε_t is the error term at time t. The number of lags has been confirmed by a lag test. We can interpret the equation as meaning that the price of yesterday and the price of the day before yesterday are major determinants for the price of today plus trend of time, and seasonality. We can follow the same pattern to find AR (2) for the cheddar cheese production function, American cheese stocks, total milk supply, and cheese export. The results for level forecast and difference forecast using AR (2) method are presented in the Table 2.3, and Table 2.5 respectively.

The AR (2) model shows that that last period's cheddar cheese price is significant in describing the current value of cheddar cheese price today. Also, trend and seasonality play an important role during March, April, May, July, and August. We calculated the one month to 12 months ahead forecast for the out of sample period, January 2010 to December 2013, by using AR(2) model for price of cheddar cheese at level and difference (cheddar cheese price is differenced $p_{(t-1)}$, and $p_{(t-2)}$), the results are presented in Table 2.4 and Table 2.6. In Eviews our sample data are from January 1990 to December 2009. The first forecast is January 2010 using the in sample data of 1990-2009, we then calculated the second month for 2010 knowing the February 1990 through January 2010, and this process continues until we calculate the December of 2010 using November 2010 as one month forecast, and January 2010 as 12 months ahead forecast. This can be demonstrated in the following equations, where p_t is the actual price of cheddar cheese in sample, p_{t-j} is lagged cheddar cheese price (j=1, 2), $\widehat{p_{t+1}}$ is the forecast for one-month ahead, and $\widehat{p_{t+12}}$ is the forecast of cheddar cheese price for 12 months ahead. pd_t is the actual production of cheddar cheese, pd_{t-j} is lagged cheddar cheese production, $\widehat{pd_{t+1}}$ is the forecast of cheddar cheese production for one-month ahead, and $\widehat{pd_{t+12}}$ is the forecast of cheddar cheese production for 12 months ahead. s_t is the actual total milk supply in sample, s_{t-j} is lagged total milk supply (j=1, 2), $\widehat{s_{t+1}}$ is the forecast of total milk supply for one-month ahead, and $\widehat{p_{t+12}}$ is the forecast of total milk supply for 12 months ahead. st_t is the actual total milk supply in sample, st_{t-j} is lagged American cheese stock (j=1, 2), $\widehat{st_{t+1}}$ is the forecast of American cheese stock for one-month ahead, and $\widehat{st_{t+12}}$ is the forecast of American cheese stock for 12 months ahead. x_t is the actual cheese exports in sample, x_{t-j} is lagged cheese exports (j=1, 2), $\widehat{x_{t+1}}$ is the forecast of cheese exports for one-month ahead, and $\widehat{x_{t+12}}$ is the forecast of cheese exports for 12 months ahead. Current price used one and two lags of prices of cheddar cheese as well as other variables in the model. One-month ahead forecast used current prices and one lag of prices of cheddar cheese and other variables. Two- months ahead forecast used one-month ahead forecast, and current values of variables. From three-months ahead forecast through 12-months ahead forecast only forecasted values of variables were used.

$$p_t = \mu + \beta_1 p_{t-1} + \beta_2 p_{t-2} + \gamma_1 pd_{t-1} + \gamma_2 pd_{t-2} + \delta_1 s_{t-1} + \delta_2 s_{t-2} + \varphi_1 st_{t-1} + \varphi_2 st_{t-2} + \rho_1 x_{t-1} + \rho_2 x_{t-2} \quad \text{Equation 2-3}$$

$$\widehat{p_{t+1}} = \mu + \beta_1 p_t + \beta_2 p_{t-1} + \gamma_1 pd_t + \gamma_2 pd_{t-1} + \delta_1 s_t + \delta_2 s_{t-1} + \varphi_1 st_t + \varphi_2 st_{t-1} + \rho_1 x_t + \rho_2 x_{t-1} \quad \text{Equation 2-4}$$

$$\widehat{p_{t+2}} = \mu + \beta_1 \widehat{p_{t+1}} + \beta_2 p_t + \gamma_1 \widehat{pd_{t+1}} + \gamma_2 pd_t + \delta_1 \widehat{s_{t+1}} + \delta_2 s_t + \varphi_1 \widehat{st_{t+1}} + \varphi_2 st_t + \rho_1 \widehat{x_{t+1}} + \rho_2 x_t \quad \text{Equation 2-5}$$

$$\widehat{p_{t+3}} = \mu + \beta_1 \widehat{p_{t+2}} + \beta_2 \widehat{p_{t+1}} + \gamma_1 \widehat{pd_{t+2}} + \gamma_2 \widehat{pd_{t+1}} + \delta_1 \widehat{s_{t+2}} + \delta_2 \widehat{s_{t+1}} + \varphi_1 \widehat{st_{t+2}} + \varphi_2 \widehat{st_{t+1}} + \rho_1 \widehat{x_{t+2}} + \rho_2 \widehat{x_{t+1}} \quad \text{Equation 2-6}$$

$$\widehat{p_{t+12}} = \mu + \beta_1 \widehat{p_{t+11}} + \beta_2 \widehat{p_{t+10}} + \gamma_1 \widehat{pd_{t+11}} + \gamma_2 \widehat{pd_{t+10}} + \delta_1 \widehat{s_{t+11}} + \delta_2 \widehat{s_{t+10}} + \varphi_1 \widehat{st_{t+11}} + \varphi_2 \widehat{st_{t+10}} + \rho_1 \widehat{x_{t+11}} + \rho_2 \widehat{x_{t+10}} \quad \text{Equation 2-7}$$

Vector Autoregressive Model

In the absence of non-stationary data, the Vector Autoregressive (VAR) model allows for time series multi-variable analysis. The VAR models are systems of equations that are solved simultaneously. The difference between Vector Autoregressive, and Vector Error Correction Models is the existence of a cointegration equation. The conintegration equation dictates the relationship among the variables within the model.

$$\mathrm{Y_t} = \begin{bmatrix} P_t \\ Pd_t \\ St_t \\ S_t \\ X_t \end{bmatrix}, \mathrm{X_t} = \begin{bmatrix} Seasonal\ Dummy \\ Trend \\ Structural\ Break \end{bmatrix}$$

Where $\mathrm{Y_t}$ is a vector of endogenous variables in the VAR model, and $\mathrm{X_t}$ are seasonality and trend variables that are exogenous in the models. P_t is the current cheddar cheese price, Pd_t is the current cheddar cheese production, St_t is the current American Cheese Stock, S_t is the current total milk supply, and X_t is the current cheese exports. The second order VAR, VAR (2) is represented by the following equation:

$$\begin{aligned} price_t = \alpha_1 &+ \sum_{j=1}^{k} \beta_{1j} p_{t-j} \\ &+ \sum_{j=1}^{k} \gamma_{1j} pd_{t-j} + \sum_{j=1}^{k} \delta_{1j} s_{t-j} + \sum_{j=1}^{k} \varphi_{1j} st_{t-j} \\ &+ \sum_{j=1}^{k} \rho_{1j} x_{t-j} + \beta_{2j} trend_{1i} + \beta_{3j} D_{1i} + \beta_{4j} I_{1i} + \beta_{5j} I_{2i} \\ &+ \mu_{1t} \end{aligned} \qquad \text{Equation 2-8}$$

This equation is only indicating the price equation; we will also have four other equations for production of cheddar cheese, American cheese stock, total milk supply, and cheese exports. The VAR (2) model solves all five equations simultaneously. Where k indicates the number of lags (the optimum number of lags was determined to be 2), p_{t-j} is lagged cheddar cheese price, pd_{t-j} is lagged cheddar cheese production, s_{t-j} is lagged milk production, $st_{t-j}$is the lagged American cheese stock, and x_{t-j} is the lagged cheese exports. The variable D is a dummy variable for seasonality, the I_1 variable is the interaction term between trend variable and the first structural break in June 1993, I_2 is the interaction term between trend variable and the second structural break in January 2005 and trend variable indicates linear trend in the VAR (2) model. The µ is the stochastic error term for VAR (2) model.

The level and difference VAR (2) estimation results for the cheddar cheese price equation are presented in Table 2.7 and Table 2.9. We ran two models one with structural breaks, trend and one without. Comparing Akaike and Schwarz criteria, the second VAR (2) model including structural breaks and trend variables is preferred to the first VAR (2) model. We then forecasted monthly cheddar cheese price for out of sample from January 2010 to December 2013 via level and difference VAR (2), the results are presented in Table 2.8 and Table 2.10.

Vector Error Correction Model (VECM)

We used the Johansen co-integration test to examine cointegration among non-stationary endogenous variables for the vector autoregressive model. The test verifies whether there is a relationship among residuals of endogenous variables and indicates whether restrictions are useful. There was one cointegration equation within our model, and the results of the test are presented in Table 2.11. The same results have been captured through both trace and eigen value tests. The null hypothesis in either test is that there is none, one, two, or three cointegration equations. By comparing the trace statistic with the critical values in each stage we confirm that long run association among variables exists. As a result, total milk supply, American cheese stock, production of cheddar cheese and cheese exports are moving together in the long run, and we should run VECM (2) to consider conitegration among variables.

The Engle-Granger cointegration test has also been calculated. Production of cheddar cheese, American cheese stock and total milk supply, and cheese export are non-stationary. The order of integration is one I (1) based on ADF test, and the long run equilibrium relationship between the variables has been estimated by using the OLS method. The third step is to save the residual and test whether the residual is stationary or not. Our test results for the residual show that the residual is stationary, meaning that there is a cointegration of degree 1 among production of cheddar cheese, American cheese stock, and total milk supply, and cheese export exists. This is also confirmed by the XY graphs which are used for cointegration tests. The results for the Engle-Granger test was similar using total milk supply, production of cheddar cheese, and American cheese stock meaning that based on all regressions, the residual will be stationary indicating that there is a cointegration of degree 1 among the variables. The results for total milk supply have been presented in the Table 2.13. There exists a cointegration equation among the variables within the model, which illustrates the need to use VECM for forecasting of variables such as price of cheddar cheese for out of sample data January 2010 to December of 2013.

The vector error correction forecasting model results for cheddar cheese price level and difference have been presented in Table 2.14 and Table 2.16. The out of sample forecast from January 2010 to December 2013 for both cheddar cheese price level and difference of cheddar cheese price via vector error correction model has been calculated and are shown in Table 2.15 and Table 2.17. It is not clear why our out of sample forecast for price of cheddar cheese level and differences when using VECM method is explosive. This would be an area for future research.

V. FORECASTING COMPARISONS FOR CHEDDAR CHEESE PRICE

Methods of Comparison

The cheddar cheese price was forecasted for the out of sample period of January 2010 to December of 2013 via a one-month ahead forecast of cheddar cheese price for one year at a time for level and difference forecasting methods. The level forecasting methods for each AR (2), VAR (2), and VECM (2) contain lagged price in the first month, and lagged price in the second month. The difference forecasting methods include the difference between each lagged price (first month, and second month) from the USDA National Agricultural Statics Services (NASS). For each level/difference forecasting method, monthly prices of cheddar cheese have been forecasted from January 2010 through December 2010, the next step is to forecast from February 2010 through January 2011. This process proceeds until we forecast through December 2013. We forecasted one month ahead to 12 months ahead for each model of AR (2), VAR (2), and VECM (2). The results for level forecasting methods have been shown in Table 2.4, Table 2.8, and Table 2.15, and the results for the difference forecasting methods are shown in Table 2.6, Table 2.10, and Table 2.17.

The level and difference forecasted cheddar cheese prices for different methods are graphed versus actual NASS USDA for January of 2010 in Figure 2.8 and Figure 2.9 . The next procedure is to compare our forecasted results for cheddar cheese price with actual data derived from NASS USDA, and use the root mean square and Diebold Mariano (D-M) tests to choose the most accurate and reliable forecast model.

Root Mean Squared Error Test

The root mean squared error (RMSE) was calculated for January 2010 through December 2013. The following formula is used to calculate the accuracy of our forecast results:

$$RMSE = \sqrt{\frac{\sum(y - \hat{y})^2}{n}} \qquad \text{Equation 2-9}$$

Where y is the NASS USDA cheddar cheese prices, and $\hat{y}$ is the forecasted cheddar cheese prices over time using AR (2), VAR, and VECM, and n is the number of periods forecasted out of sample which is 4 years. The results for both level/difference for all forecasting methods one month ahead to 12 months ahead forecast have been shown in Table 2.18. The calculated RMSE for AR price level is ranged from 13 to 27 cents, meaning that the forecast with AR level model is different from actual cheddar cheese prices from 13 cents to 27 cents, the calculated RMSE for VAR price level varies from 15 cents to 20 cents, and the calculated RMSE for VECM price levels varies from 16 cents to 24 cents. For AR price difference, the RMSE varies from 5 cents to 47 cents, where for VAR price difference the RMSE varies from 15 cents to 22 cents, and for the explosive VECM price difference RMSE varies from 24 cents to 2 dollars and 30 cents. For forecasting of price levels, AR (2) does a better job than other forecasting methods for January and February months, and VAR has more accurate results starting with March. For forecasting of price differences, AR (2) has closer predictions from January through April, and VAR (2) forecasting results are more accurate than the rest of the models starting in May.

Diebold-Mariano Test

The Diebold-Mariano (D-M) test statistic is used to check the forecast accuracy of two forecasts. We want to discover whether using AR(2), which is the simplest model, is a better forecasting model or using VAR (2) or VECM (2), which makes the forecasting more cumbersome. The null hypothesis of the test is whether both forecast models of cheddar cheese prices are the same, and the alternative hypothesis of the test is whether one model forecasts cheddar cheese prices more accurately.

We compared the model that has the lowest RMSE with the model that has the second lowest RMSE via D-M test. For example, if AR (2), and VAR (2) have the lowest RMSE in the first month ahead for 2010, we denote $\{p_t\}$ as USDA NASS cheddar cheese price to be forecasted and p_{t+h}^1 is the cheddar cheese price h-step forecast by VAR (2) and p_{t+h}^2 is the h-step cheddar cheese price forecast by AR (2). We then calculated the forecast errors from the two models with the NASS USDA price are e_{t+h}^1, e_{t+h}^2 respectively.

$$e_{t+h}^1 = (p_t - p_{t+h}^1), h = 1,2, \ldots 12 \qquad \text{Equation 2-10}$$

$$e_{t+h}^2 = (p_t - p_{t+h}^2), h = 1,2, \ldots 12 \qquad \text{Equation 2-11}$$

The next step is to calculate the absolute and squared loss functions for each step ahead forecast. The absolute loss function (ABSL) is the absolute difference between the forecasted errors and the squared loss function (SqL) is the squared difference between the forecasted errors between each step ahead forecast.

$$ABSL = |e_{t+h}^1 - e_{t+h}^2|, h = 1,2, \ldots 12 \qquad \text{Equation 2-12}$$

$$SqL = (e_{t+h}^1 - e_{t+h}^2)^2, h = 1,2, \ldots 12 \qquad \text{Equation 2-13}$$

We can calculate the D-M test statistic as a ratio of absolute loss to standard error of absolute loss, and ratio of squared loss to standard error of squared loss. The null hypothesis is that both forecasting methods lead to similar results and the alternative hypothesis is that forecasting methods result in different forecast results.

A separate ordinary least squares (OLS) of each step ahead forecast for absolute/squared loss functions was performed. By looking at the P-value of 95% confidence interval of the OLS regression, if the P-value is equal or less than 0.05, then the forecasting methods have similar results, otherwise the forecasting results are different from each other. If the forecasting methods differ from each other, the model with lower RMSE will be chosen as our accurate forecasting method. The D-M tests have been calculated for both the absolute loss and squared loss differential function of USDA NASS in February, June, October and December. The results have been presented in Table 2.19. Based on absolute loss criteria, AR (2), and VAR, and AR (2), and VECM (2) are different from each other in February and June, and there is not a significant difference among those models in October and December. Comparing our results with the RMSE criteria, AR (2) of price levels performs better for the first couple of months, and VAR (2) does a better job forecasting price levels starting in March. The D-M test results validate the conclusion from the RMSE criteria. We then compare absolute loss, and squared loss for forecasting models of price differences, where we discovered that AR (2) is no different than VAR (2), and VECM (2) forecasting models. Comparing D-M results to RMSE, we will choose AR (2) which is has lower forecasting error using RMSE criteria. Figure 2.10 and Figure 2.11 present forecasting models of price levels and price differences against USDA NASS cheddar cheese price.

VI. CAUSALITY TESTS

Granger Causality Test

Granger causality was used to test whether current and past values of one variable are useful to forecast future values of other variables. We have monthly relationship among variables. The results (coefficients have small probability values) for the Granger causality test show that our model is specified correctly at a 5% level of significance, and is presented in Table 2.20. As you see in the Table, based on the Granger causality test, cheddar cheese price causes the cheese export indirectly through production and American cheese stock. Cheddar cheese price causes production of cheddar cheese and production of cheddar cheese causes cheese export, and cheddar cheese price causes American cheese stock and American cheese stock causes the cheese export. Cheddar cheese price also causes production of cheddar cheese, total milk supply, American cheese stock and cheese export directly. American cheese stock also causes cheese export directly and indirectly through the production of cheddar cheese. In other words, total milk supply affects production of cheddar cheese (low/high quantity) that leads to high/low price of cheddar cheese which influences low/ high stock of American cheese, which affects the cheese exports decisions. The monthly causality relationship among variables is presented in the Figure 2.12.

We should mention that the Granger causality test indicates weak relationships as well as strong ones. The dashed arrows show mutual relationship among the variables of the model, where solid arrows indicate one-way relationship at a 99% confidence interval and the dash and dot arrows indicate one-way relationships at 98% confidence intervals.

VII. CONCLUSIONS AND IMPLICATIONS

Western dairy producers face large amounts of price risk but the risk is derived from variability in dairy product markets. Within this environment, there are interests in forecasts of manufacturing product prices. Forecasts of cheese prices are useful in developing price expectations and implementing dairy risk management plans.

One-to twelve month ahead forecast horizons for level/difference cheddar cheese were calculated via various forecasting methods from the simplest AR (2) to the more complicated VECM (2) for the out of sample period of January 2010 to December 2013. The forecasts' accuracy was compared using RMSE, and D-M tests to USDA NASS cheddar cheese prices, and futures market. The futures forecast is almost always better than our best forecasting method, that might be due to market industrial concentration, for example in dairy market Kraft has market power and their production affects market price and that makes the forecasting job much harder. The D-M test is comparable to RMSE test for the forecasting model of price level: AR (2) forecasting method has lower forecasted error in January and February, and VAR (2) is more accurate from March onward. VAR (2) has the lowest RMSE at forecasting model of price level. In the forecasting model of price differences AR (2) forecasting method results are more accurate from January to April and VAR (2) has more accurate results from May onwards. VECM (2) were never better than simpler forecasting methods in both forecasting models of price levels and price differences.

TABLES

TABLE 2.1: DAIRY DATA SUMMARY STATISTICS FOR JANUARY 1990 TO DECEMBER 2013

				In Sample Jan 1990- Dec 2009				**Out of Sample Jan 2010-Dec 2013**			
Variable	Symbol	Unit	Data Type	*Mean*	*Std. Dev.*	*Min*	*Max*	*Mean*	*Std. Dev.*	*Min*	*Max*
Price of Cheddar Cheese	price	$/lbs	Monthly	1.39	0.241	1.046	2.169	1.691	0.197	1.298	2.115
Production of Cheddar Cheese	prod	1000 lbs	Monthly	227182.15	97114.288	167835	287233	264052.98	12966.688	239470	287658
American Cheese Stocks	stock	1000 lbs	Monthly	457926.77	97114.288	258943	628284	631054.5	31096.73	581091	714637
Total Milk Supply	supply	Million lbs	Monthly	13760.05	1233.19	11437	16803	16470.313	658.773	14758	17813
Cheese Exports	Export	Metric Tons	Every 3 Months	4121.156	2736.857	622.1	13149.3	20297.735	5117.992	9625.2	31091.4

TABLE 2.2: RESULTS OF AUGMENTED DICKEY FULLER TEST

Variables	Definition	Test Statistic(t)		1% Critical Value	5% Critical Value	10% Critical Value
		Before	After First Difference Correction			
Price	Price of Cheddar Cheese	-4.88		-3.45	-2.87	-2.57
Prod	Production of Cheddar Cheese	-3.18	-23.57	-3.45	-2.87	-2.57
Stock	American Cheese Stocks	-2.41	-11.05	-3.45	-2.87	-2.57
Supply	Total Milk Supply	-2.13	-31.67	-3.45	-2.87	-2.57
Export	Cheese Exports	1.41	-21.44	-3.45	-2.87	-2.57

TABLE 2.3: AR LEVEL FORECAST MODEL, JANUARY 1990 TO DECEMBER 2009

Variable	Coefficient	Std	P-Value
FEB	0.0569	0.03	0.09
MAR	0.072	0.033	0.029
APR	0.08	0.033	0.016
MAY	0.051	0.033	0.12
JUNE	0.081	0.033	0.014
JUL	0.072	0.033	0.03
AUG	0.104	0.033	0.0018
SEP	0.079	0.033	0.018
OCT	-0.006	0.033	0.85
NOV	-0.0002	0.033	0.07
DEC	0.06	0.032	0.23
TREND	0.0002	0.0001	0.041
Price(t-1)	1.125	0.064	0
Price(t-2)	-0.28	0.0638	0
C	0.133	0.047	0.004
R-squared=0.837 D-W=1.94		F-Stat=78.08 Prob(F-Stat)=0	

TABLE 2.4: OUT OF SAMPLE FORECAST OF CHEDDAR CHEESE PRICE VIA AR-LEVEL

Year/Month	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12
2010M01	1.599	1.541	1.471	1.407	1.356	1.316	1.285	1.262	1.245	1.232	1.222	1.214
2010M02	1.415	1.371	1.388	1.419	1.450	1.475	1.496	1.511	1.523	1.532	1.539	1.544
2010M03	1.485	1.521	1.553	1.578	1.598	1.614	1.625	1.634	1.640	1.645	1.649	1.652
2010M04	1.318	1.341	1.405	1.471	1.526	1.571	1.605	1.631	1.650	1.665	1.676	1.685
2010M05	1.470	1.527	1.544	1.546	1.545	1.542	1.539	1.537	1.535	1.534	1.533	1.532
2010M06	1.492	1.549	1.592	1.625	1.649	1.668	1.681	1.692	1.700	1.705	1.710	1.713
2010M07	1.425	1.457	1.499	1.536	1.566	1.590	1.608	1.622	1.633	1.640	1.646	1.651
2010M08	1.649	1.755	1.803	1.827	1.841	1.850	1.856	1.860	1.863	1.865	1.867	1.868
2010M09	1.672	1.711	1.722	1.724	1.723	1.721	1.719	1.718	1.717	1.716	1.715	1.715
2010M10	1.676	1.608	1.520	1.440	1.374	1.323	1.284	1.255	1.232	1.216	1.203	1.193
2010M11	1.700	1.673	1.653	1.638	1.626	1.618	1.612	1.607	1.603	1.600	1.598	1.597
2010M12	1.388	1.304	1.305	1.329	1.356	1.380	1.399	1.414	1.425	1.434	1.440	1.445
2011M01	1.331	1.275	1.249	1.235	1.227	1.222	1.219	1.216	1.214	1.213	1.212	1.211
2011M02	1.561	1.614	1.623	1.618	1.610	1.602	1.596	1.591	1.587	1.584	1.582	1.580
2011M03	1.981	2.065	2.028	1.963	1.900	1.848	1.806	1.774	1.750	1.732	1.718	1.708
2011M04	1.773	1.728	1.715	1.713	1.715	1.717	1.719	1.721	1.722	1.723	1.724	1.725
2011M05	1.536	1.460	1.452	1.464	1.481	1.496	1.508	1.517	1.524	1.530	1.534	1.537
2011M06	1.717	1.753	1.761	1.760	1.756	1.753	1.750	1.747	1.745	1.744	1.743	1.742
2011M07	2.151	2.208	2.142	2.051	1.968	1.900	1.847	1.806	1.775	1.751	1.734	1.720
2011M08	2.084	2.049	2.015	1.985	1.962	1.944	1.930	1.920	1.912	1.906	1.902	1.899
2011M09	1.895	1.807	1.770	1.754	1.745	1.740	1.737	1.735	1.734	1.733	1.732	1.731
2011M10	1.606	1.436	1.349	1.298	1.266	1.244	1.228	1.216	1.207	1.201	1.196	1.192
2011M11	1.696	1.666	1.648	1.637	1.630	1.624	1.620	1.618	1.615	1.614	1.613	1.612
2011M12	1.852	1.829	1.768	1.705	1.652	1.610	1.577	1.552	1.533	1.519	1.508	1.500

2012M01	1.484	1.335	1.276	1.251	1.240	1.235	1.232	1.230	1.229	1.228	1.227	1.227
2012M02	1.543	1.530	1.536	1.546	1.556	1.565	1.571	1.576	1.580	1.583	1.585	1.587
2012M03	1.492	1.505	1.538	1.572	1.600	1.623	1.640	1.653	1.663	1.671	1.676	1.681
2012M04	1.565	1.617	1.651	1.675	1.693	1.705	1.715	1.722	1.727	1.731	1.734	1.736
2012M05	1.509	1.514	1.524	1.532	1.540	1.545	1.550	1.553	1.556	1.558	1.559	1.560
2012M06	1.565	1.612	1.648	1.675	1.695	1.710	1.722	1.730	1.737	1.742	1.745	1.748
2012M07	1.672	1.718	1.727	1.725	1.720	1.715	1.711	1.708	1.705	1.703	1.702	1.701
2012M08	1.735	1.791	1.824	1.846	1.862	1.873	1.881	1.887	1.892	1.895	1.898	1.900
2012M09	1.853	1.884	1.871	1.848	1.826	1.807	1.792	1.781	1.772	1.766	1.761	1.757
2012M10	1.839	1.743	1.631	1.532	1.452	1.390	1.343	1.307	1.280	1.260	1.244	1.233
2012M11	2.048	2.017	1.947	1.877	1.819	1.772	1.736	1.709	1.688	1.673	1.661	1.652
2012M12	1.795	1.669	1.606	1.571	1.549	1.534	1.523	1.516	1.510	1.506	1.502	1.500
2013M01	1.621	1.481	1.405	1.358	1.326	1.305	1.289	1.277	1.268	1.262	1.257	1.253
2013M02	1.669	1.639	1.625	1.619	1.616	1.614	1.612	1.611	1.611	1.610	1.610	1.610
2013M03	1.637	1.632	1.643	1.656	1.668	1.678	1.686	1.692	1.697	1.700	1.702	1.704
2013M04	1.640	1.658	1.679	1.697	1.712	1.724	1.733	1.739	1.744	1.748	1.751	1.753
2013M05	1.841	1.861	1.823	1.774	1.730	1.694	1.667	1.645	1.629	1.617	1.608	1.601
2013M06	1.795	1.784	1.779	1.777	1.776	1.775	1.774	1.774	1.774	1.773	1.773	1.773
2013M07	1.688	1.659	1.660	1.668	1.678	1.686	1.693	1.698	1.702	1.705	1.707	1.709
2013M08	1.739	1.774	1.807	1.835	1.856	1.872	1.885	1.894	1.901	1.906	1.910	1.913
2013M09	1.763	1.779	1.781	1.779	1.776	1.773	1.770	1.769	1.767	1.766	1.765	1.765
2013M10	1.720	1.633	1.543	1.467	1.406	1.359	1.323	1.296	1.276	1.261	1.249	1.241
2013M11	1.787	1.762	1.736	1.714	1.697	1.683	1.673	1.666	1.660	1.655	1.652	1.650
2013M12	1.806	1.759	1.706	1.661	1.625	1.597	1.575	1.559	1.547	1.537	1.530	1.525

TABLE 2.5: AR DIFFERENCE FORECAST MODEL, JANUARY 1990 TO DECEMBER 2009

Variable	Coefficient	Std	P-Value
FEB	0.065	0.035	0.062
MAR	0.076	0.035	0.030
APR	0.091	0.034	0.009
MAY	0.063	0.035	0.069
JUNE	0.093	0.035	0.008
JUL	0.075	0.035	0.031
AUG	0.107	0.035	0.002
SEP	0.074	0.035	0.034
OCT	-0.011	0.035	0.741
NOV	0.058	0.035	0.093
DEC	0.027	0.034	0.428
TREND	0.000	0.000	0.821
D1	0.240	0.066	0.000
D2	-0.165	0.066	0.014
C	-0.062	0.028	0.027
R-squared=0.169 D-W=2.032		F-Stat=3.23 Prob(F-Stat)=0.0001	

TABLE 2.6: OUT OF SAMPLE FORECAST OF CHEDDAR CHEESE PRICE VIA AR-DIFFERENCE

Year/Month	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12
2010M01	1.397	1.310	1.242	1.184	1.125	1.065	1.004	0.943	0.883	0.822	0.762	0.701
2010M02	1.403	1.388	1.402	1.417	1.428	1.437	1.447	1.457	1.467	1.477	1.487	1.497
2010M03	1.350	1.415	1.442	1.458	1.478	1.500	1.522	1.544	1.566	1.588	1.610	1.631
2010M04	1.416	1.450	1.494	1.533	1.570	1.608	1.645	1.683	1.721	1.758	1.796	1.834
2010M05	1.504	1.552	1.560	1.562	1.568	1.577	1.585	1.593	1.601	1.609	1.617	1.625
2010M06	1.419	1.442	1.481	1.523	1.564	1.604	1.644	1.684	1.724	1.764	1.804	1.844
2010M07	1.559	1.575	1.597	1.619	1.640	1.660	1.681	1.701	1.722	1.742	1.763	1.784
2010M08	1.734	1.815	1.870	1.921	1.975	2.031	2.087	2.142	2.197	2.252	2.308	2.363
2010M09	1.749	1.745	1.760	1.783	1.804	1.824	1.844	1.864	1.884	1.904	1.924	1.944
2010M10	1.668	1.574	1.493	1.422	1.351	1.278	1.205	1.132	1.060	0.987	0.914	0.841
2010M11	1.445	1.427	1.428	1.434	1.438	1.440	1.443	1.446	1.449	1.451	1.454	1.457
2010M12	1.291	1.243	1.218	1.192	1.161	1.130	1.099	1.068	1.037	1.007	0.976	0.945
2011M01	1.482	1.462	1.407	1.341	1.278	1.219	1.159	1.098	1.038	0.978	0.918	0.857
2011M02	1.961	1.997	2.006	2.012	2.022	2.032	2.043	2.053	2.063	2.074	2.084	2.094
2011M03	1.905	1.926	1.936	1.956	1.979	2.002	2.024	2.046	2.068	2.090	2.113	2.135
2011M04	1.552	1.510	1.543	1.593	1.635	1.672	1.709	1.747	1.785	1.823	1.861	1.898
2011M05	1.659	1.675	1.691	1.700	1.707	1.715	1.724	1.732	1.740	1.749	1.757	1.765
2011M06	2.191	2.285	2.329	2.362	2.400	2.441	2.482	2.522	2.563	2.603	2.644	2.684
2011M07	2.220	2.251	2.261	2.277	2.299	2.321	2.342	2.362	2.383	2.404	2.425	2.446
2011M08	1.960	1.940	1.988	2.055	2.114	2.169	2.224	2.279	2.335	2.390	2.446	2.502
2011M09	1.738	1.750	1.774	1.797	1.817	1.837	1.857	1.878	1.898	1.918	1.939	1.959
2011M10	1.628	1.561	1.494	1.422	1.348	1.276	1.203	1.131	1.058	0.986	0.913	0.841
2011M11	1.902	1.948	1.957	1.954	1.955	1.959	1.962	1.966	1.969	1.972	1.975	1.978
2011M12	1.630	1.610	1.575	1.542	1.512	1.482	1.451	1.421	1.390	1.360	1.330	1.299

2012M01	1.414	1.300	1.240	1.189	1.131	1.070	1.010	0.950	0.890	0.830	0.770	0.710
2012M02	1.516	1.576	1.595	1.599	1.607	1.618	1.629	1.639	1.650	1.660	1.671	1.682
2012M03	1.532	1.566	1.593	1.615	1.636	1.659	1.681	1.704	1.726	1.748	1.771	1.793
2012M04	1.561	1.623	1.663	1.698	1.736	1.774	1.813	1.851	1.889	1.927	1.965	2.004
2012M05	1.521	1.522	1.530	1.540	1.549	1.558	1.566	1.575	1.583	1.592	1.600	1.609
2012M06	1.676	1.727	1.770	1.809	1.849	1.890	1.931	1.971	2.012	2.053	2.093	2.134
2012M07	1.728	1.754	1.773	1.793	1.814	1.836	1.857	1.878	1.899	1.921	1.942	1.963
2012M08	1.873	1.918	1.973	2.030	2.087	2.143	2.198	2.254	2.310	2.366	2.422	2.478
2012M09	1.968	1.989	2.006	2.025	2.046	2.067	2.088	2.108	2.129	2.150	2.170	2.191
2012M10	2.009	1.904	1.822	1.754	1.684	1.612	1.539	1.467	1.395	1.322	1.250	1.178
2012M11	1.931	1.923	1.921	1.925	1.929	1.933	1.936	1.939	1.943	1.946	1.950	1.953
2012M12	1.652	1.576	1.546	1.523	1.495	1.464	1.433	1.403	1.373	1.343	1.313	1.283
2013M01	1.630	1.587	1.532	1.471	1.410	1.350	1.291	1.231	1.171	1.112	1.052	0.992
2013M02	1.667	1.710	1.726	1.733	1.742	1.753	1.764	1.775	1.786	1.797	1.808	1.819
2013M03	1.640	1.673	1.699	1.721	1.743	1.765	1.788	1.811	1.834	1.857	1.879	1.902
2013M04	1.863	1.917	1.959	1.996	2.033	2.072	2.111	2.149	2.188	2.226	2.265	2.303
2013M05	1.864	1.889	1.894	1.899	1.908	1.917	1.926	1.935	1.944	1.953	1.962	1.971
2013M06	1.715	1.721	1.760	1.806	1.849	1.889	1.930	1.971	2.012	2.053	2.094	2.135
2013M07	1.708	1.731	1.756	1.778	1.799	1.821	1.842	1.864	1.885	1.907	1.928	1.950
2013M08	1.815	1.897	1.958	2.011	2.066	2.122	2.179	2.235	2.291	2.347	2.403	2.460
2013M09	1.827	1.855	1.876	1.896	1.916	1.937	1.958	1.979	2.000	2.021	2.042	2.063
2013M10	1.748	1.659	1.582	1.511	1.441	1.369	1.297	1.225	1.153	1.081	1.009	0.938
2013M11	1.846	1.842	1.844	1.849	1.853	1.857	1.861	1.864	1.868	1.872	1.876	1.879
2013M12	1.923	1.888	1.855	1.826	1.796	1.767	1.737	1.707	1.677	1.647	1.617	1.587

TABLE 2.7: VAR LEVEL ESTIMATES

Standard errors in ( ) & t-statistics in [ ]

	D(SUPPLY)	D(STOCK)	D(PROD)	D(EXPORT)	PRICE
D(SUPPLY(-1))	-0.440512	-3.668655	0.580600	0.240379	-7.76E-05
	(0.07405)	(6.85960)	(3.36369)	(0.33976)	(5.4E-05)
	[-5.94844]	[-0.53482]	[0.17261]	[0.70749]	[-1.43519]
D(SUPPLY(-2))	-0.203125	8.038607	2.378863	-0.651140	-6.62E-05
	(0.08724)	(8.08118)	(3.96270)	(0.40027)	(6.4E-05)
	[-2.32827]	[0.99473]	[0.60031]	[-1.62677]	[-1.03960]
D(STOCK(-1))	0.001791	0.152213	0.051899	0.005536	-1.03E-06
	(0.00077)	(0.07093)	(0.03478)	(0.00351)	(5.6E-07)
	[2.33877]	[2.14603]	[1.49221]	[1.57572]	[-1.83508]
D(STOCK(-2))	-0.002127	-0.038246	-0.130939	0.003437	3.04E-07
	(0.00075)	(0.06983)	(0.03424)	(0.00346)	(5.5E-07)
	[-2.82143]	[-0.54766]	[-3.82366]	[0.99375]	[0.55261]
D(PROD(-1))	0.001456	0.464692	-0.198539	0.006270	-6.12E-07
	(0.00153)	(0.14186)	(0.06956)	(0.00703)	(1.1E-06)
	[0.95104]	[3.27581]	[-2.85418]	[0.89241]	[-0.54728]
D(PROD(-2))	-0.000554	0.077575	-0.303629	0.005999	-8.36E-07
	(0.00163)	(0.15144)	(0.07426)	(0.00750)	(1.2E-06)
	[-0.33903]	[0.51224]	[-4.08866]	[0.79980]	[-0.70093]
D(EXPORT(-1))	0.014432	-0.999767	1.158486	-0.349293	3.11E-05
	(0.01588)	(1.47072)	(0.72118)	(0.07285)	(1.2E-05)
	[0.90896]	[-0.67978]	[1.60637]	[-4.79497]	[2.68215]
D(EXPORT(-2))	0.029996	-1.854033	0.414722	-0.018357	7.88E-06
	(0.01565)	(1.44955)	(0.71081)	(0.07180)	(1.1E-05)
	[1.91680]	[-1.27904]	[0.58345]	[-0.25568]	[0.68947]
PRICE(-1)	16.95398	6560.091	7704.598	-817.3493	1.073477
	(96.5846)	(8946.49)	(4387.02)	(443.126)	(0.07050)
	[0.17554]	[0.73326]	[1.75623]	[-1.84451]	[15.2266]
PRICE(-2)	97.16054	-3711.291	-4267.911	592.3299	-0.207394
	(97.3725)	(9019.47)	(4422.80)	(446.741)	(0.07108)
	[0.99782]	[-0.41148]	[-0.96498]	[1.32589]	[-2.91795]
C	264.4654	4758.123	-1635.896	-584.8397	0.164287
	(83.7475)	(7757.41)	(3803.94)	(384.230)	(0.06113)
	[3.15789]	[0.61336]	[-0.43005]	[-1.52211]	[2.68750]
FEB	-1125.602	-6361.797	-16335.14	974.2216	0.106104
	(92.7143)	(8588.00)	(4211.23)	(425.370)	(0.06768)
	[-12.1405]	[-0.74078]	[-3.87895]	[2.29029]	[1.56785]
MAR	733.7400	-692.4854	16237.61	1825.367	-0.046128

	(116.975)	(10835.2)	(5313.18)	(536.677)	(0.08538)
	[6.27262]	[-0.06391]	[3.05610]	[3.40124]	[-0.54024]
APR	-286.9966	13946.22	-4705.164	2.985017	0.063535
	(76.9673)	(7129.37)	(3495.97)	(353.123)	(0.05618)
	[-3.72881]	[1.95616]	[-1.34588]	[0.00845]	[1.13090]
MAY	253.9860	-6325.348	8695.445	1560.687	0.104846
	(145.667)	(13492.9)	(6616.41)	(668.314)	(0.10633)
	[1.74361]	[-0.46879]	[1.31422]	[2.33526]	[0.98607]
JUNE	-955.4059	2312.332	-12574.24	172.5712	0.070915
	(53.5591)	(4961.10)	(2432.73)	(245.727)	(0.03909)
	[-17.8384]	[0.46609]	[-5.16877]	[0.70229]	[1.81395]
JUL	-612.8760	-1485.458	-7215.225	978.8366	0.014076
	(106.461)	(9861.32)	(4835.61)	(488.438)	(0.07771)
	[-5.75682]	[-0.15063]	[-1.49210]	[2.00401]	[0.18114]
AUG	-784.4615	-15838.73	-16636.62	769.7798	0.004815
	(81.3821)	(7538.31)	(3696.50)	(373.378)	(0.05940)
	[-9.63924]	[-2.10110]	[-4.50064]	[2.06167]	[0.08105]
SEP	-1016.692	-18773.00	-13144.96	1014.363	-0.032201
	(81.8589)	(7582.47)	(3718.16)	(375.565)	(0.05975)
	[-12.4201]	[-2.47584]	[-3.53535]	[2.70089]	[-0.53891]
OCT	-339.5730	-17221.34	-231.1895	1407.014	-0.142306
	(91.3194)	(8458.79)	(4147.87)	(418.970)	(0.06666)
	[-3.71852]	[-2.03591]	[-0.05574]	[3.35827]	[-2.13490]
NOV	-735.5732	-16827.65	-9264.361	788.3810	-0.025979
	(56.4547)	(5229.32)	(2564.26)	(259.012)	(0.04121)
	[-13.0294]	[-3.21794]	[-3.61288]	[3.04380]	[-0.63044]
DEC	143.2538	2139.272	16980.90	1260.800	-0.028864
	(86.0943)	(7974.79)	(3910.53)	(394.997)	(0.06284)
	[1.66392]	[0.26825]	[4.34235]	[3.19192]	[-0.45931]
TREND	-0.059014	-20.41548	5.676438	0.239859	0.000126
	(0.29513)	(27.3376)	(13.4053)	(1.35405)	(0.00022)
	[-0.19996]	[-0.74679]	[0.42345]	[0.17714]	[0.58381]
BREAK1	11.16512	2148.375	-869.4235	-8.933436	-0.007454
	(62.3118)	(5771.85)	(2830.29)	(285.884)	(0.04548)
	[0.17918]	[0.37222]	[-0.30718]	[-0.03125]	[-0.16387]
BREAK2	437.6858	-7152.062	2440.408	-260.4662	-0.019052
	(230.914)	(21389.2)	(10488.5)	(1059.42)	(0.16855)
	[1.89545]	[-0.33438]	[0.23268]	[-0.24586]	[-0.11304]
BT1	-0.337840	-176.9934	76.17645	-0.473590	0.000229
	(2.10361)	(194.854)	(95.5492)	(9.65128)	(0.00154)
	[-0.16060]	[-0.90834]	[0.79725]	[-0.04907]	[0.14910]
BT2	-2.077443	44.59133	-18.78119	1.710392	0.000138
	(1.12049)	(103.789)	(50.8943)	(5.14076)	(0.00082)

	[-1.85405]	[0.42963]	[-0.36902]	[0.33271]	[0.16904]
R-squared	0.961116	0.574793	0.821219	0.285519	0.845175
Adj. R-squared	0.956302	0.522148	0.799084	0.197059	0.826006
Sum sq. resids	4039033.	3.47E+10	8.33E+09	85019126	2.151998
S.E. equation	138.6849	12846.18	6299.277	636.2806	0.101230
F-statistic	199.6428	10.91835	37.10078	3.227675	44.09099
Log likelihood	-1490.888	-2564.166	-2395.277	-1851.942	220.8587
Akaike AIC	12.80918	21.86638	20.44115	15.85605	-1.635938
Schwarz SC	13.20428	22.26147	20.83625	16.25115	-1.240843
Mean dependent	11.89451	1237.025	215.5274	47.96456	1.390961
S.D. dependent	663.4354	18583.50	14053.47	710.0794	0.242685

Determinant resid covariance (dof adj.)	4.15E+23
Determinant resid covariance	2.27E+23
Log likelihood	-8054.112
Akaike information criterion	69.10643
Schwarz criterion	71.08190

TABLE 2.8: OUT OF SAMPLE FORECAST OF CHEDDAR CHEESE PRICE VIA VAR-LEVEL

Year/Month	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12
2010M01	1.645	1.622	1.625	1.659	1.666	1.691	1.708	1.754	1.776	1.702	1.680	1.656
2010M02	1.389	1.423	1.490	1.528	1.582	1.623	1.687	1.723	1.661	1.647	1.630	1.577
2010M03	1.487	1.557	1.588	1.628	1.659	1.716	1.746	1.679	1.662	1.641	1.586	1.584
2010M04	1.417	1.444	1.507	1.567	1.642	1.686	1.632	1.625	1.612	1.563	1.566	1.598
2010M05	1.486	1.551	1.593	1.656	1.697	1.642	1.633	1.618	1.568	1.570	1.601	1.649
2010M06	1.560	1.592	1.649	1.692	1.637	1.629	1.615	1.566	1.568	1.600	1.648	1.663
2010M07	1.452	1.524	1.591	1.560	1.568	1.566	1.526	1.537	1.576	1.629	1.648	1.685
2010M08	1.600	1.653	1.608	1.606	1.597	1.551	1.557	1.591	1.641	1.658	1.692	1.718
2010M09	1.600	1.653	1.608	1.606	1.597	1.551	1.557	1.591	1.641	1.658	1.692	1.718
2010M10	1.543	1.535	1.552	1.527	1.540	1.576	1.628	1.648	1.685	1.712	1.766	1.794
2010M11	1.678	1.662	1.620	1.620	1.641	1.679	1.687	1.716	1.737	1.785	1.809	1.737
2010M12	1.401	1.392	1.435	1.492	1.560	1.594	1.642	1.679	1.739	1.773	1.709	1.694
2011M01	1.559	1.592	1.609	1.647	1.661	1.695	1.721	1.773	1.800	1.729	1.710	1.688
2011M02	1.599	1.639	1.667	1.670	1.701	1.727	1.778	1.803	1.732	1.712	1.690	1.633
2011M03	2.051	2.057	1.980	1.933	1.908	1.924	1.919	1.824	1.784	1.746	1.677	1.665
2011M04	1.871	1.823	1.795	1.792	1.831	1.847	1.767	1.740	1.711	1.649	1.643	1.667
2011M05	1.428	1.460	1.527	1.622	1.681	1.637	1.637	1.629	1.585	1.592	1.627	1.678
2011M06	1.734	1.737	1.782	1.809	1.738	1.717	1.693	1.635	1.632	1.658	1.703	1.715
2011M07	2.168	2.143	2.085	1.950	1.885	1.828	1.742	1.716	1.724	1.755	1.756	1.778
2011M08	1.981	1.946	1.846	1.808	1.769	1.695	1.678	1.694	1.731	1.737	1.764	1.783
2011M09	1.835	1.741	1.726	1.707	1.647	1.641	1.665	1.707	1.719	1.749	1.771	1.821
2011M10	1.617	1.595	1.604	1.574	1.584	1.618	1.670	1.690	1.726	1.753	1.807	1.835
2011M11	1.734	1.724	1.661	1.646	1.668	1.711	1.722	1.751	1.773	1.822	1.847	1.776
2011M12	1.967	1.862	1.802	1.789	1.806	1.797	1.811	1.820	1.860	1.876	1.799	1.773
2012M01	1.523	1.527	1.570	1.633	1.660	1.701	1.734	1.792	1.823	1.756	1.740	1.720
2012M02	1.532	1.570	1.629	1.654	1.697	1.732	1.790	1.821	1.755	1.739	1.719	1.664

2012M03	1.504	1.551	1.581	1.638	1.686	1.754	1.793	1.733	1.721	1.705	1.653	1.655
2012M04	1.674	1.691	1.721	1.750	1.806	1.833	1.764	1.747	1.725	1.669	1.667	1.695
2012M05	1.558	1.638	1.682	1.741	1.780	1.724	1.715	1.700	1.649	1.651	1.682	1.730
2012M06	1.745	1.799	1.828	1.836	1.765	1.749	1.728	1.672	1.669	1.696	1.741	1.753
2012M07	1.592	1.652	1.704	1.664	1.669	1.664	1.621	1.629	1.665	1.716	1.734	1.770
2012M08	1.693	1.735	1.694	1.695	1.685	1.637	1.641	1.674	1.724	1.740	1.774	1.800
2012M09	1.768	1.693	1.692	1.685	1.639	1.644	1.676	1.725	1.741	1.775	1.800	1.852
2012M10	1.771	1.742	1.731	1.682	1.679	1.704	1.746	1.757	1.788	1.811	1.861	1.886
2012M11	2.051	1.965	1.860	1.821	1.817	1.836	1.829	1.844	1.855	1.895	1.913	1.836
2012M12	1.753	1.661	1.661	1.695	1.742	1.753	1.784	1.807	1.858	1.884	1.813	1.793
2013M01	1.655	1.648	1.689	1.748	1.761	1.788	1.809	1.860	1.885	1.814	1.794	1.771
2013M02	1.752	1.782	1.814	1.807	1.824	1.839	1.884	1.904	1.829	1.806	1.780	1.721
2013M03	1.668	1.733	1.748	1.778	1.802	1.854	1.881	1.811	1.791	1.769	1.712	1.709
2013M04	1.758	1.757	1.782	1.813	1.864	1.887	1.815	1.795	1.772	1.714	1.711	1.738
2013M05	1.829	1.851	1.866	1.902	1.917	1.839	1.815	1.787	1.726	1.721	1.746	1.788
2013M06	1.879	1.895	1.921	1.929	1.849	1.822	1.793	1.731	1.725	1.749	1.791	1.801
2013M07	1.709	1.782	1.813	1.748	1.741	1.731	1.683	1.686	1.718	1.767	1.782	1.816
2013M08	1.834	1.859	1.782	1.765	1.749	1.697	1.698	1.727	1.774	1.788	1.821	1.845
2013M09	1.786	1.692	1.686	1.688	1.648	1.659	1.697	1.750	1.769	1.806	1.833	1.887
2013M10	1.660	1.686	1.692	1.647	1.658	1.697	1.750	1.769	1.806	1.833	1.887	1.915
2013M11	1.842	1.792	1.721	1.720	1.747	1.789	1.800	1.830	1.852	1.902	1.927	1.856
2013M12	1.836	1.772	1.754	1.767	1.805	1.814	1.841	1.861	1.909	1.932	1.860	1.839

TABLE 2.9: VAR DIFFERENCE ESTIMATES

	D(SUPPLY)	D(STOCK)	D(PROD)	D(EXPORT)	D(PRICE)
D(SUPPLY(-1))	-0.421665	-3.244428	1.134681	0.202993	-0.000101
	(0.07463)	(6.79994)	(3.35450)	(0.33889)	(5.6E-05)
	[-5.65043]	[-0.47713]	[0.33826]	[0.59899]	[-1.81111]
D(SUPPLY(-2))	-0.208544	6.273436	1.740043	-0.648329	-9.69E-05
	(0.08969)	(8.17251)	(4.03161)	(0.40729)	(6.7E-05)
	[-2.32520]	[0.76763]	[0.43160]	[-1.59180]	[-1.44880]
D(STOCK(-1))	0.001769	0.151275	0.051137	0.005576	-1.01E-06
	(0.00078)	(0.07067)	(0.03486)	(0.00352)	(5.8E-07)
	[2.28140]	[2.14047]	[1.46676]	[1.58307]	[-1.74654]
D(STOCK(-2))	-0.002392	-0.057285	-0.142553	0.003901	3.34E-07
	(0.00077)	(0.07028)	(0.03467)	(0.00350)	(5.7E-07)
	[-3.10174]	[-0.81505]	[-4.11141]	[1.11357]	[0.58010]
D(PROD(-1))	0.002027	0.500324	-0.175116	0.005249	-7.96E-07
	(0.00156)	(0.14207)	(0.07008)	(0.00708)	(1.2E-06)
	[1.30009]	[3.52171]	[-2.49864]	[0.74131]	[-0.68452]
D(PROD(-2))	0.000291	0.135403	-0.267455	0.004510	-9.94E-07
	(0.00168)	(0.15348)	(0.07572)	(0.00765)	(1.3E-06)
	[0.17278]	[0.88219]	[-3.53234]	[0.58959]	[-0.79203]
D(EXPORT(-1))	0.009153	-1.417489	0.916071	-0.340266	3.08E-05
	(0.01630)	(1.48507)	(0.73261)	(0.07401)	(1.2E-05)
	[0.56163]	[-0.95449]	[1.25043]	[-4.59747]	[2.53408]
D(EXPORT(-2))	0.028585	-1.969044	0.348950	-0.015960	7.72E-06
	(0.01587)	(1.44599)	(0.71333)	(0.07206)	(1.2E-05)
	[1.80134]	[-1.36172]	[0.48919]	[-0.22148]	[0.65256]
D(PRICE(-1))	-20.71235	7086.738	6998.316	-735.9891	0.150995
	(96.6719)	(8808.85)	(4345.52)	(439.007)	(0.07206)
	[-0.21425]	[0.80450]	[1.61047]	[-1.67649]	[2.09538]
D(PRICE(-2))	-97.83610	-12022.08	-5741.933	146.6405	-0.102746
	(93.7129)	(8539.22)	(4212.51)	(425.569)	(0.06986)
	[-1.04400]	[-1.40787]	[-1.36307]	[0.34457]	[-1.47084]
C	381.4113	6308.298	1486.475	-822.0574	-0.004051
	(68.5897)	(6249.96)	(3083.19)	(311.479)	(0.05113)
	[5.56077]	[1.00933]	[0.48212]	[-2.63920]	[-0.07923]
FEB	-1122.834	-4837.075	-15827.02	975.7965	0.135915
	(94.8666)	(8644.35)	(4264.37)	(430.808)	(0.07072)
	[-11.8359]	[-0.55957]	[-3.71145]	[2.26504]	[1.92200]
MAR	782.7203	2316.803	18234.04	1737.415	-0.063035
	(119.154)	(10857.4)	(5356.10)	(541.101)	(0.08882)

	[6.56900]	[0.21338]	[3.40435]	[3.21089]	[-0.70970]
APR	-290.0622	14075.81	-4737.343	10.02590	0.071814
	(77.9620)	(7103.98)	(3504.49)	(354.041)	(0.05811)
	[-3.72056]	[1.98140]	[-1.35179]	[0.02832]	[1.23573]
MAY	280.4410	-2344.523	10461.11	1524.562	0.149208
	(151.055)	(13764.3)	(6790.10)	(685.971)	(0.11260)
	[1.85655]	[-0.17033]	[1.54064]	[2.22249]	[1.32513]
JUNE	-934.4088	4176.043	-11550.99	137.6389	0.076696
	(55.7370)	(5078.82)	(2505.45)	(253.113)	(0.04155)
	[-16.7646]	[0.82225]	[-4.61035]	[0.54378]	[1.84599]
JUL	-563.2678	2054.351	-5049.645	892.1337	0.008125
	(109.680)	(9994.12)	(4930.23)	(498.077)	(0.08176)
	[-5.13557]	[0.20556]	[-1.02422]	[1.79116]	[0.09938]
AUG	-736.1669	-13494.66	-14849.97	680.0488	-0.026006
	(81.9144)	(7464.13)	(3682.15)	(371.990)	(0.06106)
	[-8.98702]	[-1.80793]	[-4.03296]	[1.82814]	[-0.42591]
SEP	-959.1891	-15244.43	-10802.42	911.0856	-0.052148
	(84.2092)	(7673.23)	(3785.30)	(382.411)	(0.06277)
	[-11.3906]	[-1.98670]	[-2.85378]	[2.38248]	[-0.83077]
OCT	-275.8132	-13857.84	2206.036	1289.848	-0.176892
	(92.3678)	(8416.65)	(4152.05)	(419.461)	(0.06885)
	[-2.98603]	[-1.64648]	[0.53131]	[3.07501]	[-2.56914]
NOV	-705.9563	-15328.00	-8150.555	733.6533	-0.043469
	(57.0176)	(5195.51)	(2563.01)	(258.928)	(0.04250)
	[-12.3814]	[-2.95024]	[-3.18007]	[2.83342]	[-1.02276]
DEC	170.3535	3794.578	18082.66	1212.091	-0.038438
	(87.4716)	(7970.50)	(3931.95)	(397.226)	(0.06520)
	[1.94753]	[0.47608]	[4.59890]	[3.05139]	[-0.58952]
TREND	0.008778	-18.88696	7.670241	0.105391	4.25E-05
	(0.29769)	(27.1260)	(13.3816)	(1.35188)	(0.00022)
	[0.02949]	[-0.69627]	[0.57319]	[0.07796]	[0.19148]
BREAK1	6.883417	1868.963	-1048.716	-1.323915	-0.006347
	(63.1323)	(5752.68)	(2837.87)	(286.696)	(0.04706)
	[0.10903]	[0.32489]	[-0.36954]	[-0.00462]	[-0.13487]
BREAK2	430.1129	-6006.285	2601.865	-239.0848	0.020150
	(234.115)	(21332.8)	(10523.8)	(1063.16)	(0.17451)
	[1.83719]	[-0.28155]	[0.24724]	[-0.22488]	[0.11546]
BT1	-0.408476	-174.6744	75.24047	-0.314582	0.000405
	(2.13073)	(194.154)	(95.7788)	(9.67606)	(0.00159)
	[-0.19171]	[-0.89967]	[0.78557]	[-0.03251]	[0.25471]
BT2	-1.984608	40.54697	-17.84188	1.496600	-0.000115
	(1.13498)	(103.420)	(51.0186)	(5.15416)	(0.00085)
	[-1.74859]	[0.39206]	[-0.34971]	[0.29037]	[-0.13613]

R-squared	0.960104	0.577809	0.820344	0.281786	0.247398
Adj. R-squared	0.955165	0.525538	0.798101	0.192865	0.154219
Sum sq. resids	4144175.	3.44E+10	8.37E+09	85463261	2.302697
S.E. equation	140.4784	12800.53	6314.674	637.9404	0.104715
F-statistic	194.3728	11.05407	36.88074	3.168927	2.655074
Log likelihood	-1493.933	-2563.322	-2395.855	-1852.560	212.8381
Akaike AIC	12.83488	21.85926	20.44604	15.86126	-1.568254
Schwarz SC	13.22997	22.25435	20.84113	16.25636	-1.173158
Mean dependent	11.89451	1237.025	215.5274	47.96456	0.001605
S.D. dependent	663.4354	18583.50	14053.47	710.0794	0.113862

Determinant resid covariance (dof adj.)	4.46E+23
Determinant resid covariance	2.43E+23
Log likelihood	-8062.520
Akaike information criterion	69.17739
Schwarz criterion	71.15286

TABLE 2.10: OUT OF SAMPLE FORECAST OF CHEDDAR CHEESE PRICE VIA VAR-DIFFERENCE

Year/Month	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12
2010M01	1.604	1.598	1.634	1.679	1.699	1.738	1.769	1.828	1.862	1.799	1.788	1.773
2010M02	1.377	1.412	1.465	1.482	1.519	1.553	1.613	1.646	1.583	1.571	1.557	1.507
2010M03	1.499	1.565	1.583	1.621	1.655	1.714	1.746	1.683	1.672	1.658	1.607	1.615
2010M04	1.389	1.389	1.414	1.449	1.511	1.544	1.480	1.469	1.455	1.405	1.412	1.450
2010M05	1.461	1.487	1.510	1.563	1.598	1.537	1.526	1.511	1.461	1.468	1.506	1.560
2010M06	1.523	1.533	1.572	1.605	1.547	1.536	1.520	1.470	1.478	1.516	1.569	1.592
2010M07	1.415	1.453	1.483	1.427	1.417	1.401	1.350	1.358	1.396	1.450	1.472	1.514
2010M08	1.583	1.597	1.544	1.539	1.522	1.470	1.478	1.517	1.570	1.592	1.634	1.668
2010M09	1.674	1.621	1.614	1.600	1.550	1.555	1.593	1.647	1.670	1.712	1.746	1.807
2010M10	1.541	1.515	1.539	1.508	1.507	1.541	1.596	1.619	1.661	1.695	1.756	1.793
2010M11	1.677	1.671	1.652	1.667	1.700	1.750	1.772	1.815	1.849	1.910	1.947	1.887
2010M12	1.387	1.382	1.404	1.429	1.476	1.503	1.548	1.581	1.641	1.678	1.619	1.610
2011M01	1.555	1.579	1.566	1.606	1.641	1.684	1.715	1.776	1.813	1.754	1.745	1.734
2011M02	1.590	1.607	1.634	1.656	1.700	1.734	1.795	1.832	1.772	1.764	1.752	1.705
2011M03	2.068	2.114	2.109	2.140	2.178	2.240	2.276	2.216	2.208	2.197	2.149	2.159
2011M04	1.867	1.872	1.890	1.916	1.979	2.020	1.961	1.952	1.940	1.893	1.903	1.944
2011M05	1.440	1.483	1.541	1.603	1.636	1.581	1.574	1.561	1.513	1.524	1.565	1.621
2011M06	1.759	1.759	1.813	1.857	1.804	1.795	1.780	1.733	1.744	1.785	1.842	1.867
2011M07	2.192	2.200	2.222	2.169	2.164	2.149	2.101	2.112	2.153	2.210	2.235	2.280
2011M08	2.002	2.034	2.011	2.012	1.992	1.943	1.955	1.997	2.053	2.078	2.123	2.160
2011M09	1.877	1.839	1.868	1.858	1.804	1.816	1.858	1.914	1.939	1.984	2.021	2.085
2011M10	1.645	1.650	1.654	1.613	1.624	1.664	1.720	1.745	1.790	1.827	1.891	1.931
2011M11	1.761	1.753	1.700	1.705	1.746	1.804	1.830	1.874	1.911	1.975	2.015	1.958
2011M12	1.978	1.902	1.881	1.923	1.987	2.011	2.053	2.091	2.156	2.195	2.138	2.133
2012M01	1.513	1.538	1.583	1.637	1.659	1.705	1.744	1.808	1.847	1.790	1.785	1.776
2012M02	1.546	1.575	1.634	1.659	1.704	1.743	1.807	1.846	1.790	1.784	1.775	1.731

2012M03	1.481	1.515	1.537	1.580	1.619	1.687	1.726	1.669	1.663	1.654	1.610	1.623
2012M04	1.659	1.673	1.696	1.736	1.808	1.844	1.786	1.781	1.773	1.729	1.741	1.785
2012M05	1.548	1.624	1.653	1.703	1.740	1.687	1.684	1.674	1.629	1.642	1.687	1.746
2012M06	1.742	1.798	1.813	1.830	1.783	1.783	1.773	1.727	1.741	1.785	1.845	1.873
2012M07	1.587	1.621	1.661	1.616	1.612	1.602	1.558	1.571	1.615	1.674	1.703	1.750
2012M08	1.687	1.720	1.684	1.684	1.673	1.628	1.641	1.685	1.744	1.773	1.820	1.860
2012M09	1.768	1.685	1.701	1.702	1.654	1.667	1.711	1.771	1.799	1.846	1.886	1.954
2012M10	1.778	1.766	1.786	1.753	1.763	1.803	1.863	1.892	1.940	1.979	2.046	2.089
2012M11	2.077	2.023	1.986	2.011	2.054	2.110	2.137	2.186	2.227	2.293	2.336	2.282
2012M12	1.756	1.708	1.751	1.801	1.853	1.881	1.931	1.971	2.038	2.080	2.026	2.024
2013M01	1.679	1.702	1.765	1.838	1.865	1.908	1.947	2.015	2.058	2.004	2.001	1.996
2013M02	1.771	1.830	1.887	1.908	1.953	1.994	2.062	2.104	2.050	2.048	2.042	2.001
2013M03	1.684	1.776	1.803	1.843	1.883	1.951	1.995	1.940	1.937	1.932	1.891	1.907
2013M04	1.762	1.764	1.799	1.851	1.923	1.961	1.905	1.904	1.899	1.857	1.873	1.920
2013M05	1.832	1.867	1.918	1.987	2.025	1.970	1.968	1.963	1.922	1.938	1.984	2.047
2013M06	1.884	1.936	1.996	2.029	1.976	1.975	1.970	1.928	1.944	1.991	2.054	2.085
2013M07	1.723	1.819	1.855	1.785	1.781	1.783	1.743	1.757	1.803	1.866	1.898	1.948
2013M08	1.850	1.884	1.802	1.795	1.799	1.760	1.773	1.819	1.882	1.914	1.964	2.007
2013M09	1.774	1.662	1.649	1.655	1.617	1.632	1.678	1.741	1.773	1.823	1.866	1.936
2013M10	1.659	1.688	1.703	1.654	1.665	1.714	1.779	1.809	1.859	1.902	1.973	2.018
2013M11	1.849	1.801	1.748	1.773	1.824	1.886	1.915	1.966	2.009	2.079	2.125	2.074
2013M12	1.832	1.790	1.806	1.848	1.910	1.941	1.993	2.036	2.106	2.151	2.100	2.101

TABLE 2.11: JOHANSEN CONITEGRATION TRACE TEST

Hypothesized # of Cointegrating Equations	Eiegenvalue	Trace Statistic	0.05 Critical Value	P-Value
None*	0.110571	52.04193	47.85613	0.0192
At most 1	0.038464	18.8812	29.79707	0.5015
At most 2	0.01927	7.781148	15.49471	0.4891
At most 3	0.008005	2.274502	3.841466	0.1315
Trace test indicates 1 cointegrating equation at the 0.05 level				

TABLE 2.12: JOHANSEN COINTEGRATION EIGEN-VALUE TEST

Hypothesized # of Cointegrating Equations	Eiegenvalue	Trace Statistic	0.05 Critical Value	P-Value
None*	0.110571	33.16074	27.58434	0.0086
At most 1	0.038464	11.10005	21.13162	0.6373
At most 2	0.01927	5.506646	14.2646	0.677
At most 3	0.008005	2.274502	3.841466	0.1315
Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level				

TABLE 2.13: ENGLE GRANGER COINTEGRATION TEST FOR SUPPLY AS DEPENDENT VARIABLE

Variable	Coefficient	Prob
C	5731.56	0
Stock	.00134	.0019
Prod	0.031	0
Export	0.0827	0
N=288 R-Squared 0.939	F statistic 1478.71 Prob(F) 0	

TABLE 2.14: VECM LEVEL FORECAST ESTIMATES

Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq	CointEq1
D(SUPPLY(-1))	1.000000
D(STOCK(-1))	0.000476
	(0.00093)
	[0.51089]
D(PROD(-1))	0.018111
	(0.00252)
	[7.19660]
D(EXPORT(-1))	-0.126586
	(0.02699)
	[-4.69052]
PRICE(-1)	-89.01534
	(35.8574)
	[-2.48248]
C	115.9533

Error Correction:	D(SUPPLY,2)	D(STOCK,2)	D(PROD,2)	D(EXPORT,2)	D(PRICE)
CointEq1	-0.893534	11.13986	-39.20963	1.513113	-0.000217
	(0.10856)	(10.6536)	(5.14141)	(0.53664)	(7.6E-05)
	[-8.23044]	[1.04564]	[-7.62624]	[2.81960]	[-2.84962]
D(SUPPLY(-1),2)	-0.313788	-11.35597	26.45199	-0.995646	0.000111
	(0.09545)	(9.36656)	(4.52029)	(0.47181)	(6.7E-05)
	[-3.28748]	[-1.21240]	[5.85183]	[-2.11027]	[1.66282]
D(SUPPLY(-2),2)	-0.178970	0.369062	8.596082	-0.964863	1.02E-05
	(0.08247)	(8.09300)	(3.90567)	(0.40766)	(5.8E-05)
	[-2.17009]	[0.04560]	[2.20092]	[-2.36684]	[0.17562]
D(STOCK(-1),2)	0.002943	-0.521988	0.098526	0.003626	-8.85E-07
	(0.00069)	(0.06799)	(0.03281)	(0.00342)	(4.9E-07)
	[4.24804]	[-7.67794]	[3.00295]	[1.05881]	[-1.81864]
D(STOCK(-2),2)	0.001102	-0.328003	-0.009745	0.002491	-2.94E-07
	(0.00072)	(0.07037)	(0.03396)	(0.00354)	(5.0E-07)
	[1.53672]	[-4.66134]	[-0.28697]	[0.70267]	[-0.58378]
D(PROD(-1),2)	0.012888	0.291544	-0.176241	-0.012027	2.59E-06
	(0.00176)	(0.17239)	(0.08320)	(0.00868)	(1.2E-06)
	[7.33597]	[1.69115]	[-2.11836]	[-1.38499]	[2.10263]
D(PROD(-2),2)	0.006924	0.183453	-0.137803	-0.002813	1.27E-06
	(0.00147)	(0.14424)	(0.06961)	(0.00727)	(1.0E-06)
	[4.71086]	[1.27188]	[-1.97967]	[-0.38712]	[1.22983]

D(EXPORT(-1),2)	-0.065613	0.910478	-2.902486	-0.756621	-1.20E-05
	(0.01646)	(1.61493)	(0.77936)	(0.08135)	(1.2E-05)
	[-3.98700]	[0.56379]	[-3.72417]	[-9.30115]	[-1.03993]
D(EXPORT(-2),2)	0.004683	-0.559747	-0.901866	-0.296463	-1.38E-05
	(0.01342)	(1.31713)	(0.63565)	(0.06635)	(9.4E-06)
	[0.34892]	[-0.42497]	[-1.41882]	[-4.46841]	[-1.46533]
D(PRICE(-1))	-35.90777	17492.66	10.89908	-1293.722	0.154065
	(101.501)	(9960.42)	(4806.89)	(501.724)	(0.07130)
	[-0.35377]	[1.75622]	[0.00227]	[-2.57855]	[2.16089]
D(PRICE(-2))	3.896439	2718.341	-13610.57	353.1639	-0.129273
	(100.901)	(9901.57)	(4778.49)	(498.760)	(0.07088)
	[0.03862]	[0.27454]	[-2.84830]	[0.70808]	[-1.82394]
C	444.3327	12252.43	367.0764	-1579.199	0.030120
	(72.1365)	(7078.85)	(3416.25)	(356.575)	(0.05067)
	[6.15961]	[1.73085]	[0.10745]	[-4.42880]	[0.59442]
FEB	-1285.809	-13319.42	-7957.426	1629.663	0.104261
	(113.926)	(11179.7)	(5395.33)	(563.144)	(0.08002)
	[-11.2863]	[-1.19139]	[-1.47487]	[2.89386]	[1.30286]
MAR	785.0412	-8145.292	18918.42	2340.963	-0.075452
	(126.117)	(12376.0)	(5972.64)	(623.401)	(0.08859)
	[6.22472]	[-0.65815]	[3.16751]	[3.75515]	[-0.85172]
APR	-392.6768	-4622.007	-768.6759	400.6504	0.057571
	(87.5626)	(8592.64)	(4146.80)	(432.827)	(0.06151)
	[-4.48453]	[-0.53790]	[-0.18537]	[0.92566]	[0.93602]
MAY	-82.24361	-26529.62	23802.86	2090.541	0.096817
	(181.327)	(17793.9)	(8587.31)	(896.310)	(0.12737)
	[-0.45356]	[-1.49094]	[2.77187]	[2.33239]	[0.76013]
JUNE	-1090.902	-10830.61	-2089.638	-629.3469	0.083667
	(99.2047)	(9735.10)	(4698.15)	(490.374)	(0.06968)
	[-10.9965]	[-1.11253]	[-0.44478]	[-1.28340]	[1.20066]
JUL	-606.6927	-17552.25	-5231.127	2154.819	-0.043954
	(125.643)	(12329.5)	(5950.23)	(621.061)	(0.08826)
	[-4.82869]	[-1.42359]	[-0.87915]	[3.46957]	[-0.49803]
AUG	-666.4615	-29567.24	-19037.79	1850.988	-0.058602
	(80.3538)	(7885.23)	(3805.40)	(397.193)	(0.05644)
	[-8.29409]	[-3.74970]	[-5.00283]	[4.66017]	[-1.03825]
SEP	-1009.102	-27487.10	-12166.39	2707.439	-0.114067
	(130.759)	(12831.6)	(6192.50)	(646.349)	(0.09185)
	[-7.71726]	[-2.14215]	[-1.96470]	[4.18882]	[-1.24190]
OCT	-272.0292	-15646.71	-1287.388	2458.323	-0.219329
	(108.203)	(10618.1)	(5124.30)	(534.854)	(0.07600)
	[-2.51406]	[-1.47358]	[-0.25123]	[4.59625]	[-2.88572]

NOV	-701.3185	-9400.543	-12204.14	1607.627	-0.080288
	(86.1918)	(8458.12)	(4081.88)	(426.051)	(0.06054)
	[-8.13672]	[-1.11142]	[-2.98983]	[3.77332]	[-1.32612]
DEC	109.8968	11884.73	17344.81	2086.862	-0.065669
	(123.198)	(12089.6)	(5834.42)	(608.974)	(0.08654)
	[0.89203]	[0.98306]	[2.97284]	[3.42685]	[-0.75885]
BREAK1	-10.30722	654.6190	-966.1804	-152.8440	-0.026434
	(59.9649)	(5884.44)	(2839.82)	(296.410)	(0.04212)
	[-0.17189]	[0.11125]	[-0.34023]	[-0.51565]	[-0.62758]
BREAK2	117.3784	3431.643	20829.52	-1089.877	0.022536
	(239.584)	(23510.7)	(11346.3)	(1184.28)	(0.16829)
	[0.48993]	[0.14596]	[1.83581]	[-0.92029]	[0.13391]
BT1	0.456406	-25.06992	73.32797	5.991653	0.001007
	(2.31549)	(227.222)	(109.657)	(11.4456)	(0.00163)
	[0.19711]	[-0.11033]	[0.66870]	[0.52349]	[0.61896]
BT2	-0.585111	-10.71458	-102.7056	5.552357	-0.000122
	(1.13432)	(111.313)	(53.7194)	(5.60702)	(0.00080)
	[-0.51582]	[-0.09626]	[-1.91189]	[0.99025]	[-0.15269]
R-squared	0.985550	0.517958	0.911832	0.620102	0.247236
Adj. R-squared	0.983752	0.457991	0.900864	0.572842	0.153590
Sum sq. resids	4653140.	4.48E+10	1.04E+10	1.14E+08	2.295875
S.E. equation	149.2107	14642.25	7066.333	737.5563	0.104810
F-statistic	548.2386	8.637404	83.13385	13.12107	2.640128
Log likelihood	-1501.798	-2584.166	-2412.224	-1878.922	211.7912
Akaike AIC	12.95591	22.12853	20.67139	16.15188	-1.566027
Schwarz SC	13.35220	22.52481	21.06767	16.54816	-1.169741
Mean dependent	3.953390	-29.80085	86.40254	6.503814	0.001188
S.D. dependent	1170.572	19888.62	22442.87	1128.499	0.113923

Determinant resid covariance (dof adj.)	1.22E+24
Determinant resid covariance	6.65E+23
Log likelihood	-8147.205
Akaike information criterion	70.23055
Schwarz criterion	72.28536

TABLE 2.15: OUT OF SAMPLE FORECAST OF CHEDDAR CHEESE PRICE VIA VECM-LEVEL

Year/Month	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12
2010M01	1.582	1.545	1.621	1.653	1.676	1.718	1.742	1.811	1.842	1.781	1.772	1.757
2010M02	1.390	1.486	1.498	1.535	1.576	1.595	1.668	1.697	1.636	1.628	1.612	1.564
2010M03	1.572	1.619	1.629	1.669	1.699	1.764	1.798	1.735	1.725	1.712	1.663	1.669
2010M04	1.281	1.248	1.300	1.343	1.403	1.441	1.370	1.364	1.352	1.301	1.309	1.349
2010M05	1.426	1.469	1.522	1.572	1.609	1.543	1.536	1.524	1.472	1.480	1.520	1.570
2010M06	1.497	1.540	1.587	1.624	1.561	1.554	1.540	1.489	1.497	1.538	1.587	1.609
2010M07	1.388	1.439	1.467	1.418	1.412	1.391	1.342	1.349	1.392	1.441	1.462	1.507
2010M08	1.605	1.643	1.584	1.587	1.568	1.511	1.523	1.563	1.614	1.635	1.679	1.716
2010M09	1.668	1.604	1.607	1.589	1.535	1.544	1.585	1.636	1.657	1.701	1.737	1.801
2010M10	1.593	1.594	1.559	1.538	1.551	1.573	1.628	1.650	1.697	1.732	1.793	1.834
2010M11	1.735	1.662	1.633	1.659	1.688	1.739	1.755	1.806	1.842	1.903	1.942	1.884
2010M12	1.341	1.326	1.356	1.390	1.430	1.451	1.502	1.538	1.599	1.638	1.580	1.574
2011M01	1.479	1.450	1.501	1.512	1.539	1.610	1.632	1.696	1.732	1.676	1.672	1.659
2011M02	1.535	1.639	1.652	1.654	1.723	1.750	1.821	1.853	1.794	1.792	1.779	1.734
2011M03	2.174	2.248	2.232	2.262	2.300	2.376	2.415	2.350	2.344	2.336	2.290	2.300
2011M04	1.808	1.809	1.856	1.895	1.956	2.001	1.938	1.932	1.923	1.876	1.887	1.931
2011M05	1.501	1.609	1.635	1.711	1.751	1.676	1.681	1.669	1.623	1.634	1.676	1.731
2011M06	1.798	1.764	1.822	1.891	1.825	1.820	1.802	1.759	1.773	1.815	1.869	1.893
2011M07	2.116	2.106	2.168	2.120	2.122	2.101	2.050	2.067	2.112	2.164	2.189	2.237
2011M08	2.048	2.122	2.068	2.080	2.064	2.002	2.023	2.067	2.121	2.145	2.192	2.233
2011M09	1.951	1.891	1.897	1.909	1.846	1.854	1.901	1.955	1.982	2.027	2.067	2.135
2011M10	1.621	1.582	1.587	1.551	1.562	1.602	1.651	1.682	1.729	1.768	1.835	1.876
2011M11	1.737	1.713	1.681	1.689	1.729	1.784	1.810	1.858	1.897	1.964	2.006	1.952
2011M12	1.923	1.853	1.854	1.889	1.953	1.983	2.024	2.065	2.131	2.175	2.121	2.116
2012M01	1.488	1.536	1.585	1.634	1.657	1.702	1.748	1.812	1.854	1.800	1.796	1.791
2012M02	1.586	1.661	1.695	1.730	1.774	1.812	1.882	1.922	1.869	1.865	1.859	1.817

2012M03	1.484	1.496	1.534	1.602	1.633	1.699	1.737	1.686	1.685	1.676	1.634	1.647
2012M04	1.564	1.555	1.626	1.653	1.728	1.770	1.710	1.712	1.703	1.661	1.675	1.723
2012M05	1.537	1.685	1.704	1.751	1.794	1.738	1.749	1.734	1.689	1.706	1.753	1.811
2012M06	1.755	1.813	1.858	1.869	1.815	1.837	1.825	1.776	1.789	1.839	1.898	1.925
2012M07	1.610	1.722	1.719	1.674	1.693	1.669	1.633	1.642	1.693	1.751	1.777	1.831
2012M08	1.791	1.801	1.742	1.768	1.749	1.705	1.717	1.767	1.826	1.852	1.905	1.947
2012M09	1.752	1.650	1.668	1.691	1.646	1.644	1.692	1.754	1.785	1.835	1.876	1.948
2012M10	1.808	1.764	1.779	1.758	1.766	1.805	1.860	1.895	1.948	1.988	2.058	2.104
2012M11	2.047	1.957	1.925	1.972	2.017	2.066	2.088	2.147	2.191	2.260	2.305	2.254
2012M12	1.741	1.679	1.728	1.796	1.842	1.859	1.914	1.962	2.032	2.076	2.024	2.026
2013M01	1.645	1.636	1.712	1.769	1.793	1.846	1.885	1.960	2.005	1.953	1.954	1.951
2013M02	1.734	1.813	1.863	1.883	1.936	1.978	2.053	2.097	2.044	2.046	2.043	2.004
2013M03	1.736	1.852	1.862	1.896	1.940	2.015	2.067	2.010	2.009	2.009	1.969	1.987
2013M04	1.713	1.684	1.727	1.778	1.852	1.907	1.843	1.846	1.846	1.805	1.824	1.874
2013M05	1.825	1.898	1.941	2.011	2.065	2.000	2.007	2.005	1.964	1.983	2.032	2.094
2013M06	1.911	1.970	2.039	2.080	2.016	2.028	2.026	1.984	2.001	2.052	2.114	2.146
2013M07	1.731	1.876	1.911	1.843	1.845	1.841	1.811	1.824	1.873	1.935	1.967	2.024
2013M08	1.876	1.903	1.826	1.825	1.828	1.799	1.809	1.859	1.920	1.954	2.010	2.054
2013M09	1.719	1.614	1.604	1.634	1.603	1.607	1.655	1.718	1.754	1.808	1.852	1.927
2013M10	1.705	1.760	1.789	1.737	1.743	1.788	1.861	1.893	1.945	1.991	2.065	2.116
2013M11	1.829	1.786	1.719	1.764	1.816	1.878	1.902	1.959	2.009	2.081	2.131	2.082
2013M12	1.808	1.725	1.781	1.829	1.889	1.917	1.971	2.022	2.094	2.144	2.095	2.100

TABLE 2.16: VECM DIFFERENCE FORECAST ESTIMATES

Cointegration Restrictions:
B(1,5)=0
Convergence achieved after 73 iterations.
Not all cointegrating vectors are identified
LR test for binding restrictions (rank = 1):

Chi-square(1)	4.372198
Probability	0.036530

Cointegrating Eq:	CointEq1
D(SUPPLY(-1))	0.010456
D(STOCK(-1))	2.38E-06
D(PROD(-1))	0.000166
D(EXPORT(-1))	-0.002177
D(PRNEW(-1))	0.000000
C	-0.027730

Error Correction:	D(SUPPLY,2)	D(STOCK,2)	D(PROD,2)	D(EXPORT,2)	D(PRNEW,2)
CointEq1	-66.34384	1546.174	-3032.361	222.8625	-0.026924
	(10.1139)	(968.776)	(486.550)	(45.2504)	(0.00682)
	[-6.55965]	[1.59601]	[-6.23238]	[4.92510]	[-3.95007]
D(SUPPLY(-1),2)	-0.596052	-11.71473	24.56467	-2.538766	0.000118
	(0.10668)	(10.2186)	(5.13210)	(0.47730)	(7.2E-05)
	[-5.58723]	[-1.14641]	[4.78648]	[-5.31903]	[1.64334]
D(SUPPLY(-2),2)	-0.287849	-0.360120	7.420803	-1.571764	2.07E-05
	(0.08551)	(8.19047)	(4.11351)	(0.38257)	(5.8E-05)
	[-3.36636]	[-0.04397]	[1.80401]	[-4.10847]	[0.35847]
D(STOCK(-1),2)	0.002818	-0.533644	0.086702	0.003048	-7.32E-07
	(0.00071)	(0.06784)	(0.03407)	(0.00317)	(4.8E-07)
	[3.97913]	[-7.86581]	[2.54459]	[0.96187]	[-1.53365]
D(STOCK(-2),2)	0.001043	-0.347437	-0.034363	0.003168	-5.00E-08
	(0.00074)	(0.07046)	(0.03539)	(0.00329)	(5.0E-07)
	[1.41727]	[-4.93108]	[-0.97109]	[0.96265]	[-0.10081]
D(PROD(-1),2)	0.010994	0.225841	-0.334990	-0.009422	3.32E-06
	(0.00169)	(0.16177)	(0.08124)	(0.00756)	(1.1E-06)
	[6.50958]	[1.39610]	[-4.12325]	[-1.24700]	[2.91388]
D(PROD(-2),2)	0.005819	0.149469	-0.223129	-0.001787	1.64E-06
	(0.00146)	(0.14003)	(0.07033)	(0.00654)	(9.9E-07)
	[3.98038]	[1.06737]	[-3.17262]	[-0.27313]	[1.66411]
D(EXPORT(-1),2)	-0.088258	2.325310	-3.975148	-0.560386	-3.43E-05

	(0.02062)	(1.97485)	(0.99183)	(0.09224)	(1.4E-05)
	[-4.28080]	[1.17746]	[-4.00789]	[-6.07511]	[-2.47054]
D(EXPORT(-2),2)	-0.007879	0.069138	-1.358531	-0.227804	-2.37E-05
	(0.01458)	(1.39679)	(0.70151)	(0.06524)	(9.8E-06)
	[-0.54029]	[0.04950]	[-1.93658]	[-3.49167]	[-2.40690]
D(PRNEW(-1),2)	-7.257724	19297.72	2562.593	-1249.982	0.131475
	(103.416)	(9905.81)	(4975.00)	(462.688)	(0.06969)
	[-0.07018]	[1.94812]	[0.51509]	[-2.70156]	[1.88645]
D(PRNEW(-2),2)	30.96259	3090.960	-10820.67	167.2506	-0.130350
	(102.857)	(9852.30)	(4948.13)	(460.189)	(0.06932)
	[0.30103]	[0.31373]	[-2.18682]	[0.36344]	[-1.88047]
C	441.2717	9430.645	-4688.110	-1231.611	0.062890
	(74.9143)	(7175.77)	(3603.90)	(335.172)	(0.05049)
	[5.89035]	[1.31423]	[-1.30084]	[-3.67457]	[1.24567]
FEB	-1345.376	-11417.56	-5223.337	1106.370	0.082023
	(118.829)	(11382.2)	(5716.48)	(531.647)	(0.08008)
	[-11.3220]	[-1.00311]	[-0.91373]	[2.08102]	[1.02424]
MAR	621.9757	-2202.807	27486.74	846.7773	-0.145274
	(146.473)	(14030.1)	(7046.35)	(655.328)	(0.09871)
	[4.24636]	[-0.15701]	[3.90085]	[1.29214]	[-1.47170]
APR	-193.5703	-8413.274	-4095.045	1640.293	0.104268
	(105.118)	(10068.9)	(5056.91)	(470.306)	(0.07084)
	[-1.84145]	[-0.83557]	[-0.80979]	[3.48771]	[1.47184]
MAY	-251.7576	-20733.05	29908.80	893.4624	0.024965
	(195.221)	(18699.5)	(9391.46)	(873.430)	(0.13156)
	[-1.28960]	[-1.10875]	[3.18468]	[1.02293]	[0.18976]
JUNE	-1218.434	-11756.26	-3865.249	-1291.714	0.096304
	(102.140)	(9783.58)	(4913.62)	(456.979)	(0.06883)
	[-11.9291]	[-1.20163]	[-0.78664]	[-2.82664]	[1.39908]
JUL	-681.2425	-11794.25	3643.331	1147.491	-0.111993
	(137.471)	(13167.8)	(6613.28)	(615.052)	(0.09264)
	[-4.95555]	[-0.89569]	[0.55091]	[1.86568]	[-1.20885]
AUG	-577.1586	-27798.51	-13522.85	1841.442	-0.076506
	(78.2321)	(7493.58)	(3763.51)	(350.016)	(0.05272)
	[-7.37751]	[-3.70965]	[-3.59315]	[5.26103]	[-1.45111]
SEP	-876.9457	-23348.76	-3132.196	2763.656	-0.161419
	(127.916)	(12252.6)	(6153.65)	(572.306)	(0.08621)
	[-6.85562]	[-1.90561]	[-0.50900]	[4.82899]	[-1.87248]
OCT	-218.0441	-10615.80	8387.239	2047.108	-0.277405
	(109.052)	(10445.7)	(5246.14)	(487.904)	(0.07349)
	[-1.99946]	[-1.01629]	[1.59875]	[4.19572]	[-3.77460]
NOV	-548.9303	-7500.298	-7404.632	2114.207	-0.102415
	(84.1991)	(8065.13)	(4050.56)	(376.712)	(0.05674)

	[-6.51943]	[-0.92997]	[-1.82805]	[5.61226]	[-1.80486]
DEC	72.28157	17694.58	26027.73	1345.556	-0.135415
	(131.641)	(12609.4)	(6332.82)	(588.969)	(0.08872)
	[0.54908]	[1.40329]	[4.10997]	[2.28460]	[-1.52639]
BREAK1	-22.06530	802.2925	-1357.551	-150.8263	-0.029093
	(61.2488)	(5866.81)	(2946.49)	(274.031)	(0.04128)
	[-0.36026]	[0.13675]	[-0.46073]	[-0.55040]	[-0.70482]
BREAK2	229.3042	-1632.244	13825.24	-29.11676	0.082999
	(250.226)	(23968.2)	(12037.6)	(1119.53)	(0.16863)
	[0.91639]	[-0.06810]	[1.14851]	[-0.02601]	[0.49218]
BT1	0.795239	-27.01846	83.36157	6.411987	0.001047
	(2.36508)	(226.542)	(113.777)	(10.5815)	(0.00159)
	[0.33624]	[-0.11926]	[0.73268]	[0.60596]	[0.65703]
BT2	-1.100440	13.72200	-65.59879	0.110318	-0.000408
	(1.18702)	(113.700)	(57.1036)	(5.31078)	(0.00080)
	[-0.92706]	[0.12069]	[-1.14877]	[0.02077]	[-0.51014]
R-squared	0.984990	0.522923	0.904843	0.670412	0.279073
Adj. R-squared	0.983113	0.463288	0.892949	0.629214	0.188957
Sum sq. resids	4833372.	4.43E+10	1.12E+10	96750876	2.195194
S.E. equation	152.4381	14601.50	7333.324	682.0179	0.102732
F-statistic	524.9673	8.768772	76.07191	16.27274	3.096825
Log likelihood	-1500.398	-2572.497	-2410.653	-1852.498	215.6640
Akaike AIC	12.99913	22.12338	20.74599	15.99573	-1.605651
Schwarz SC	13.39662	22.52086	21.14347	16.39321	-1.208167
Mean dependent	3.736170	-24.29787	-34.77872	-3.654894	0.000889
S.D. dependent	1173.066	19930.89	22413.26	1120.041	0.114073

Determinant resid covariance (dof adj.)	1.07E+24
Determinant resid covariance	5.84E+23
Log likelihood	-8097.270
Akaike information criterion	70.10442
Schwarz criterion	72.16545

TABLE 2.17: OUT OF SAMPLE FORECAST OF CHEDDAR CHEESE PRICE VIA VECM-DIFFERENCE

Year/Month	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12
2010M01	1.7583	1.9272	2.1788	2.4484	2.688	2.9543	3.2368	3.5595	3.8669	4.0918	4.3802	4.6808
2010M02	1.2618	1.2032	1.0797	0.9617	0.8615	0.7388	0.6646	0.5501	0.3448	0.1914	0.0316	-0.1609
2010M03	1.6346	1.7679	1.8994	2.0335	2.1563	2.3252	2.4556	2.4938	2.5826	2.6673	2.718	2.823
2010M04	1.0066	0.6357	0.3065	-0.0196	-0.3158	-0.6387	-1.0667	-1.4373	-1.8103	-2.2214	-2.5753	-2.8958
2010M05	1.5633	1.7841	2.0056	2.235	2.4413	2.5435	2.7092	2.8685	2.9884	3.1669	3.3785	3.6
2010M06	1.5129	1.5832	1.6486	1.7005	1.6527	1.6638	1.668	1.6336	1.6579	1.7159	1.7831	1.8221
2010M07	1.2874	1.1869	1.0669	0.8603	0.7115	0.5486	0.3504	0.2105	0.1055	0.009	-0.1164	-0.2183
2010M08	1.7712	1.9749	2.0915	2.2608	2.4169	2.5366	2.7173	2.9313	3.154	3.3478	3.565	3.7736
2010M09	1.7004	1.6615	1.6846	1.6865	1.6532	1.6865	1.7485	1.8209	1.8635	1.9298	1.988	2.0729
2010M10	1.6621	1.6527	1.6049	1.5541	1.5696	1.5979	1.6418	1.6555	1.6962	1.7273	1.7833	1.8163
2010M11	1.867	1.9342	2.0085	2.1296	2.2665	2.4329	2.5598	2.7159	2.8604	3.0309	3.1799	3.2299
2010M12	1.0676	0.7317	0.4543	0.1853	-0.0719	-0.3603	-0.6134	-0.881	-1.124	-1.3893	-1.7519	-2.0617
2011M01	1.5185	1.6425	1.7877	1.9096	2.0184	2.1782	2.3075	2.4656	2.5985	2.637	2.7293	2.8145
2011M02	1.5705	1.7594	1.9108	2.0526	2.2363	2.3759	2.5651	2.7215	2.7838	2.8995	3.0067	3.0817
2011M03	2.545	3.1544	3.7343	4.3425	4.9196	5.5456	6.1394	6.6371	7.1868	7.7308	8.2417	8.8073
2011M04	1.4462	1.0071	0.631	0.2634	-0.08	-0.4554	-0.9322	-1.3509	-1.7718	-2.2316	-2.6349	-3.0037
2011M05	1.2974	1.0978	0.8764	0.6927	0.4877	0.1628	-0.0942	-0.3565	-0.6566	-0.8989	-1.1096	-1.3095
2011M06	1.982	2.1365	2.3237	2.5035	2.5766	2.7215	2.8428	2.933	3.0831	3.2645	3.4569	3.619
2011M07	2.4173	2.7599	3.1063	3.3357	3.6331	3.9137	4.1618	4.4695	4.8081	5.1574	5.4773	5.8212
2011M08	2.0476	2.0632	1.9631	1.9233	1.8649	1.7659	1.7385	1.7385	1.7478	1.7284	1.732	1.7282
2011M09	1.8753	1.6446	1.473	1.3017	1.0837	0.9351	0.8129	0.701	0.5624	0.445	0.3203	0.222
2011M10	1.4259	1.1164	0.8065	0.4487	0.1648	-0.0865	-0.3362	-0.6094	-0.8624	-1.1217	-1.354	-1.6125
2011M11	1.8392	1.9702	2.0642	2.2022	2.3691	2.5506	2.7093	2.8856	3.0534	3.249	3.4199	3.4952
2011M12	2.0578	2.1975	2.3706	2.571	2.7952	2.9948	3.2097	3.4167	3.651	3.8621	3.9769	4.1413
2012M01	1.1817	0.8648	0.5963	0.3403	0.0444	-0.2368	-0.5133	-0.7664	-1.044	-1.419	-1.7437	-2.0688
2012M02	1.6529	1.7779	1.8878	1.9841	2.1017	2.2115	2.346	2.4558	2.4712	2.5363	2.5993	2.6247

2012M03	1.3772	1.2128	1.0517	0.9241	0.7823	0.6693	0.524	0.2883	0.1037	-0.0851	-0.3104	-0.4796
2012M04	1.5996	1.6588	1.751	1.8016	1.8965	1.9676	1.9405	1.9658	1.9841	1.9691	2.0103	2.0856
2012M05	1.4766	1.6067	1.6846	1.7824	1.8487	1.8163	1.8547	1.8773	1.8636	1.9081	1.9863	2.0747
2012M06	1.7416	1.869	2.0232	2.1419	2.1632	2.2624	2.3384	2.3806	2.4806	2.6143	2.7592	2.8734
2012M07	1.4863	1.3954	1.2564	1.0614	0.9395	0.7715	0.58	0.4455	0.349	0.2609	0.1397	0.0453
2012M08	1.8666	1.9456	1.968	2.0618	2.1172	2.1535	2.2378	2.363	2.4966	2.5977	2.7259	2.8426
2012M09	1.7869	1.6364	1.5622	1.4856	1.3824	1.3211	1.2959	1.2831	1.2419	1.2241	1.1949	1.1949
2012M10	1.9805	2.0941	2.206	2.2726	2.393	2.5541	2.7222	2.8631	3.0255	3.1787	3.3611	3.5176
2012M11	2.3145	2.5078	2.6531	2.8669	3.1184	3.3792	3.6072	3.8587	4.1027	4.3746	4.6211	4.7706
2012M12	1.6013	1.3229	1.1262	0.9498	0.7742	0.5674	0.3936	0.209	0.0499	-0.134	-0.4147	-0.6424
2013M01	1.6486	1.6058	1.5897	1.5631	1.5148	1.5017	1.4722	1.4702	1.4427	1.3194	1.2491	1.1739
2013M02	1.7862	1.9625	2.1133	2.2276	2.3701	2.5025	2.6707	2.8076	2.8468	2.9403	3.0296	3.0828
2013M03	1.6435	1.683	1.6823	1.6948	1.699	1.7361	1.7504	1.6635	1.6288	1.5917	1.5177	1.5011
2013M04	1.6016	1.4335	1.2984	1.1803	1.0925	0.9845	0.7602	0.5959	0.4324	0.2288	0.0836	-0.0298
2013M05	1.9339	2.1483	2.3622	2.5951	2.8077	2.8999	3.0643	3.2232	3.3411	3.5187	3.7273	3.9473
2013M06	1.8917	1.9633	2.061	2.1308	2.0814	2.1099	2.1284	2.1075	2.145	2.2143	2.2955	2.3478
2013M07	1.5337	1.4394	1.3114	1.0741	0.9038	0.717	0.5019	0.3416	0.2137	0.0966	-0.0497	-0.172
2013M08	1.8521	1.8797	1.7952	1.7777	1.7608	1.7184	1.7162	1.7518	1.7983	1.8169	1.8593	1.8897
2013M09	1.5929	1.3037	1.082	0.8903	0.6649	0.473	0.3188	0.1774	0.0111	-0.1342	-0.2917	-0.419
2013M10	1.7829	1.9288	2.1131	2.216	2.3558	2.537	2.7433	2.9181	3.1098	3.2921	3.5045	3.6935
2013M11	1.933	1.9587	1.8894	1.9172	1.99	2.0795	2.1202	2.1868	2.25	2.3401	2.406	2.3719
2013M12	1.8268	1.7663	1.8281	1.8923	1.966	2.0052	2.0751	2.138	2.2238	2.2867	2.2514	2.2693

TABLE 2.18: CALCULATED-MONTHLY RMSE FOR AR, VAR, AND VECM

	RMSE-ARlevel	RMSE-ARdiff	RMSE-VARlevel	RMSE-VARdif	RMSE-VECMlevel	RMSE-VECMdif	RMSE-Futures
1monthahead	0.134[1]	0.055[2]	0.152	0.151	0.162	0.238	0.119
2monthahead	0.153	0.103	0.153	0.160	0.189	0.413	0.160
3monthahead	0.171	0.136	0.156	0.163	0.197	0.591	0.177
4monthahead	0.190	0.169	0.172	0.179	0.205	0.776	0.184
5monthahead	0.208	0.205	0.185	0.197	0.219	0.956	0.196
6monthahead	0.224	0.242	0.196	0.213	0.233	1.143	0.199
7monthahead	0.237	0.279	0.198	0.220	0.240	1.336	0.196
8monthahead	0.248	0.317	0.195	0.224	0.238	1.519	0.196
9monthahead	0.256	0.354	0.189	0.230	0.239	1.704	0.195
10monthahead	0.263	0.392	0.178	0.232	0.240	1.896	0.145
11monthahead	0.268	0.430	0.167	0.232	0.239	2.086	0.118
12monthahead	0.272	0.468	0.163	0.236	0.244	2.266	0.098

[1].Green indicates the lowest RMSE among level forecasting methods, which leads to best forecasting methods.
[2].Purple indicates the lowest RMSE among difference forecasting methods, which leads to best forecasting methods.

TABLE 2.19: DIEBOLD-MARIANO TEST FOR STATISTICAL SIGNIFICANCE BETWEEN FORECASTED MODELS

Forecast Model Comparisons		D-Absolute Loss		
Level		Coefficient	Standard Error	P-Value
Month=10, OCT				
Vector Autoregression	Autoregressive	-0.062	0.027	0.0277
Vector Autoregression	Vector Error Correction	-0.1486	0.0217	0.008
Month=12, Dec				
Vector Autoregression	Autoregressive	-0.047	0.017	0.011
Vector Autoregression	Vector Error Correction	0.038	0.01	0.0005
Month=2, February				
Autoregressive	Vector Autoregression	0.0026	0.0121	0.829
Autoregressive	Vector Error Correction	0.019	0.015	0.218
Difference				
Month=2, February				
Autoregressive	Vector Autoregression	0.047	0.015	0.0037
Autoregressive	Vector Error Correction	0.18	0.030	0

TABLE 2.20: PAIRWISE GRANGER CAUSALITY TEST

Null Hypothesis	F-Statistic	P-Value
Prod $\nrightarrow$ Price	4.86	0.008
Price $\nrightarrow$ Prod	1.6	0.203
Stock $\nrightarrow$ Price	5.23	0.0059
Price $\nrightarrow$ Stock	0.44	0.64
Supply $\nrightarrow$ Price	8.16	0.0004
Price $\nrightarrow$ Supply	0.301	0.74
Stock $\nrightarrow$ Prod	1.41	0.24
Prod $\nrightarrow$ Stock	42.75	6.00E-17
Supply $\nrightarrow$ Prod	17.72	6.00E-08
Prod $\nrightarrow$ Supply	7.064	0.001
Supply $\nrightarrow$ Stock	16.02	3.00E-07
Stock $\nrightarrow$ Supply	1.42	0.24
Export $\nrightarrow$ Supply	7.52	0.0007
Supply $\nrightarrow$ Export	1.91	0.149
Export $\nrightarrow$ Stock	4.163	0.0165
Stock $\nrightarrow$ Export	0.77	0.461
Export $\nrightarrow$ Prod	4.09	0.017
Prod $\nrightarrow$ Export	2.25	0.106
Price $\nrightarrow$ Export	4.94	0.007
Export $\nrightarrow$ Price	9.63	9.00E-05

FIGURES

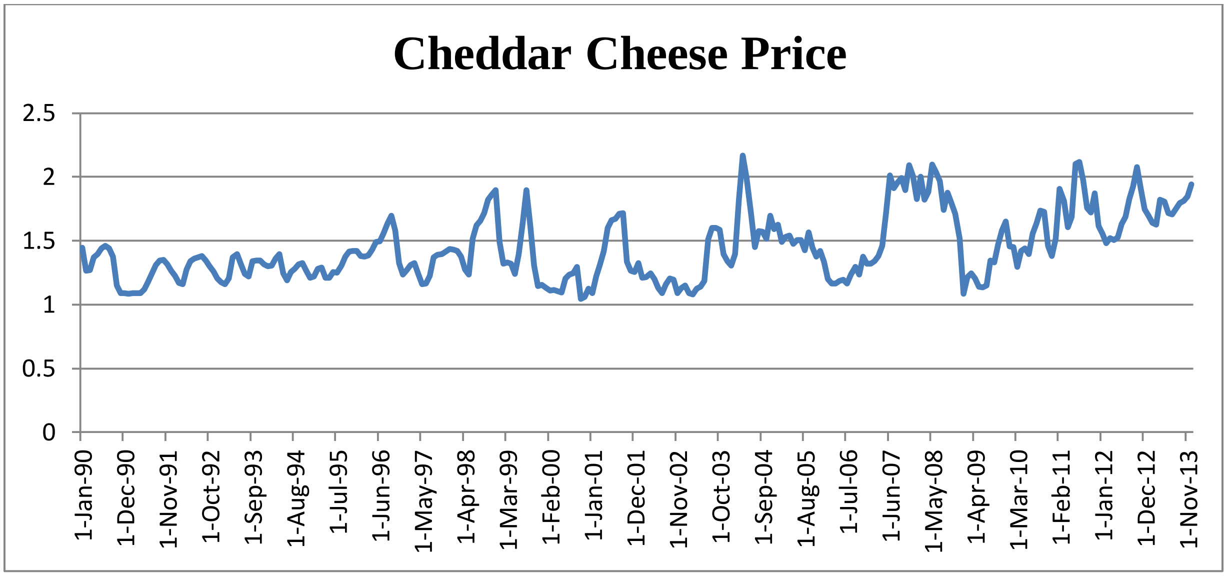


FIGURE 2.1: CHEDDAR CHEESE SPOT PRICE TREND 1990-2013

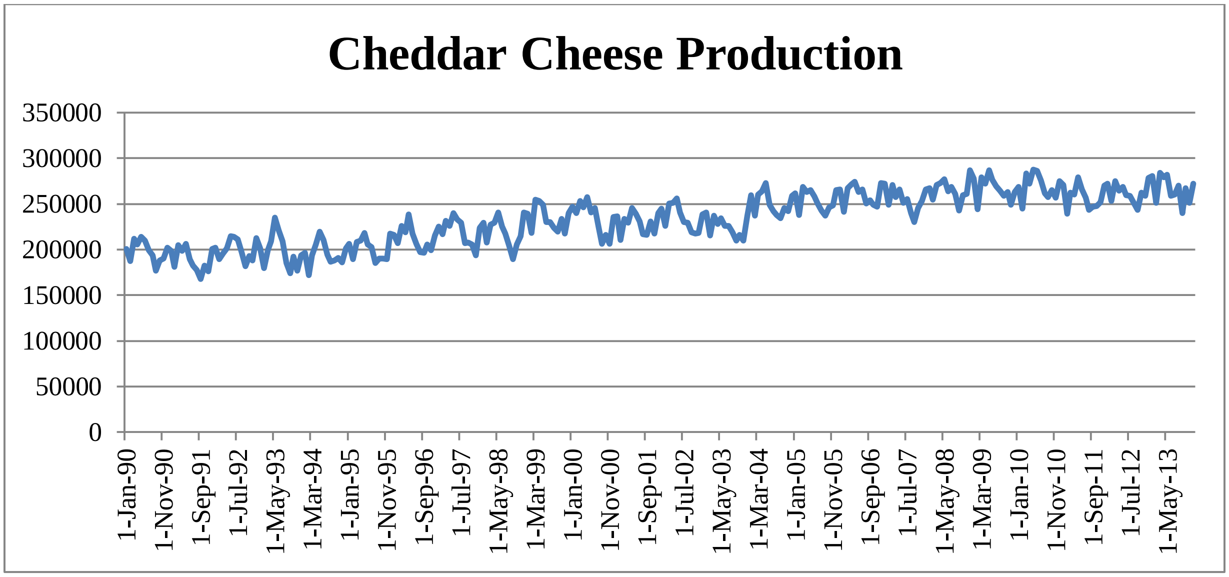


FIGURE 2.2: CHEDDAR CHEESE PRODUCTION TREND 1990-2013

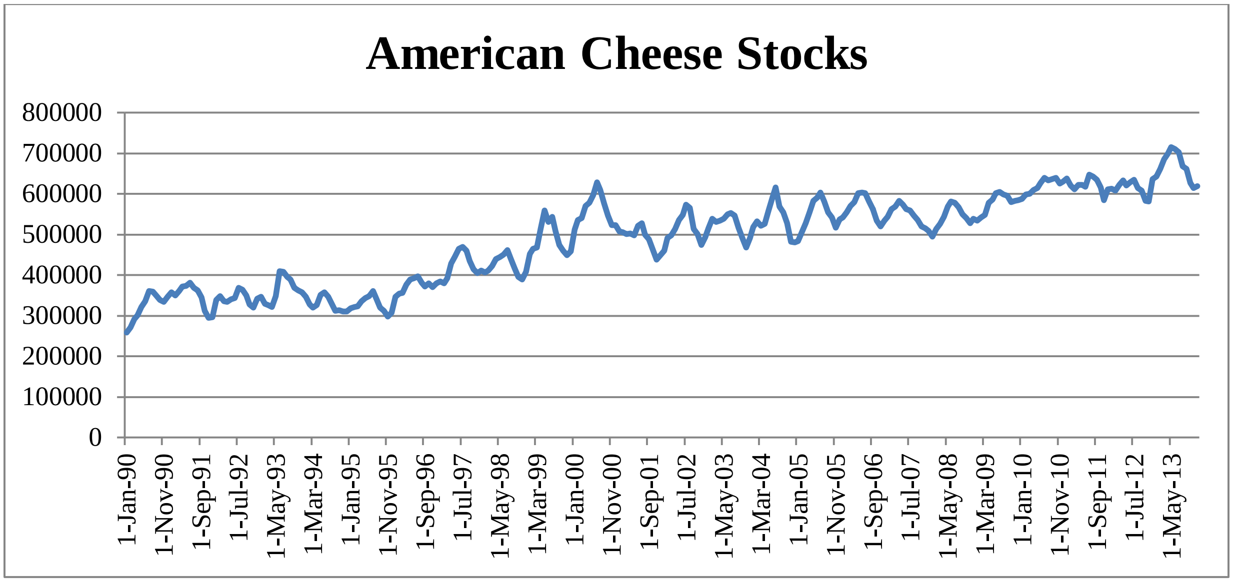


FIGURE 2.3: AMERICAN CHEESE STOCKS TREND 1990-2013

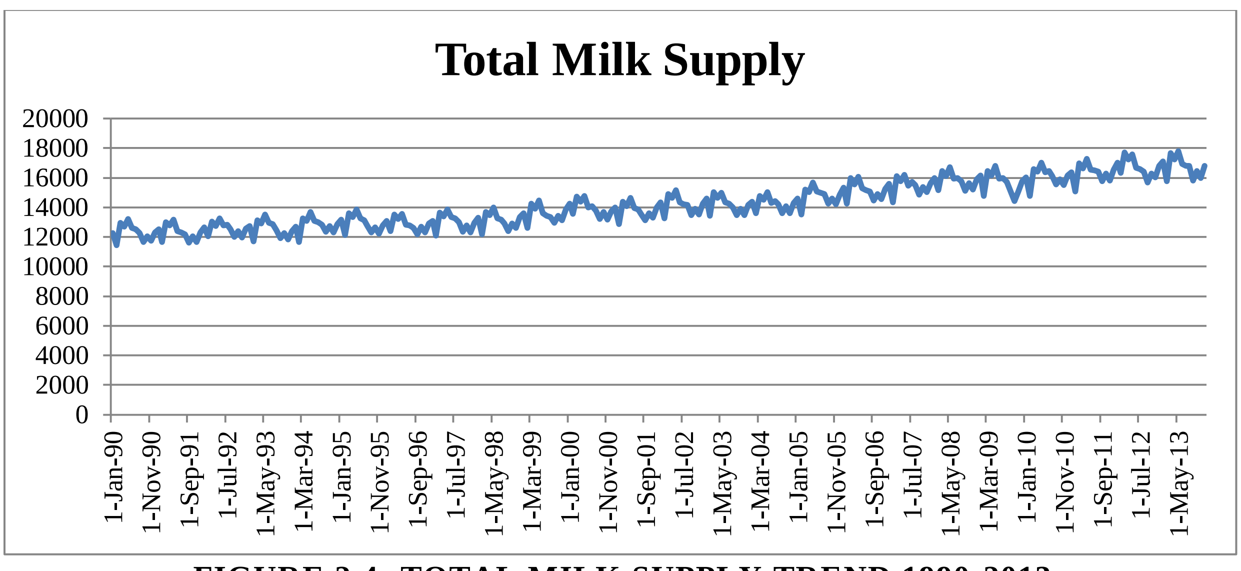


FIGURE 2.4: TOTAL MILK SUPPLY TREND 1990-2013

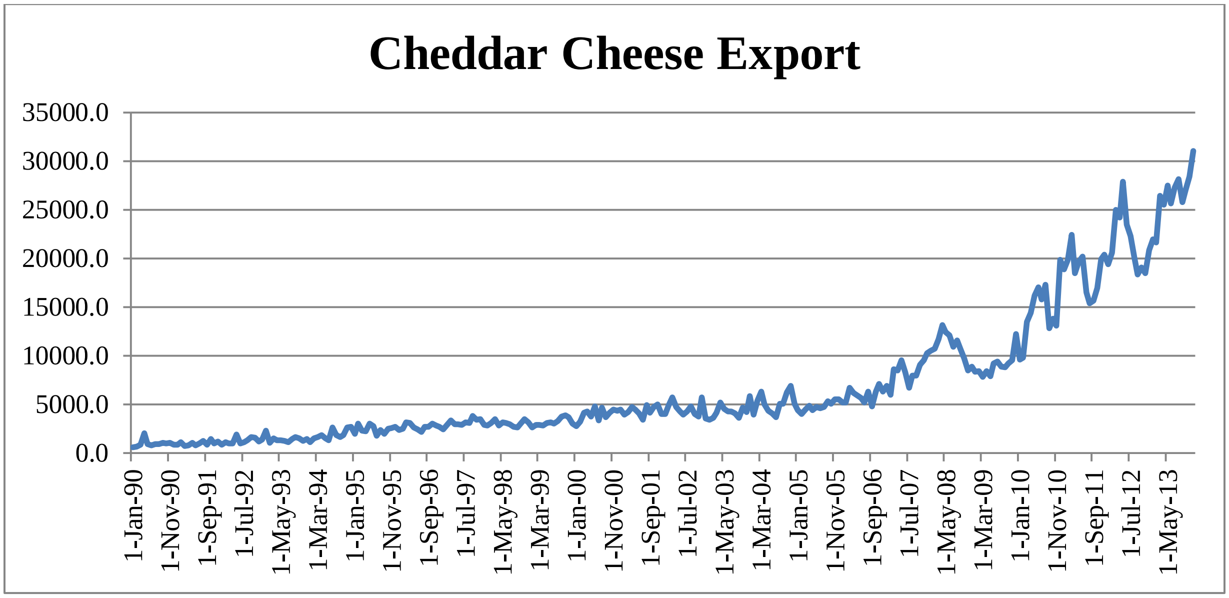


FIGURE 2.5: CHEDDAR CHEESE EXPORT TREND 1990-2013

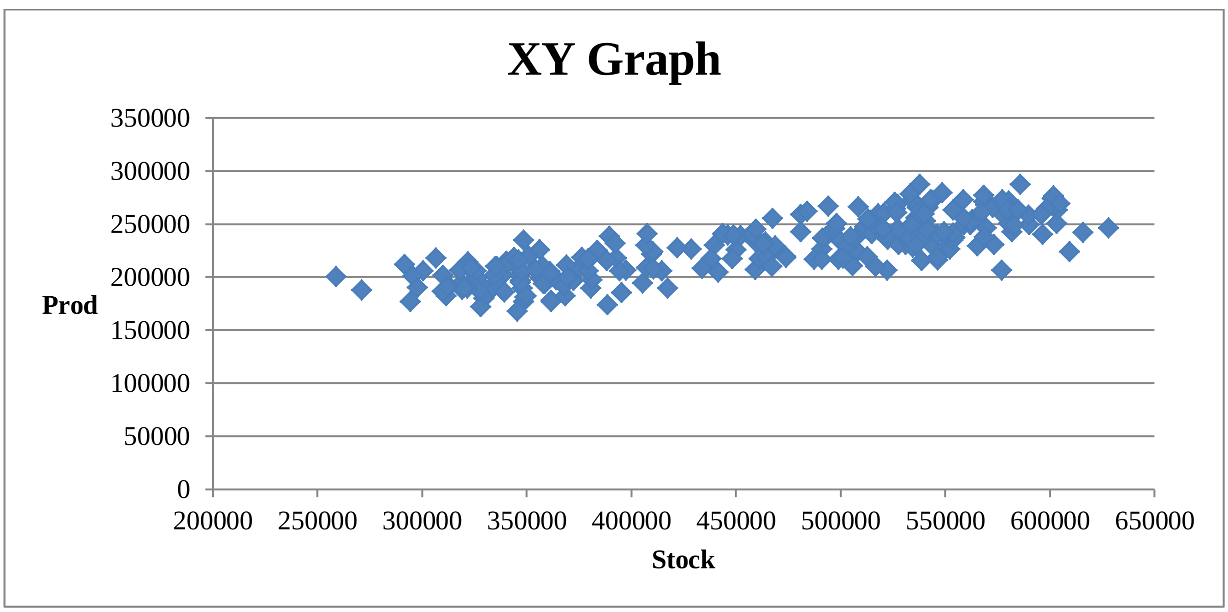


FIGURE 2.6: CHEDDAR CHEESE PRODUCTION VS. AMERICAN CHEESE STOCKS

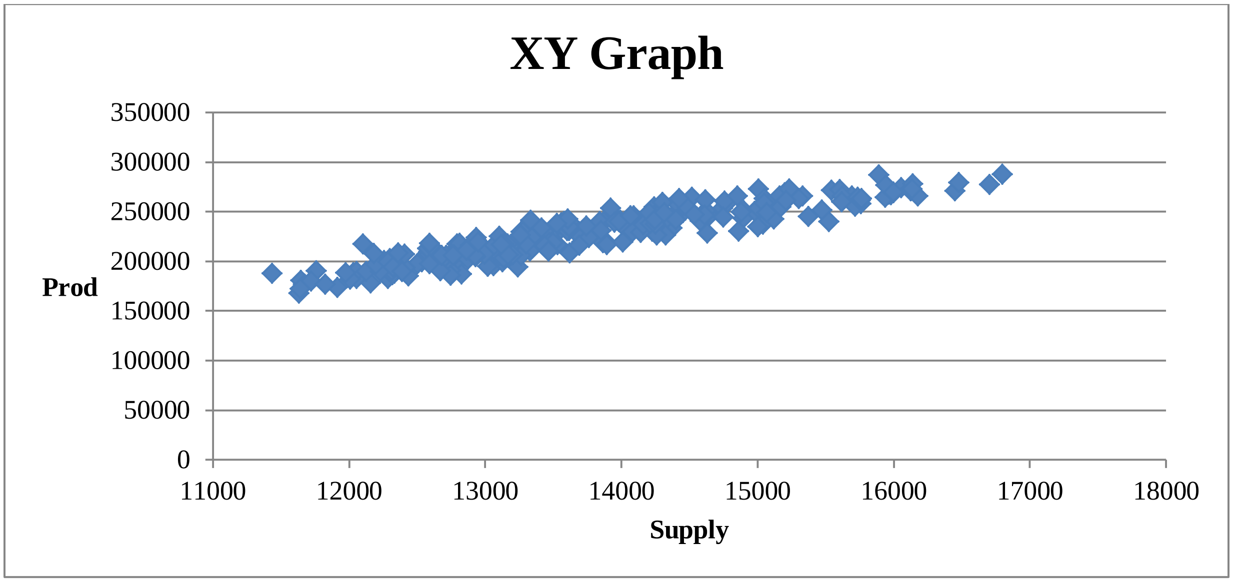


FIGURE 2.7: PRODUCTION OF CHEDDAR CHEESE VS TOTAL MILK SUPPLY

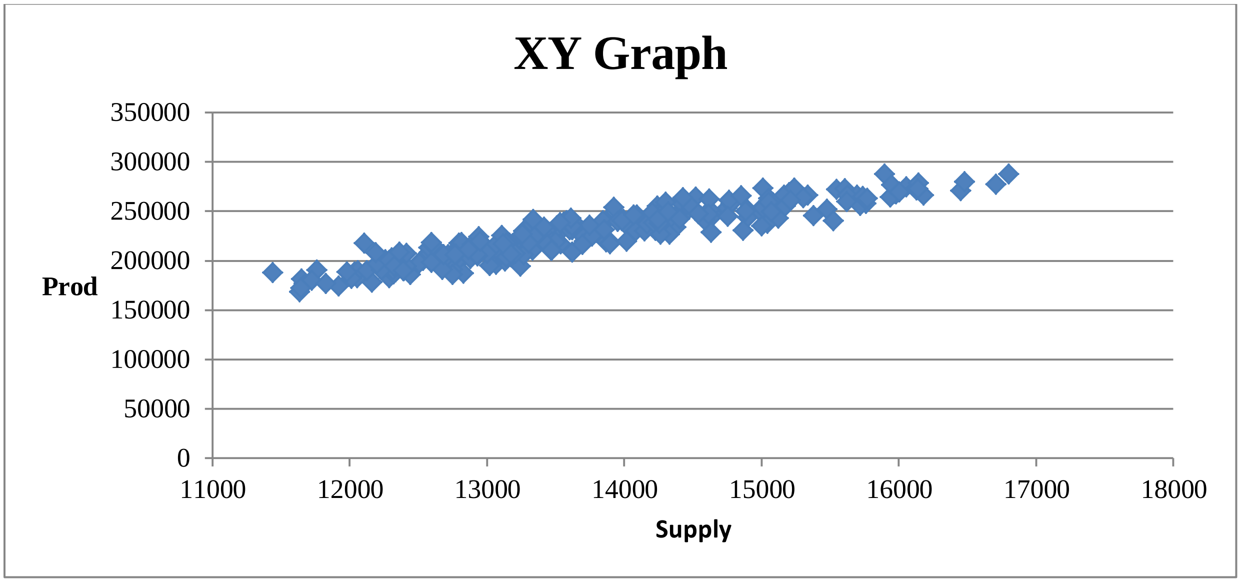


FIGURE 2.8: CHEDDAR CHEESE PRODUCTION VS TOTAL MILK SUPPLY

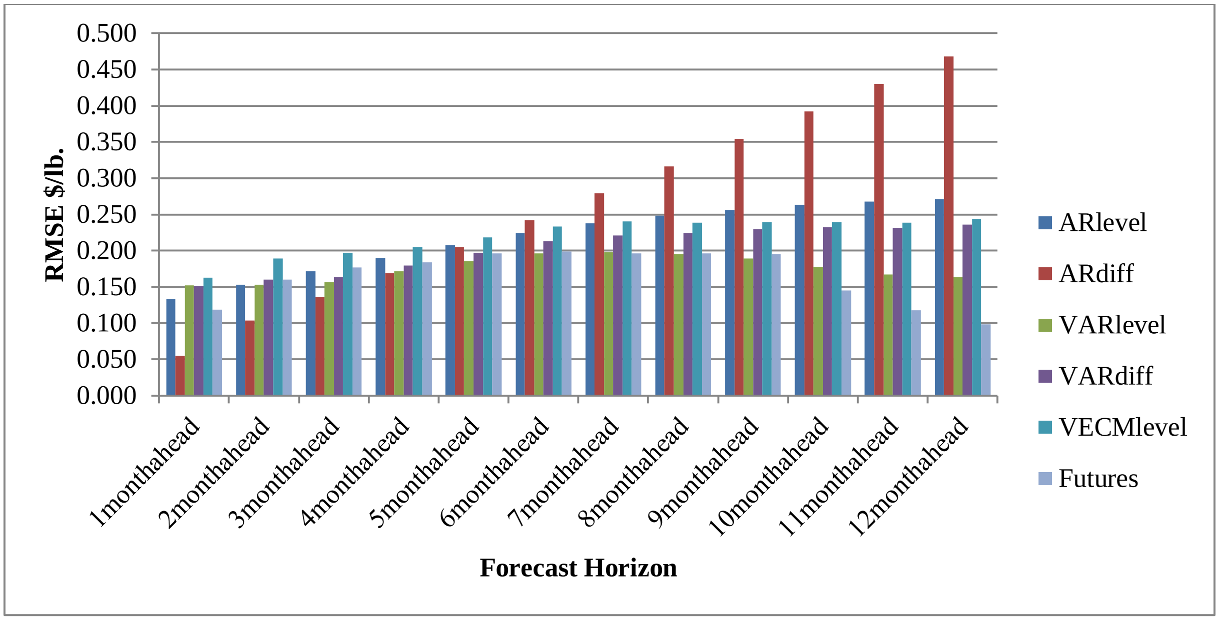


FIGURE 2.9: RMSE GRAPH FOR DIFFERENT FORECASTING METHODS OVER FORECAST HORIZON

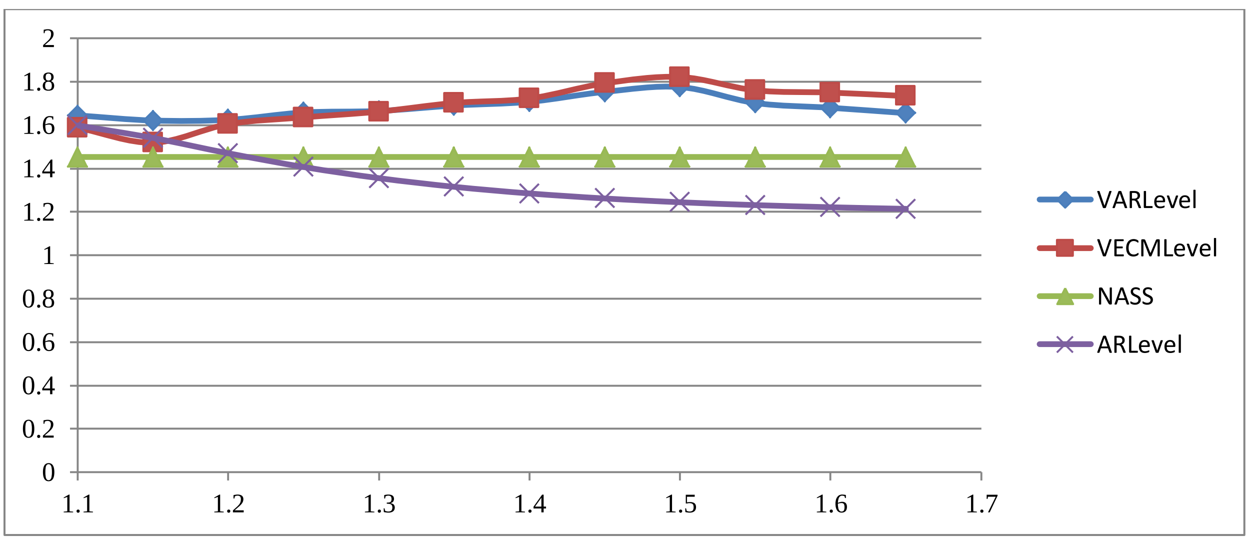


FIGURE 2.10: FORECASTED CHEDDAR CHEESE PRICE LEVELS FOR JANUARY 2010 VS. USDA NASS

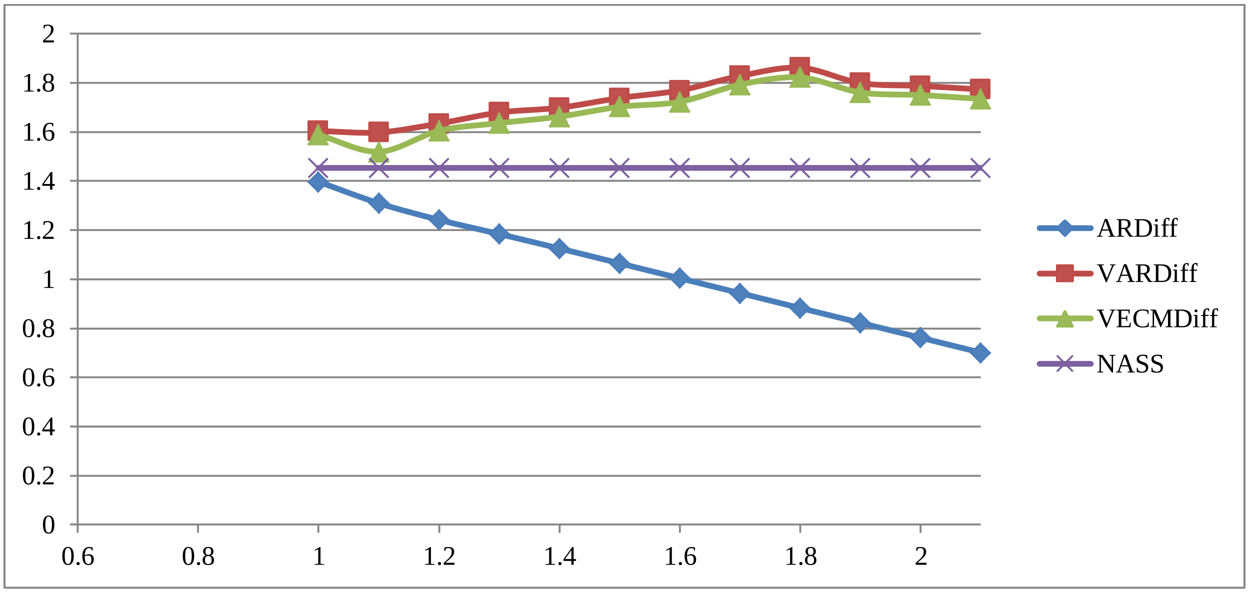


FIGURE 2.11: FORECASTED CHEDDAR CHEESE PRICE DIFFERENCES FOR JANUARY 2010 V.S. USDA NASS

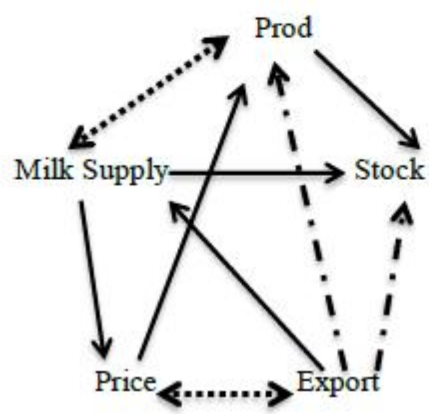


FIGURE 2.12.GRANGER CAUSALITY GRAPH OF MONTHLY RELATIONSHIP AMONG VARIBLES OF MODEL[3]

[3]. The solid arrows indicate one-way relationship at a 99% confidence interval , the dash arrows show mutual relationship among the variables of the model, and the dash and dot arrows indicate one-way relationships at 98% confidence intervals.

CHAPTER THREE
Non-Market Benefits of Reducing Environmental Effects of Potential Wildfires in Beetle Killed Trees: A Contingent Valuation Study

I. INTRODUCTION

Problem Statement

In the last few years, the Mountain pine beetle invasion of lodge pole pine forests in the intermountain USA has left 21.7 millions of acres of dead trees since 1996. In particular, one of the contributing factors to the intensity and rapid spread of fires in the summer of 2012 in Colorado is that the region contained 70 percent beetle-killed pine trees. The High Park Fire near Fort Collins, Colorado burned an estimated 87,250 acres. The Waldo Canyon fire near Colorado Springs, Colorado burned 18,247 acres. Table 3.1 shows total number of forest fires and acreage burned in State of Colorado by agency in 2012 alone. (All Tables are presented at the end of chapter).

The purpose of this study is to estimate Larimer County Colorado households' non-market values for two forest management options for reducing intensity of future wildfires and associated non-market environmental effects of wildfires. In the presence of the non-commercial size lodgepole pines, one approach for reducing the intensity of future wildfires involves the agency paying a contractor to harvest dead and dying beetle-killed trees throughout the forest. The collected Mountain pine beetle-killed trees would then be burned in a safe area at a safe time (usually in the spring just after the snow melts, so the ground is still wet). However, there have been both public concerns about the associated smoke, which although less than wildfire smoke, can still be a problem in some wildland urban interface (WUI) areas. In fact, burning of the dead logs and residual materials is often constrained by local, state and federal air quality regulations.

An alternative approach is to collect the dead trees and move them off the forest where they can be burnt in a largely closed system which converts the dead trees into "biochar" which can be put to use as a soil amendment (see http://www.biochar-international.org/biochar/soils for more details). However, partly for space constraints in the survey, and partly to focus on the non-market aspects of the biochar process (e.g., reduced smoke, greenhouse gas emissions, reduce time of recreation site closure) our survey did not emphasize the various uses of biochar. This would require a full survey in and of itself. Therefore this chapter quantifies the non-market benefits of these two forest management options and their environmental effects compared to the limited current management taking place only in high hazard areas. These results should be useful to the US Forest Service and state forest management organizations in choosing among proposed management options to deal with pine beetle-killed trees and reduce the risk of high intensity forest fires. Thus our second objective is to see if there is an incremental willingness to pay for the added environmental benefits associated with burning off site to produce biochar.

CVM Studies of Wildfires

The non-market values arising from forest management specifically aimed at reducing the intensity and spread of wildfires has been previously studied. These studies were first conducted in Florida, then California and Montana. Loomis and Gonzalez-Caban (2009) conducted a phone-mail-phone process in three states of Florida, California and Montana. They compared forest fire reduction methods of prescribed burning and mechanical fuel reductions in the states of California, Florida, and Montana for Caucasian and Hispanic populations. The calculated mean WTP per household of Caucasians for prescribed burn for the states of California, Florida, and Montana was $460, $392, and $323 respectively. The calculated mean

WTP of Caucasians for mechanical fuel reduction method was $510, $239, and $189 respectively.

Walker et al (2007) used CVM to calculate WTP for two methods of fire reductions thinning versus burning on site for urban and WUI regions in northern Colorado. The per household WTP of WUI residents in both counties was higher for thinning than prescribed burnings, and the per household WTP of WUI residents also higher than per household WTP of residents in the urban area. The WTP for thinning for Larimer County and Boulder County for urban respondents are $289, and $412, and for WUI respondents is $311, and $493. The WTP of burning on site method for the Larimer County and Boulder County for urban respondents is $140, $213, and for WUI respondents is $150, and $202.

Talberth et al (2006) used an induced-value experiment and a contingent valuation (CVM) survey to examine the simultaneous effect of wildfire insurance and private/public averting behavior of households in the mountainous areas of eastern New Mexico along the WUI. They concluded that households take averting behavior with regards to forest fires regardless of whether they have full home insurance. WTP per household for private risk reduction activities, neighborhood risk reduction activities, public land risk reduction activities, and private wildfire insurance were $240.04, $94.45, $64.12, and $184.42 respectively. Talberth et al (2006) also came up with total WTP that sums up to $583.03 considering WTP for private, neighborhood, public risk reductions activities and private wildfire insurance.

Table 3.2 presents a summary of these existing WTP studies. Our study makes a contribution by valuing burning forest fuel in an offsite redactor for conversion of the dead trees into biochar. This further reduces the environmental effects of forest fire management, but is more costly. This study asks whether the non-market benefit of the reduced environmental effects might justify the higher costs of offsite disposal of the trees.

II. SURVEY DEVELOPMENT

Economists measure the economic value of a good/service by what people will pay for it. In the case of private goods sold in markets, willingness to pay is measured by price, although for large changes in the availability of the good that affects its price, there may be a change in consumer surplus for the private good. With public goods such as air quality or water quality, there is rarely any formal market, but economists still measure economic values as the person's willingness to pay (WTP).

The contingent valuation method (CVM) is a widely used method for estimating WTP for public goods. This method has been used by state and federal agencies in a variety of natural resource management contexts (e.g., wetlands, dam removal to benefit salmon, wolf introduction, and public land recreation, see for example Loomis, 2006). In this study we will ask our participants their WTP for two increases in forest fire management compared to the limited current forest management that is limited to tree removal only in high hazard areas (e.g., right along roads, around public recreation facilities, etc.)

Smith (2000) categorized WTP question formats into open-ended, payment card, discrete choice (routinely called dichotomous choice when applied to CVM), and discrete choice with follow up. In the open-ended questionnaire respondents are asked about the maximum amount that they would pay to keep a public good preserved. In the payment card option, the respondent is shown a card with a range of values and asked which one they would be willing to pay to get the proposed management option or to protect the public good. In a dichotomous choice questionnaire each participant is presented with a single bid that they indicate they would or would not pay for the change in environmental quality. In this method the bid amounts would vary across the sample to allow calculation of the maximum willingness to pay for the sample. The advantage of the dichotomous choice format is that it is similar to price taking behavior of consumers in a market and to voting in a referendum.

The Public Goods to be Valued

The survey design began by assembling information about problems facing Colorado forests including pine beetle and fires. Then we researched possible management solutions such as harvesting with burning on site and harvest with conversion to biochar. We researched the key differences in the environmental effects of current management (option#1), add burn dead trees on site (option#2) and then convert to biochar (option#3). We selected 7 non-price attributes and a cost variable: (1) Acres of pine beetle killed trees; (2) Percentage of forest that burns each year; (3) frequency of wildfires; (4) air pollution; (5) greenhouse gas emission; (6) water quality in streams; (7) months recreation sites would be closed; (8) annual cost to taxpayers. Pine beetle killed trees are dead and dying trees that are invaded by bark beetles (pine beetles). Percentage of forest that burns each year under each management option was compared. The frequency of wildfires is the number and intensity of forest fires that occur. Air pollution includes unhealthy days where everyone experiences undesirable health effects, where people with existing conditions such as lung and heart problems have to avoid going outside. Greenhouse gas emission (GHG) is the gases that absorb the heat in the atmosphere and contribute to climate change. The water quality in the stream as a consequence of forest fires had two levels: it could be muddy, or rarely muddy. In rarely muddy there are possibilities for fishing, kayaking, and minimal water treatment is required. The month’s recreation areas such as hiking trails, and camping areas are closed as a consequence of forest fires. There would be an annual tax which will be continued for 10 years as federal and state tax on residents of the state of Colorado and the U.S. residents. This annual cost varies from $5 to $900 per household.

The levels of these attributes varied from Current Management to Management Option #2 (harvest and burn on site) and Management Option #3 (harvest and convert to biochar). See Figure 3.1 and Figure 3.2 to see how these were illustrated with icons.

We only varied three attributes (air pollution, greenhouse gas emissions, and recreation site closure) across the 3 management alternatives. The other 4 attributes only changed from current management (option#1) to identical levels for option 2 and 3. Across all the choice sets, prices did vary however. Cost ranged from $5 to $900. We did not conduct a main effects design due to budget limits and the logic of the environmental effects. Focus groups indicated that it did not make sense for all the attributes in options 2, and 3 to vary independently as changes in fire risk were identical since both options involved thinning.

Payment Vehicle

Respondents were told that because of the large amount of federal lands such as National Forests in Colorado, the cost of reducing the wildfire hazard will be shared between all U.S. taxpayers and Colorado taxpayers. Two combined federal and state taxes would increase with the amount of the increase depending on the management option. The federal tax would be in form of an increase on income tax. Colorado state taxes would be an increase in sales tax and state income tax. This annual tax increase would be for 10 years and would take effect in 2014 and expire in 2024. The money would go in a separate "pine beetle-killed tree removal fund" that would be monitored by a citizen advisory panel.

Testing Survey Instrument

Venkatachalam (2004) discusses major issues that ideally should be addressed to the extent practical in CVM studies, one is validity and the other is reliability. Validity will be divided into internal validity and external validity. With regard to internal validity there is face validity, construct or convergent validity and criterion validity. Rarely is one study able to address all of these. Given the project research budget, we were able to just emphasize face validity. Face validity focuses on whether the theoretical concept (here WTP) is clear to respondents, and the survey itself is understood by the respondents as intended by the researchers. To address face validity, we conducted two focus groups in the geographic area where they survey would be mailed (e.g., Larimer County, Colorado). Respondents read each page of the survey, noting anything specific on the survey that was not clear. Then the page was discussed as a group to gain additional insight on their responses. Surveys were revised after each focus group to address the suggestions of the focus group. Then a pre-test of the resulting mail survey was conducted by handing the survey out at one of the local grocery stores, and having respondents mail it back. Part of the intent at this phase was to test whether the bid distribution was realistic.

Protest responses are a major problem when respondents respond “no” or refuse to pay for a commodity that they appear to value (Venkatachalam, 2004). If we don’t account for this possibility we might incorrectly conclude they had no value, when they may in fact have a value but just object to some feature of the CVM survey. This approach will presumably bias WTP estimate upwards for both lower and upper bounds. In our survey we account for this issue by asking the participants to write a reason for the chosen management option. In this case if they mention that taxes are already too high or that only people who live in the area close to forest fires should pay the cost, we put them in the protest categories and we omit from the analysis as their response is not a true reflection of their WTP. Rather it is a reflection of some feature of our constructed or simulated market (Cameron and Carson, 1989).

In the CVM studies, respondents often agree to pay more than what the respondent is actually willing to pay (Murphy, et al. 2005). There are various strategies to reduce hypothetical bias (Loomis, 2014) but due to budget constraints and length of the survey we were able to only implement one of them. Thus we tried to minimize the hypothetical bias by making our survey as consequential possible to respondents. Carson and Groves (2007) suggested that if respondents believe the survey results will actually influence the implementation of the policy and their payment of taxes, then the survey responses are more likely to be valid. Vossler and colleagues has shown that consequential surveys do in fact reduce or eliminate hypothetical bias in non-market valuation field experiments using stated preference methods such as CVM (see for example Vossler and Kervliet, 2003; Vossler, et al. 2012; Vossler, et al. 2013). To implement consequentiality in our survey, the survey itself and cover letter stressed the survey response would be used by forest management agencies in Colorado to determine which forest management options to choose. As noted above we had a realistic payment vehicle.

Addressing Fundamental Concerns about CVM in Our Survey Instrument

While CVM has been used by environmental economists for decades, the Exxon Valdez oil spill in 1992 brought CVM to the attention of the broader economics profession. A series of articles in the *Journal of Economic Perspectives* in 1994 summarized the concerns about CVM surveys of the general public at the time (see Portney, 1994 for an overview). Nearly 20 years later, the same journal reexamined the state of progress in CVM. The overview paper attempted to provide a neutral assessment of the progress that had been made, what has been learned, and continuing concerns with CVM (see Kling, et al. 2012). Hausman (2012) revisited his original criticisms (Diamond and Hausman, 1994), and continued to find long standing fundamental problems: (a) hypothetical bias whereby stated values exceeded objective measures of actual values—often cash payments; (b) Willingness to Accept exceeding WTP; (c) embedding whereby WTP for a small quantity of a public good is equal to WTP for larger quantity of the public good—i.e., a lack of what is called scope. These are of course serious concerns and ones that have been well researched over the last twenty years (see Kling, et al. 2012 for a summary of the evidence on these concerns).

Our survey response, like nearly every CVM study, is of course susceptible to hypothetical bias since respondents were not actually required to pay their stated WTP. However, we have taken some (but not all) of the literature's suggestions to minimize the hypothetical bias (see Loomis, 2014 for a summary of the available strategies to minimize hypothetical bias). For example, we cast the choice in a binary format (status quo versus Option #2, then another binary choice with status quo versus Option #3—See Carson and Groves for more detail on the importance of asking the WTP question in a binary form). We stressed the consequentiality of the choice to them in terms of: (a) payment of taxes (a compulsory payment vehicle rather than as a voluntary donation)—See Carson and Groves for more details on the importance of a compulsory tax payment vehicle; (b) the results would be used by federal and state forest management officials in their decisions about how to address the pine beetle kill problem. Vossler and colleagues have shown that consequential surveys do in fact reduce or even eliminate hypothetical bias in some cases in non-market valuation field experiments using stated preference methods such as CVM (see for example Vossler and Kervliet, 2003; Vossler, et al. 2012; Vossler, et al. 2013).

However, as with most policy driven (i.e., applied not basic) research and modestly funded CVM studies we did not conduct a scope test. While it is possible that our respondents valued a program larger than just the state of Colorado, evidence from our focus groups suggests otherwise. In particular, discussions in the focus groups indicated that respondents were focusing on the benefits just in Colorado (and even more locally to where they lived in Northern Colorado) rather than the entire western United States for example. Specifically, we conducted two focus groups in the geographic area where the survey would be mailed (i.e., Larimer County, Colorado). Respondents read each page of the survey, noting anything specific on the survey that was not clear. Then the page was discussed as a group to gain additional insight on their responses. Surveys were revised after each focus group to address the suggestions of the focus group. Then a pre-test of the resulting mail survey was conducted by handing the survey out at one of the local grocery stores, and having respondents mail it back. Part of the intent at this phase was to test whether the bid distribution was realistic.

III. SURVEY IMPLEMENTATION

To implement the CVM we created a color mail survey that was sent to a random sample of 500 residents of Larimer County, Colorado. We used Dillman repeated mailing method (Dillman and Sallant, 1994) as follows: we sent the first mailing to 500 residents of Larimer County in the May of 2013 with a $1 bill attached, and a follow-up post card reminder two weeks after our initial mailing. We sent a second mailing to non-respondents, followed by post-card reminders one month after our first mailing, and a third mailing in June of 2013 to a portion of our second mailing non-respondents, followed up with post-card reminders. We sent fourth mailing in August. Accounting for non-deliverable, non-usable data, and ineligible data (the ones who moved to out of state) our response rate for usable (the surveys that answer the willingness to pay question) and returned surveys was 47.14%. Our high response rate may in part be due to increased interest in wildfires due to seriously destructive wildfires that hit Colorado Springs just as our survey went into the field.

IV. ANALYSIS OF DATA

Descriptive Statistics Analysis and Correlation Matrix of Income vs. Bid Amount

Table 3.3 shows that 39.1% of respondents were female, 27.6% lives in the rural area, and 86.9% are visiting forest for recreational activities such as hiking, mountain biking, skiing, camping,…etc, sixty eight percent have higher education(bachelor and higher), and 33% of our participants are in a middle income range.

THE CORRELATION AMONG BID AMOUNTS FOR THE BURN ON SITE OR MANAGEMENT OPTIONS AND ALL OTHER EXPLANATORY VARIABLES DISTANCE FROM FIRE, RESPIRATORY PROBLEMS, EVACUATION AS A PEOPLE IN A HOUSEHOLD, EDUCATION, WHETHER THEY LIVE IN A PROPERTY OR RENT, WHETHER THEY VISIT FOREST TO RECREATE OR PROVIDE COMMENT OR NOT HAS BEEN PROVIDED IN TABLE 3.7 AND

	costtwo	choicetwo	heardbio	distfire	respprob	evachpfire	gender	ageyears	numhh	edyears	rural	urban	rentprop	own
costtwo	1													
choicetwo	-0.008	1												
heardbio	-0.0408	0.0613	1											
distfire	0.053	0.1372	-0.0657	1										
respprob	-0.0086	-0.0141	-0.0451	-0.0036	1									
evachpfire	0.0172	-0.0736	-0.0226	-0.2226	0.0601	1								
gender	0.1031	0.1004	-0.0603	0.2207	-0.003	-0.1236	1							
ageyears	-0.0083	0.0196	-0.0301	0.0497	0.0049	0.041	-0.1671	1						
numhh	0.0376	-0.1724	0.0996	-0.0963	-0.0491	-0.0203	-0.1052	-0.558	1					
edyears	0.0254	-0.028	-0.0102	-0.0337	0.0057	-0.1536	-0.1472	-0.1357	0.0707	1				
rural	0.0233	-0.0556	0.0679	-0.0575	0.1416	0.3579	0.0528	-0.0366	0.012	-0.1406	1			
urban	-0.0216	0.0574	-0.07	0.0501	-0.1461	-0.3692	-0.0816	0.0351	-0.0018	0.1749	-0.9695	1		
rentprop	-0.0203	0.1863	-0.1002	0.0058	0.0464	-0.0022	0.1456	-0.1706	-0.1548	-0.037	-0.0629	0.0649	1	
own	0.0177	-0.1619	0.1083	0.0121	-0.0339	0.0059	-0.1643	0.1656	0.1576	0.0181	0.0308	-0.0318	-0.974	1
visitfor	-0.031	0.0222	0.132	-0.0788	0.0603	0.0773	0.0629	-0.2074	0.1341	-0.075	0.0979	-0.101	0.0713	-0.0756
income	-0.1171	0.0263	0.0683	0.0603	-0.0133	-0.1104	-0.2754	-0.2079	0.2774	0.4243	0.0616	-0.0331	-0.2259	0.2263
comment	-0.0538	-0.1147	0.0952	0.0607	-0.1278	-0.013	0.1	0.1261	-0.1891	0.0539	0.0676	-0.0697	0.0132	-0.0065

Table 3.8. In general correlations are very weak. Some of the demographic variables have correlation in the expected direction, the higher income you have the possibility of owning home as opposed to renting is higher, and vice versa. There is also a negative and weak correlation among income and willingness to pay for each management options. In other words, higher income leads to negative WTP. We graphed Income against bid amounts for each management options in Figure 3.4, and Figure 3.5. You can see that income and bid amounts are weakly and negatively correlated.

Non-Parametric Model versus Parametric Model

There are two choices in estimating the WTP from a dichotomous choice data. One is a parametric logit or probit model. In a fully parametric model, the data generating process includes two parametric components. One is the probability density function (PDF) and the other is conditional mean of the dependent variable. The PDF shows the relationship between the dependent variable and the independent variables (explanatory variables). The distributional assumption about PDF and the conditional mean of dependent variable in a fully parametric model affect the type of estimator that we use to make inference about population parameters.

Maximum likelihood assigns probabilities to parameters as we vary the parameter values. We are looking for a sample from which our unknown β's are derived, and we are maximizing the likelihood of observing the sample of data across the parameter values. The MLE are always based on the consistency theorem (Cameron and Trivedi, p126) and asymptotically efficient. For example, if the economist assumes a normal distribution, then the corresponding statistical model is a probit, while assuming a logistic distribution gives rise to the logit model. I did not use logit model since the cost coefficients were not significant due a low bid amount design.

Non-Parametric Model

A non-parametric model does not make any assumptions about the specific parameterization of conditional mean of dependent variable, nor the exact PDF of the dependent variable. Consider the model $y_i = m(x_i) + \varepsilon_i$, $E(y_i|x_i) = m(x_i),\ \varepsilon_i\ (0, \sigma^2)$

Where y is the dependent variable for individual i, $m(x_i)$ is any real-valued function, and ε_i is the disturbance term which is identically and independently distributed with mean of zero and variance of σ^2. (Cameron and Trivedi, Ch9). The non-parametric model is data-driven.

We are using “Turnbull Estimator” to smooth our WTP associated with proposed management options in the repeated CVM scenario. Non-parametric methods such as the Turnbull that we employ below have been used extensively in CVM (Haab and McConnell, 2003: 65-66).

V. NON-PARAMETRIC SMOOTHING METHOD: TURNBULL ESTIMATOR

The Turnbull non-parametric estimator does not assume any distribution for the error term. In the case of the discrete choice CVM for calculating WTP, if the respondent chooses an option over the current management option, it means their WTP is higher than or equal to the offered project price. On the other hand if the respondent says “No” to the suggested management options, their WTP is less than the offered project price. In most dichotomous choice surveys that do not have very large sample sizes at each bid amount the probability of getting a “No” response as the bid amount increases does not necessarily increase for all of the bid amounts. The advantage of using the Turnbull estimator is that we can calculate WTP even though the proportion of “No” responses did not increase uniformly as the dollar bid increased. It is important to note that Turnbull estimators give us a lower bound estimate for WTP, and it only uses a minimal amount of information to calculate the mean WTP. The process involves calculating the proportion of “No” responses associated with increasing bid amounts. For bid amounts that do not follow the monotonicity restriction, we pool the number of “No” responses to bid amount j (N_j) and N_{j+1} together, and then we drop the bid amount that does not follow the monotonic trend in No response (N_{j+1}). Then we calculate a weighted average of the prior bid (B_{nj}) and subsequent bid (B_{nj+2}). This procedure is presented in detail in Table 3.5 and Table 3.6 for our empirical analysis of our data. This procedure was followed until all cells are pooled sufficiently to derive the monotonically increasing CDF in the "No" response (Haab and McConnell, 2003).

Turnbull Distribution-Free Estimator (TDFE)

There are two proposed ways suggested by Haab and McConnell (2003, P 60-62, 65-66, 68-69) to deal with non-monotonic empirical distribution functions for some bid amounts. First, we can rely on small sample monotonicity properties; second impose a monotonicity restriction on the distribution free estimator. This second approach is called Turnbull distribution-free estimator (TDFE). One important thing to consider is that TDFE gives us lower-bound for mean willingness to pay, because it uses the minimal amount of information. Where WTP_i is individual's i WTP for the proposed management option, F_j is cumulative distribution function which is defined as probability that respondent say no to a price (bid amount) of t_j.

$$\Pr(WTP_i < \$t_j) = F_j \qquad \text{Equation 3-1}$$

The maximum likelihood function for the unrestricted distribution free estimator is the following expression:

$$L\left(F_j \middle| Y_j, N_j, T_j\right) = \binom{T_j}{Y_j} F_j^{N_j}(1 - F_j)^{Y_j} \qquad \text{Equation 3-2}$$

N_j is the number of people saying no to proposed management option, T_j is a total number of people who have returned the survey for the offered bid amount. $\binom{T_j}{Y_j}$ is the number of possible way that respondent says yes to a suggested bid amount. By taking natural log of Equation 3-2, the log likelihood function becomes

$$ln\ L = \sum_{j=1}^{M} \left[N_j \ln\left(F_j\right) + Y_j \ln(1 - F_j)\right] \quad \text{Equation 3-3}$$

By solving for the first order condition we can calculate the maximum likelihood function estimate of F_j(CDF) as the following

$$F_j = \frac{N_j}{T_j} \quad \text{Equation 3-4}$$

The unrestricted distribution-free estimator does not assure that probability of no responses increases along with increasing bid price pattern, so we impose the monotonicity restriction $\left(F_j <= F_{j+1} \middle| \forall j\right)$ to get the following log likelihood function

$$\text{Max}_{F_1, F_2, \ldots, F_M} \ln L(F_1, F_2, \ldots, F_M | Y, N, T)$$

$$= \sum_{j=1}^{M} \left[N_j \ln\left(F_j\right) + Y_j \ln\left(1 - F_j\right)\right], j \quad \text{Equation 3-5}$$

$$= 1,2,3, \ldots, M$$

$$subject\ to\ F_j <= F_{j+1}$$

Haab and McConnell (2003) derive the Kuhn-Tucker first order conditions as:

$$\frac{\partial \ln L}{\partial f_i} = \sum_{j=1}^{M} \left(\frac{N_j}{\sum_{k=1}^{j} f_k} - \frac{Y_j}{\sum_{k=1}^{j} f_k}\right) \leq 0, f_i \geq 0, f_i \frac{\partial \ln L}{\partial f_i} = 0 \quad \text{Equation 3-6}$$

$f_i = F_j - F_{j-1}$ is the weight of distribution function that falls between bid amount j and previous bid amount, solving all the first order conditions result in the following:

$$f_j = \frac{N_j}{T_j} - \frac{N_{j-1}}{T_{j-1}} \quad \text{Equation 3-7}$$

The best estimate for probability distribution of no response to bid amount j can be calculated as difference in the cumulative distribution function of no responses of current and previous bid amount. We then calculate the smooth probability distribution function for current bid amount by pooling the number of "No" responses to bid amount j (N_j) and N_{j+1} together, and then eliminate the bid amount that does not follow the monotonic trend in No response (N_{j+1}). A weighted average of current bid and following bid will be calculated to derive a smooth probability distribution function for the current bid amount.

$$f_j^* = \frac{N_j + N_{j+1}}{T_j + T_{j+1}} - \sum_{k=1}^{j-2} f_k^* = \frac{N_j^*}{T_j^*} - \sum_{k=1}^{j-2} f_k^* \qquad \text{Equation 3-8}$$

$$N_j^* = N_j + N_{j+1}, T_j^* = T_j + T_{j+1}, F_j^* = \frac{N_j^*}{T_j^*} \qquad \text{Equation 3-9}$$

VI. RESULTS

WTP for Burn on Site and Conversion to Biochar Management Options

THE CALCULATION OF THE WTP ESTIMATE IS PRESENTED IN TABLE 3.5 THE CALCULATED WTP FOR BURN ON SITE OPTION IS $411 PER BIOCHAR OPTION IS IN TABLE 3.6 AND IS $470 PER HOUSEHOLD. THE PROVIDES US WITH A LOWER BOUND ON WTP SINCE I INCLUDED THE THE SMOOTHED CDF FOR BOTH MANAGEMENT OPTIONS IS GRAPHED IN

Figure 3.3. Next we compare our result to those in the literature and then present the management implications of our results.

Loomis and Gonzalez-Caban (2009) compared forest fire reductions methods of prescribed burn and mechanical fuel reductions in three states of California, Florida, and Montana for Caucasian and Hispanic populations. Their calculated mean WTP for mechanical fuel reduction was $510, $239, and $189 in California, Florida, and Montana respectively. Montana and Colorado are both in intermountain area. Our mean WTP for both burning onsite and offsite conversion to biochar are higher than what Loomis and Gonzalez-Caban were calculated for Montana, a result that may in part be related to the higher income in Colorado than

Montana. Based on Census Burro median income for Colorado is 61,479 during 2009-2010 which is higher than median income of Montana 43, 384 during that period.

Walker et al (2007) calculated WTP for residents of Larimer County for both methods of thinning versus burning on site for urban and wildland-urban interface (WUI) region. The WTP for thinning for Larimer County for urban respondents is $289, and for WUI respondents is $311. Most of our respondents were from urban region and the WTP for burning on site was $411 per household for Larimer County. Our estimate is higher than Walker et al (2007) estimate, which may be due to the last two years of large forest fires in Colorado as compared the time of the Walker et al. study.

VII. POLICY AND MANAGEMENT IMPLICATIONS

In terms of our first objective, Larimer County households have a substantial annual WTP to avoid the effects of wildfires. In particular they are willing to pay to increase the removal of dead pine beetle killed trees to reduce the frequency and intensity of wildfires, and cut by two-thirds the amount of air pollution from wildfires and the number of months the recreation sites are closed as well as to reduce post fire sedimentation of streams.

In terms of our second objective, there does not appear to be much difference to the public over whether the additional dead trees harvested from the forest are burned on site (Option 2) or moved offsite and converted to biochar (Option 3). WTP for option 3 is 15% greater than for Option 2. That suggests some economic justification for implementing the biochar option if (a) there is not a large cost differential between Option 2 and 3; and (b) the sale of biochar product (which we did not evaluate) can compensate for the higher differential cost.

VIII. CONCLUSION

The study illustrates that the public appears to support the need for active forest management of dead and dying pine beetle killed trees to reduce the risk that lightening or human caused could quickly spread into a massive wildfire threatening air quality and post-fire water quality. They appear willing to pay for harvesting of dead timber and allow the trees to be burned on site, even if there is still some smoke and recreation site closures. The calculated WTP is lower bound since we considered the protest zeros in the calculation. We purposely did not emphasize any benefits of the biochar product itself so as to keep the focus on the non-market environmental aspects of forest management.

How generalizable our results are to other areas merits further study. Given the widespread exposure to information about the extent of beetle killed forest and the frequent severe wildfires in Colorado, we believe our results are generalizable from Larimer County to other "Front Range" counties along the wildland urban interface in Colorado. Further research is needed to investigate what the values are for these management activities are in other states.

TABLES

TABLE 3.1: FOREST FIRES AND ACREAGE BURNED IN THE STATE OF COLORADO BASED ON AGENCY 2012.

Agency	# Fires	# Acres
Bureau of Indian Affairs	111	112
Bureau of Land Management	399	7,418
County	298	32,685
National Park Service	30	1,009
State	9	824
USFS	279	153,032
Totals	1,134	195,082

Source: National Interagency Fire Center (NIFC), (Personal Communication with M. Perea from BLM)

TABLE 3.2: COMPARISON OF CVM STUDIES FOR REDUCING WILDFIRE RISKS IN THE WILDLAND URBAN INTERFACE

Author	State/County of Study	Calculated WTP	# Fires at time of survey	Acres Burned at time of survey	$/Acres Burned	Survey Response
Loomis and Gonzalez-Caban (2009)	Montana	$189	1,731	48,912	258	34%-50%
Walker et al (2007)	Northern Colorado	$289-$311	3,914	26,515	88	27%-41%
Talberth et al (2006)	New Mexico	$64.12-$204.04	2,636	607,802	868	27.3%
Current Study	Northern Colorado	$411	1,134	195,082	474	47.14%

Source: National interagency Fire Center (NICC), http://www.nifc.gov/fireInfo/fireInfo_statistics.html, Historical year-end fire statistics by state

TABLE 3.3: DESCRIPTIVE ANALYSIS FOR RCVM

Variable	Obs	Mean	Std. Dev.	Dummy Definition
Gender	464	0.391	0.488	1 if female, 0 otherwise
Visitfor	460	0.869	0.349	1 if visitfor,0 otherwise
Rural	456	0.276	0.725	1 if resides in rural,0 otherwise
Forthgrade	480	0	0	1 if edyears<=4
Fiftheight	480	0	0	1 if edyears>=5 & edyears<=8
Nintheleveth	480	0.0125	0.11	1 if edyears>=9 & edyears<=11
Nohsdiploma	480	0.0916	0.288	1 if edyears==12
HSdiploma	480	0	0	1 if edyears>12& edyears<13
Somecollege	480	0.208	0.406	1 if edyears==13
Associatedegree	480	0.0916	0.28	1 if edyears==14
College	480	0.241	0.428	1 if edyears==16
Graduate/Professional Degree	489	0.683	0.465	1 if edyears>16
Youngadult	480	0.354	0.478	1 if ageyears>=20 & ageyears<=24
Adult	480	0.0167	0.128	1 if ageyears>=25 & ageyears<=44
Middleage	480	0.225	0.418	1 if ageyears>=45 & ageyears<=64
Senior	480	0.67	0.47	1 if ageyears<=65
Lowerclass	480	0.0708	0.257	1 if income<=22000
Midlowerclass	480	0.2	0.4	1 if income>22000 & income<=45500
Middleclass	480	0.33	0.472	1 if income>45500 & income<=117450
Uppermiddleclass	480	0.304	0.46	1 if income>117450 & income<=500000

TABLE 3.4.VARIABLE'S DEFINITION

Variables	Description	Range of Data
COSTTWO	Cost associated with Burn on site	Attributes of WTP Tables
COSTTHREE	Cost associated with Biochar	Attributes of WTP Tables
CHOICETWO	1 if choose option 2, 0 otherwise	Dummy Variable
CHOICETHREE	1 if choose option 3, 0 otherwise	Dummy Variable
HEARDBIO	1 if heard about biochar prior to our survey, 0 otherwise	Dummy Variable
DISTFIRE	Distance from fire in miles	5,15,30,50,60
RESPPROB	1 if household has respiratory problems, 0 otherwise	Dummy Variable
EVACHPFIRE	1 if evacuate house from high park fire, 0 otherwise	Dummy Variable
GENDER	1 if female, 0 otherwise	Dummy Variable
AGEYEARS	Age	
NUMHH	Number of household	
EDYEARS	Years of education	Dummy Variable
RURAL	1 if the household lives in rural area, 0 otherwise	Dummy Variable
URBAN	0 if the household lives in the urban area, 0 otherwise	Dummy Variable
RENTPROP	1 if household is renting the property, 0 otherwise	Dummy Variable
OWN	0 if the household own the property, 0 otherwise	Dummy Variable
VISITFOR	1 if visit forest, 0 otherwise	Dummy Variable
INCOME	Last Year Household Income before tax	10,15,25,35,45,55,65,75, 85,95,125,175,200
NUMINC	Number of households that are contributing to the income	
COMMENT	1 if comment, 0 otherwise	Dummy Variable

TABLE 3.5: TURNBULL LOWER BOUND ESTIMATES WITH POOLING FOR BURN ON SITE MANAGEMENT OPTION

Bid Price[4]	Number Offered[5]	Number of No's[6]	Fj[7]	Fj*[8]	fj*[9]	Fj*(1-Fj*)	(t_j-t_{j-1})^2		WTP
5	21	9	0.428	0.428	0.428	0.00627	25	0.0075	411.09
15	18	10	0.55	0.446	0.0182	0.00525	100	0.011	
30	29	11	0.379	pooled	0.0268				
50	23	8	0.347	pooled	-0.133				
60	19	4	0.21	pooled	-0.0828				
90	19	9	0.474	0.474	0.171	0.011332	5625	3.354	
120	22	8	0.36	0.34	0.571	0.004488	900	0.0807	
150	28	9	0.32	pooled					
190	18	6	0.333	0.257		0.005458	4900	0.764	
270	17	3	0.176	pooled					
700	14	6	0.428	0.428		0.017493	260100	324.989	
700+			1	1				Var= 329.208	
C.I. 95%	$375.53-$446.65								

4 . Bid Price: The cost associated with management options
5 . Number Offered: the number of surveys that has been returned and answered WTP question
6 . Number of No's is the number of surveys that were not satisfied with proposed management options
7 . Fj is the cumulative distribution function
8 . Fj* is the smoothed cumulative distribution function
9 . fj* is the smoothed probability distribution function

TABLE 3.6: TURNBULL LOWER BOUND ESTIMATES WITH POOLING FOR BIOCHAR MANAGEMENT OPTION

Bid Price	Number Offered	Number of No's	Fj	Fj*	fj*	Fj*(1-Fj*)	(t_j-t_{j-1})^2	V(Fj*)	WTP
10	21	11	0.5238	0.5238	0.5238	0.249	100	1.187	469.55
20	16	12	0.75	0.75	0.226	0.187	100	1.1718	
30	2	2	1	0.433	-0.316	0.245	100	0.818	
50	28	11	0.392	pooled	-0.133			0	
70	23	6	0.26	pooled	0.057			0	
90	20	6	0.3	0.3	0.0502	0.21	3600	37.8	
120	20	8	0.4	0.357	0.106	0.229	900	4.919	
150	22	7	0.318	pooled	-0.0142			0	
190	27	11	0.407	0.407	0.5	0.241	4900	43.81	
270	17	10	0.588	0.514		0.249	6400	45.67	
350	18	8	0.444	pooled				0	
900	16	8	0.5	0.5		0.25	396900	6201.56	
900+			1	1		0		Var=6336.95	
C.I. 95%	$313.53-$625.58								

TABLE 3.7. CORRELATION MATRIX FOR BURN ON SITE BID AND OTHER EXPLANATORY VARIABLES

	costtwo	choicetwo	heardbio	distfire	respprob	evachpfire	gender	ageyears	numhh	edyears	rural	urban	rentprop	own	visitfor	income	comment
costtwo	1																
choicetwo	-0.008	1															
heardbio	-0.0408	0.0613	1														
distfire	0.053	0.1372	-0.0657	1													
respprob	-0.0086	-0.0141	-0.0451	-0.0036	1												
evachpfire	0.0172	-0.0736	-0.0226	-0.2226	0.0601	1											
gender	0.1031	0.1004	-0.0603	0.2207	-0.003	-0.1236	1										
ageyears	-0.0083	0.0196	-0.0301	0.0497	0.0049	0.041	-0.1671	1									
numhh	0.0376	-0.1724	0.0996	-0.0963	-0.0491	-0.0203	-0.1052	-0.558	1								
edyears	0.0254	-0.028	-0.0102	-0.0337	0.0057	-0.1536	-0.1472	-0.1357	0.0707	1							
rural	0.0233	-0.0556	0.0679	-0.0575	0.1416	0.3579	0.0528	-0.0366	0.012	-0.1406	1						
urban	-0.0216	0.0574	-0.07	0.0501	-0.1461	-0.3692	-0.0816	0.0351	-0.0018	0.1749	-0.9695	1					
rentprop	-0.0203	0.1863	-0.1002	0.0058	0.0464	-0.0022	0.1456	-0.1706	-0.1548	-0.037	-0.0629	0.0649	1				
own	0.0177	-0.1619	0.1083	0.0121	-0.0339	0.0059	-0.1643	0.1656	0.1576	0.0181	0.0308	-0.0318	-0.974	1			
visitfor	-0.031	0.0222	0.132	-0.0788	0.0603	0.0773	0.0629	-0.2074	0.1341	-0.075	0.0979	-0.101	0.0713	-0.0756	1		
income	-0.1171	0.0263	0.0683	0.0603	-0.0133	-0.1104	-0.2754	-0.2079	0.2774	0.4243	0.0616	-0.0331	-0.2259	0.2263	-0.1018	1	
comment	-0.0538	-0.1147	0.0952	0.0607	-0.1278	-0.013	0.1	0.1261	-0.1891	0.0539	0.0676	-0.0697	0.0132	-0.0065	0.0356	-0.061	1

TABLE 3.8.CORRELATION MATRIX FOR BIOCHAR BID AND OTHER EXPLANATORY VARIABLES

	costthree	choicethree	heardbio	distfire	respprob	evachpfire	gender	ageyears	numhh	edyears	rural	urban	rentprop	own	visitfor	income	comment
costthree	1																
choicethree	-0.0109	1															
heardbio	-0.0303	0.0408	1														
distfire	-0.0293	-0.0156	-0.0753	1													
respprob	-0.0077	0.0363	-0.06	0.1015	1												
evachpfire	0.0049	-0.0489	-0.0211	-0.0916	0.0584	1											
gender	0.1342	0.0758	-0.0555	0.168	0.0126	-0.1218	1										
ageyears	-0.0248	0.0717	-0.0479	0.1193	0.0246	0.04	-0.1678	1									
numhh	0.0407	-0.1657	0.0975	-0.1157	-0.0594	-0.0201	-0.0823	-0.5623	1								
edyears	0.0466	-0.0256	0.031	-0.0914	0.0105	-0.1504	-0.1435	-0.1523	0.0862	1							
rural	0.0097	-0.1542	0.0802	-0.0627	0.1438	0.3493	0.028	-0.0598	0.0324	-0.1308	1						
urban	-0.0082	0.1588	-0.0826	0.0615	-0.1481	-0.3598	-0.0547	0.0591	-0.0232	0.1632	-0.9709	1					
rentprop	-0.0443	0.1367	-0.1116	-0.0149	0.0552	-0.0055	0.1418	-0.163	-0.1195	-0.0657	-0.0755	0.0777	1				
own	0.0426	-0.1167	0.119	0.0216	-0.0434	0.0089	-0.1594	0.1585	0.123	0.0475	0.0452	-0.0465	-0.9761	1			
visitfor	-0.016	0.0686	0.1343	-0.0019	0.0687	0.0755	0.0423	-0.1623	0.123	-0.0742	0.0653	-0.0673	0.0777	-0.0817	1		
income	-0.0884	-0.0354	0.0835	-0.0791	-0.0408	-0.1036	-0.2685	-0.1866	0.2609	0.4389	0.102	-0.0763	-0.2348	0.2349	-0.0769	1	
comment	-0.0487	-0.1207	0.106	-0.0012	-0.1161	-0.0055	0.0759	0.1282	-0.1712	0.0648	0.0374	-0.0386	0.0128	-0.0068	0.0298	-0.0411	1

FIGURES

	Option 1: Current Management	Option 2: Burn Beetle Killed Trees on Site
Pine Beetle Killed Trees (Acres Infested)		
% Forest Burned Every 10 Years	20%	10%
Forest Fire Frequency	More frequent, intense wildfires	Less frequent, less intense wildfires
Air Pollution from Fire Smoke (# Average Days)	High Air Pollution 10 Unhealthy days	Low Air Pollution 4 Unhealthy days
Greenhouse Gas Emissions	High	Medium
Water Quality in Streams and Lakes in Areas Burned	Frequently Muddy	Rarely Muddy
# Of Months Recreation Areas are closed	6 Months	2 Months
Annual Cost to Taxpayers		

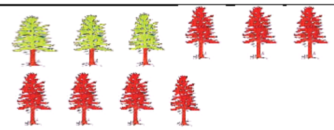
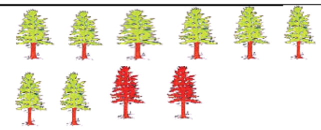
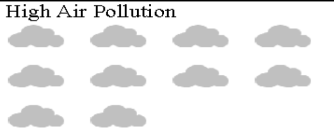
1. Using the information provided in the table above, which option would you choose? (*Check one box*).

Option 1 ☐ Option 2 ☐

There are no right or wrong answers. We are just interested in your honest opinions. Why did you select the alternative that you did? ____

____

FIGURE 3.1: CURRENT MANAGEMENT VERSUS BURNING ONSITE SCENARIO

	Option 1: Current Management	Option 3: Convert Beetle Killed Trees to Biochar
Pine Beetle Killed Trees (Acres Infested)		
% Forest Burned Every 10 Years	20%	10%
Forest Fire Frequency	 More frequent, intense wildfires	 Less frequent, less intense wildfires
Air Pollution from Fire Smoke (# Average Days)	High Air Pollution  10 Unhealthy days	Very Low Air Pollution  2 Unhealthy days
Greenhouse Gas Emissions	High	Low
Water Quality in Streams and Lakes in Areas Burned	 Frequently Muddy	 Rarely Muddy
# Of Months Recreation Areas are closed	 6 Months	 1 Month
Annual Cost to Taxpayers		

1. Using the information provided in the table above, which option would you choose? (*Check one box*).

Option 1 ☐ Option 3 ☐

There are no right or wrong answers. We are just interested in your honest opinions. Why did you select the alternative that you did?

____

____

FIGURE 3.2: CURRENT MANAGEMENT VERSUS BIOCHAR SCENARIO

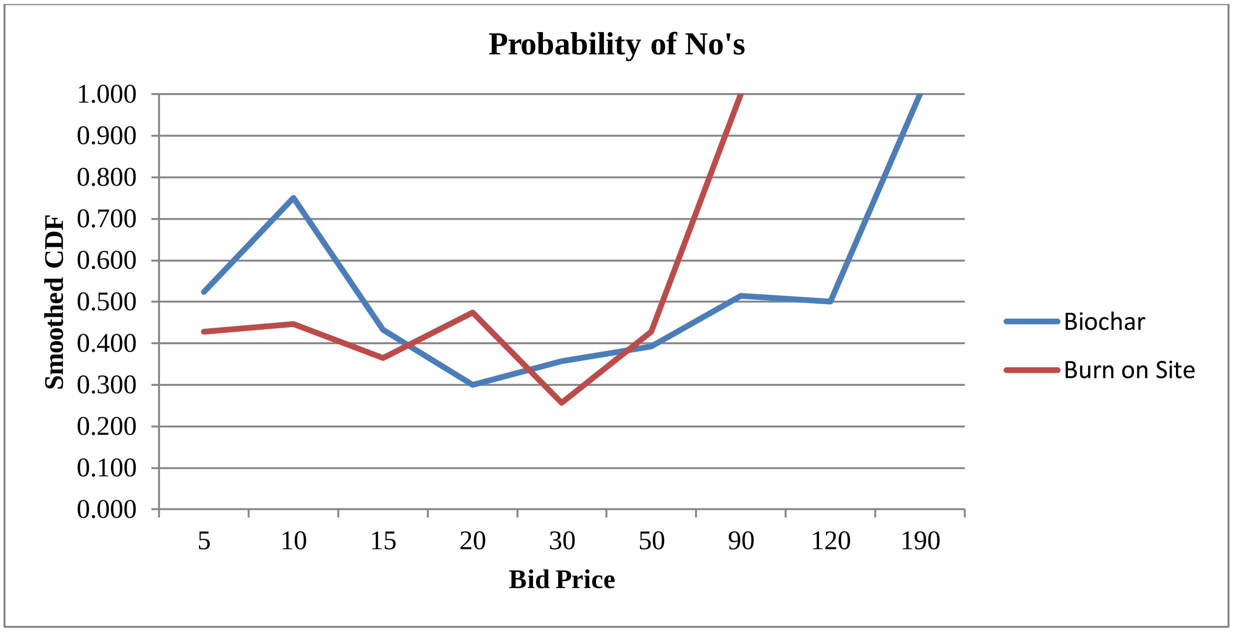


FIGURE 3.3: PROBABILITY OF NO'S: SMOOTHED CDF FOR BURN ON SITE AND BIOCHAR MANAGEMENT OPTIONS

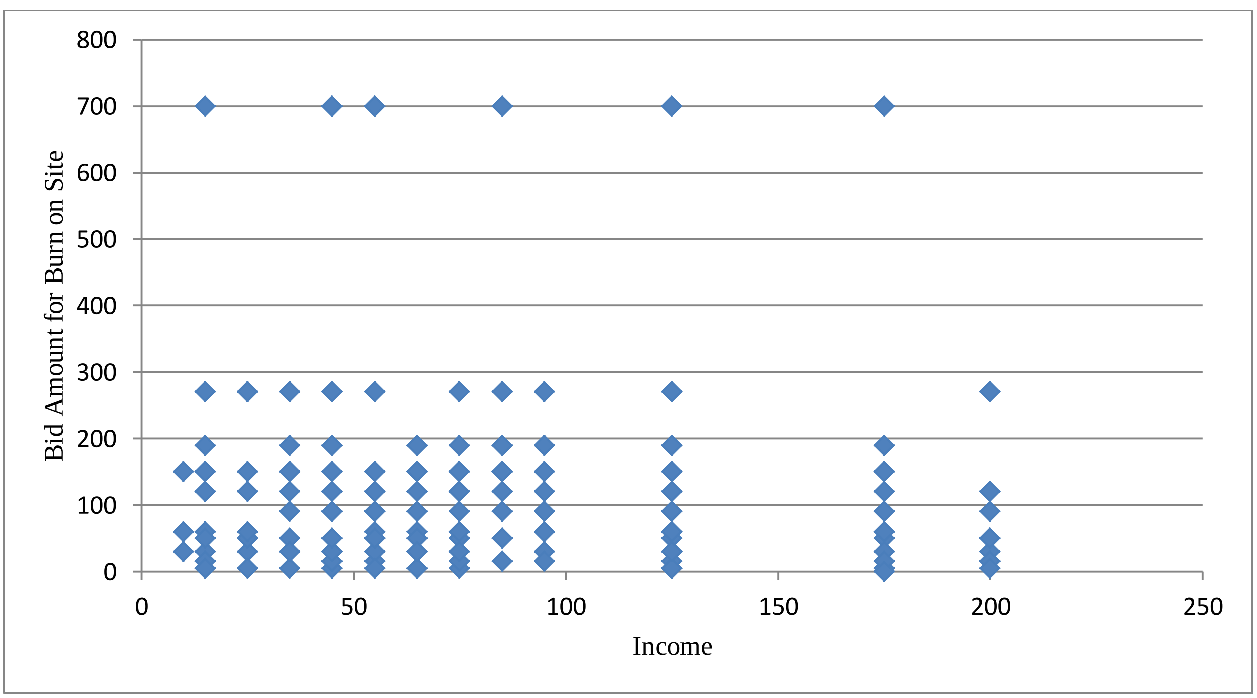


FIGURE 3.4. BID AMOUNT VARIATION OF BURNING ON SITE OPTION VERSUS INCOME

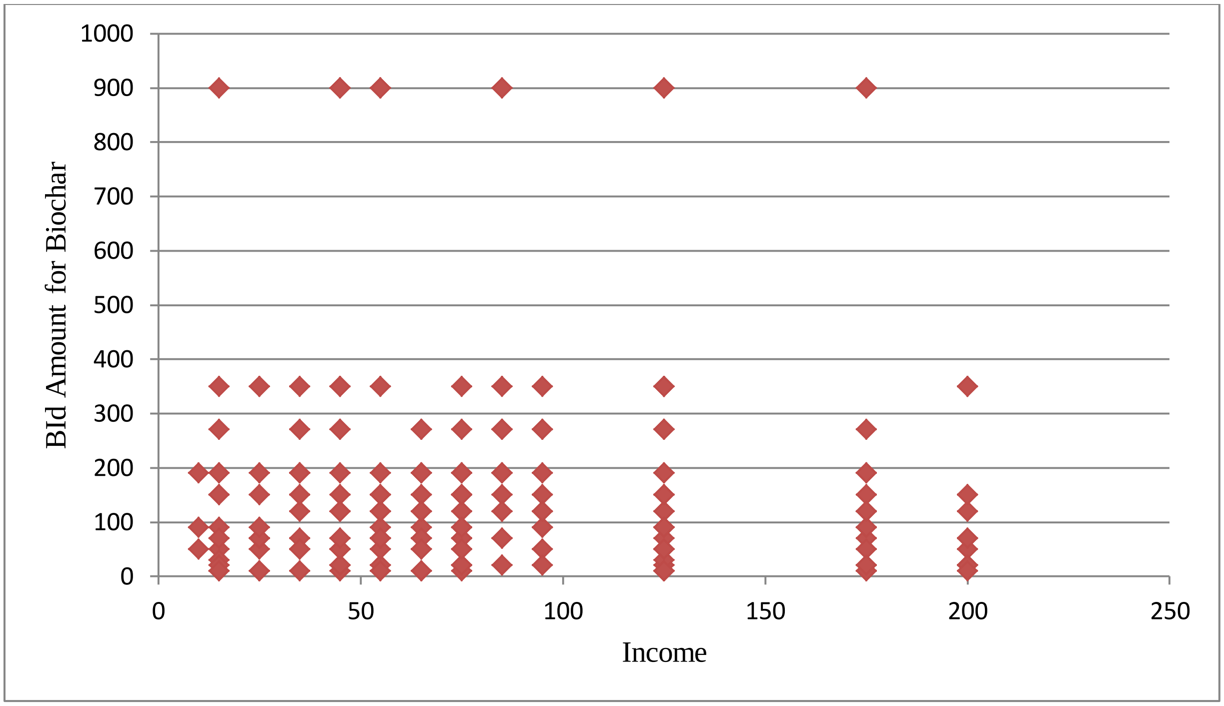


FIGURE 3.5.BID AMOUNT VARIATION OF BIOCHAR OPTION VERSUS INCOME

CHAPTER FOUR
Best-Worst CVM Management Analysis of Pine Beetle Killed Trees: Burn on Site and Biochar: A Larimer County Case Study

I. INTRODUCTION

Problem Statement

In the last few years, the pine beetle invasion of lodge pole pines in the intermountain US has left 21.7 millions of acres of dead trees since 1996. In particular, one of the contributing factors to the intensity and rapid spread of fires in the summer 2012 in Colorado is that the region contained 70 percent beetle-killed pine trees. The High Park Fire near Fort Collins, Colorado burned an estimated 87,250 acres. The Waldo Canyon fire near Colorado Springs, Colorado burned 18,247 acres.

One purpose of this study is to estimate Larimer County Colorado households' non-market values for two forest management options for reducing intensity of future wildfires and associated non-market environmental effects of wildfires. The first policy is the traditional harvesting of dead pine beetle killed trees and burn on-site. The second involves harvesting but involves moving the trees offsite and converting into biochar, reducing some of the environmental effects associated with burning the dead trees on-site. The second objective is to compare the performance of the standard conditional logit model on the respondents most preferred choice to a rank ordered logit model that is applied when respondents are given the option of identifying the most preferred option but also the worst option out of the three management options.

Choice Experiment

In the design of stated preference surveys the number of attributes and number of levels that each attribute could take should be clear. We have selected 7 non-price attributes and a cost variable: (1) Acres of pine beetle killed trees; (2) Percentage of forest that burns each year; (3) frequency of wildfires; (4) air pollution; (5) greenhouse gas emission; (6) water quality in streams; (7) months recreation sites would be closed; (8) annual cost to taxpayers. In our survey air pollution, greenhouse gas emission (GHG), and months that recreation areas were closed are the only attributes that change from one management option to another. We provide the respondents with a bid amount where each management option cost differs. So, different combinations of these three attributes cost differently and each combination gives respondents different levels of the protection from forest fires. However, because of limited budget and the color paper surveys, an orthogonal design which values level of attributes given to a subset of respondents was not possible, so the attributes only vary between management options. Another reason for not varying the other attribute is that any forest management program that involves thinning has the same effect on reducing the risk of wildfire.

Choice experiments have been used to evaluate river types, recreational moose hunting, and protection of old growth forest, landscape and wildlife protection, and value of landscape (Adamowicz et al (1994), Boxall et al (1996), Adamowicz et al (1998), Hanley et al (1998), Bergland (1997)). The distinguishing feature of the choice experiment using the most preferred and least preferred choice is that instead of just selecting the most preferred alternatives, the respondent also identifies the least preferred alternative. This provides additional information per respondent. With just three choices, identification of most preferred option and least preferred option provides a complete ranking that can be analyzed using a rank ordered logit.

Louviere and Woodworth (1983) developed least preferred and most preferred choice sets in a choice experiment settings, where an alternative will be chosen among different alternatives as least and most preferred option. Each alternative represents combinations of different attributes.

Lusk and Briggeman (2009) surveyed 2000 households, and used the best-worst scaling approach to measure 11 consumers' food value for organic food. They used the random parameters model (RPL) to analyze consumer's value for organic food and concluded that values of food safety, nutrition, taste and price were the most important to consumers. Scarpa et al (2011) used best-worst rank order to evaluate benefits of tourism in alpine grazing commons under four management alternatives to figure out a fee system that highlights the WTP of respondents.

II. SURVEY IMPLEMENTATION

In the survey, we asked participants to choose their most and least preferred management option among the current management option, burn on site option and biochar option. Ranking provides more information than just asking the participants to choose one single option and provides us with the participants' preference among three management options available to them. So a participant chooses one management option over another because the probability of the utility of that alternative is greater than the other alternatives.

IN OUR SURVEYS WE HAVE DONE TWO SURVEYS OF BEST- WORST INFORMATION PROVIDED TO RESPONDENT ABOUT BIOCHAR AND THE BOTH WE ASKED THE RESPONDENTS TO CHOOSE THEIR MOST THERE WERE JUST THREE CHOICES. THIS GAVE US THE ABILITY TO WE USE MORE INFORMATION THAN A SINGLE CHOICE MODEL. THE

WORST SURVEY IS PRESENTED IN

	Option 1: Current Management	Option 2: Burn Beetle Killed Trees on Site	Option 3: Convert Beetle Killed Trees to Biochar
Pine Beetle Killed Trees (Acres Infested)			
% Forest Burned Every 10 Years	20%	10%	10%
Forest Fire Frequency	More frequent, intense wildfires	Less frequent, less intense wildfires	Less frequent, less intense wildfires
Air Pollution from Fire Smoke (# Average Days)	High Air Pollution 10 Unhealthy days	Low Air Pollution 4 Unhealthy days	Very Low Air Pollution 2 Unhealthy days
Greenhouse Gas Emissions	High	Medium	Low
Water Quality in Streams and Lakes in Areas Burned	Frequently Muddy	Rarely Muddy	Rarely Muddy
# Of Months Recreation Areas are closed	6 Months	2 Months	1 Month
Annual Cost to Taxpayers			

1. Using the information provided in the table above which option is your **Most** Preferred? (Check one)
   Option 1 ☐ Option 2 ☐ Option 3 ☐

2. Using the information provided in the table above which option is your **Least** Preferred? (Check one)
   Option 1 ☐ Option 2 ☐ Option 3 ☐

Figure 4.1.

We created a color mail survey that was sent to a random sample of 1000 residents of Larimer County, Colorado. We used Dillman mailing method (Dillman and Sallant, 1994) as follows: we sent the first mailing to 1000 residents of Larimer County in the May of 2013 with a $1 bill attached, and a follow-up post card reminder two weeks after our initial mailing. We sent a second mailing to non-respondents, followed by post-card reminders one month after our first mailing, and a third mailing in June of 2013 to a portion of our second mailing non-respondents, followed up with post-card reminders. We sent a fourth mailing in August. Accounting for non-deliverable, non-usable data, and ineligible data (one who moved to out of state) our response rate for usable (the surveys that answer the willingness to pay question) and returned surveys for the 8 page best-worst survey, and 12 page best-worst survey are 36.29%,and 38.19%, respectively. Our high response rate of 38% may in part be due to increased interest wildfires due to seriously destructive wildfires that hit Colorado Springs just as our survey went into the field.

III. ANALYSIS OF DATA

Descriptive Statistics Analysis

Table 4.1 shows that 60% of respondents were female, 77.4% were seniors, 27.6% live in the rural area, and 84.8% visit the forest for recreational activities such as hiking, mountain biking, skiing, camping, etc, and 27.37% have higher education (Bachelor or Graduate Degree). The high level of recreation participation and high education explains why most of them vote to protect the forest and were willing to pay even at higher bids such as $900. Only 37.7% of our participants are in a middle income range. Having higher income level and higher education may have influenced our results toward biochar option, because they want to protect the forest against fires. You can weigh the higher income by index lower than 1 and lower income by index higher than1 to check whether the results would change or not. This can be investigated for future research.

We also calculate the percentage in which respondents chose burn on site management option, option 2 versus move dead branches offsite and convert into biochar, option 3. These results are shown in Table 4.2. As a result respondents chose option 3, 51% of the time, and option 2, 32.5% of time, and the no cost, no action alternative the reminder of time. This can help us understand why most of respondents chose option 3 despite the higher cost.

A Fully Parametric Model

A fully parametric model with finite number of parameters $\beta's$ (a vector of parameters) involves a unique probability distribution based on a fully defined probability distribution. In other words a known probability distribution density for dependent variable and explicit conditional mean are assumed.

Where y is the dependent variable, X is a vector of explanatory variables, β is a vector of unknown parameters, and ε is the disturbance term which has a normal distribution with a mean of zero and variance of σ^2. We utilized conditional logit and rank ordered logit models to analyze our best-worst survey data.

Random Utility Model

The choice experiments are also known as attribute-based method (Holmes, T. and Adamowicz, W. p187-188, 2003). The attribute–based surveys utilized random utility maximization models (RUM). The RUM consists of two parts, a systematic part (v) and random components (ε):

$$U_j = v(x_j, p_j; \beta) + \varepsilon_j \qquad \text{Equation 4-1}$$

Where U_j is an unobservable indirect utility associated with proposed management j, x_j is vector of attributes associated with proposed management j, p_j is the cost associated with proposed management j, β is a vector of preference parameters, ε_j random error with zero mean. If we assume that utility is linear in its parameters Holmes, and Adamowicz (2003:188) show that

$$U_j = \sum_{k=1}^{K} \beta_k x_{jk} + \beta_p p_j + \varepsilon_j \qquad \text{Equation 4-2}$$

Where β_k is the preference parameter (of the attribute that is chosen by the respondent), which is marginal utility of enjoying attribute k from proposed management j, x_{jk} is the attribute k in proposed management j (such as water quality, air quality,…etc.), and β_p is the parameter of the cost associated with proposed management, and is representative of the marginal utility of money when cost of proposed management increases, the satisfaction from applying that management option to decrease forest fires.

Conditional Logit Model

We can derive the conditional logit model from random utility model (RUM). In the conditional logit model we have the same vector of parameters (β) across different choices (X). We can use the conditional logit model to predict the probability that a new alternative will be chosen, since the parameters stay the same across choices (Amemiya, 1985).

Conditional logit models are limited to the binary nature of the dependent variable, where participants chose a management option against the current management option or not.

The derivations presented in Equation 4-3 through Equation 4-11 are from Maddala (1983: p 60). Assume the individual faces with m management options (in our case m=3), Y_i^* is the latent variable which indicates the indirect utility that individual gain from choosing choice i then you can write the following equations

$$Y_i^* = V_i(X_i) + \varepsilon_i \qquad \text{Equation 4-3}$$

X_i is vector of attributes for choice i, and ε_i is the error term that shows the unobserved variations in the attributes of alternative. The observed Y_i takes values of zero or one

$$\{Y_i = 1 \text{ if } Y_i^* = \max(Y_1^*, Y_2^*, \dots, Y_m^*) \qquad \text{Equation 4-4}$$

$$Y_i = 0 \text{ otherwise}\}$$

The error term ε_i is independently and identically distributed (iid) and has a standard type I extreme value distribution with cumulative density of the following form:

$$F(\varepsilon_i < \varepsilon) = exp^{-e^{(-\varepsilon)}} \quad \text{Equation 4-5}$$

And the probability density function (PDF) is

$$f(\varepsilon_i) = \exp(-\varepsilon_i - e^{-\varepsilon_i}) \quad \text{Equation 4-6}$$

X_j represent the vector of attributes for choice i, and β is the parameter across choices. The probability of saying yes $Pr(Y_j = 1)$ will be

$$P\big((Y_i = 1|X)\big) = \frac{\mathrm{e}^{V_i}}{\sum_{j=1}^{m} e^{V_j}} = \frac{\exp(x_j'\beta)}{\sum_{j=1}^{m} \exp(x_j'\beta)} \quad \text{Equation 4-7}$$

From the Equation 4-7, $Y_i^* = \max(Y_1^*, Y_2^*, \dots, Y_m^*)$, $\varepsilon_i + V_i > \varepsilon_j + V_j$, we can rewrite CDF as:

$$\mathrm{P}(\mathrm{Y_i} = 1) = \mathrm{P}\big(\varepsilon_\mathrm{i} + \mathrm{V_i} > \varepsilon_\mathrm{j} + \mathrm{V_j}\big) \quad \text{Equation 4-8}$$

$$= \mathrm{P}\big(\varepsilon_\mathrm{j} < \varepsilon_\mathrm{i} + \mathrm{V_i} - \mathrm{V_j}\big)$$

$$= \int_{-\infty}^{\infty} \prod_{\mathrm{i} \neq \mathrm{j}} \mathrm{F}\big(\varepsilon_\mathrm{j} < \varepsilon_\mathrm{i} + \mathrm{V_i} - \mathrm{V_j}\big)$$

$$* \mathrm{f}(\varepsilon_\mathrm{i}) d\varepsilon_\mathrm{i} \;\; \forall \, \mathrm{i} \neq \mathrm{j}$$

Let’s rewrite the second component as following:

$$\prod_{i \neq j} F\big(\varepsilon_j < \varepsilon_i + V_i - V_j\big) * f(\varepsilon_i) \quad \text{Equation 4-9}$$

$$= \prod_{i \neq j} \exp(-e^{-\varepsilon_i - V_i + V_j}) \exp(-\varepsilon_i$$

$$- e^{-\varepsilon_i}) = \exp[\varepsilon_i - e^{-\varepsilon_i}(1 + \sum_{i \neq j} \frac{\mathrm{e}^{V_j}}{\mathrm{e}^{V_i}})]$$

$$\lambda_i = \log\left(1 + \sum\nolimits_{i \neq j} \frac{\mathrm{e}^{V_j}}{\mathrm{e}^{V_i}}\right) = \log(\sum_{j=1}^{m} \frac{\mathrm{e}^{V_j}}{\mathrm{e}^{V_i}}) \qquad \text{Equation 4-10}$$

Using λ_i definition, we can rewrite equation as

$$\int_{-\infty}^{\infty} \exp(-\varepsilon_i - e^{-(\varepsilon_i - \lambda_i)}) d\varepsilon_i = \exp(-\lambda_i) \qquad \text{Equation 4-11}$$

$$= \frac{\mathrm{e}^{V_i}}{\sum_{j=1}^{m} e^{V_j}}, \varepsilon_i - \lambda_i = \varepsilon_i{}^*$$

In our model, participants are faced with a discrete choice (yes/no) among three management alternatives. The variable Y is our discrete choice among 3 alternatives. The regressor shows the characteristics of the choices such as air pollution, water pollution, number of months that recreation area is closed, etc.

Rank Ordered Logit Model

The rank-ordered logit model has higher efficiency compared to a conditional logit model where participants choose their best and worst management options and that leads to a more efficient estimator than under the conditional logit model. The rank-ordered logit model makes an assumption that disturbance term takes an extreme value distribution, and disturbance term ε is unknown to the researcher and is treated as a random component. We make use of all the information by applying a multinomial model to an exploded data set consequently. The “explosion" phrase defined as breakdown process to use additional information from ranking (Beggs, Cardell, and Hausman 1981). Each choice set includes the most preferred and least preferred management options among current management options and suggested management options of burn on site and move offsite and convert to biochar.

The logit probability of participant i choosing option j among k alternatives, which in our case is three management options can be estimated via

$$P_{ij}(Y_{ij} = k) = \frac{\exp(V_{ijk})}{\sum_{k=1}^{3} \exp(V_{ijk})} \qquad \text{Equation 4-12}$$

The likelihood of individual i ranking three management options in the order of 3, 2, 1 within their choice set j can estimated by applying exploded conditional logit function. This calculation process is as follows; multiplying the conditional logit probability of choosing alternative 1 from the choice set j times the conditional logit probability of choosing alternative 2 from the list 1, and 2 (Chapman and Staelin, 1982):

$$\Pr(Rank\ 3{,}2{,}1) = pr(3|1) * pr(2|1 - \{3\}) \qquad \text{Equation 4-13}$$

(Train, 2009, p.161) calculated the following probability of ranking alternative 3, 2, and 1 respectively:

$$\Pr(\text{Rank } 3{,}2{,}1) = \frac{\exp V_{ij3}}{\sum_{k=1,2,3}^{J} \exp V_{ijk}} * \frac{\exp V_{ij2}}{\sum_{k=1,2,3}^{J} \exp V_{ijk}} \qquad \text{Equation 4-14}$$

Where V_{ij3} is the observable indirect utility that individual i gets from choosing alternative 3, V_{ij2} is the observable indirect utility that individual i gets from choosing alternative 2.

I used clogit for conditional logit and rologit for rank ordered logit in STATA version 12. I ranked my data using the most preferred and least preferred management options that participants have chosen, where best option ranked as 1, and worst option is ranked as 3. I grouped my observation based on identification number, which is the same for all options (1, 2, and 3). The small sample of data is presented in Table 4.3.

IV. RESULTS

Econometrics, Likelihood Ratio Test (LRT)

In order to choose between rank order logit and latent class model, we calculate likelihood ratio test as following:

$$LRT = -2 \log\left(\frac{L_r(\hat{\theta})}{L_u(\hat{\theta})}\right) \qquad \text{Equation 4-15}$$

Where u stands for unrestricted logistic model and r is the restricted logistic model. The restricted model is for the 8-page survey rank-ordered logistic in which less information about biochar was provided in the survey, and 12-page survey rank-ordered logistic is our unrestricted model. Our null hypothesis is that restriction does not make any difference, and alternative hypothesis is that restricted model is better than unrestricted model. This test is asymptotically distributed as chi-squared. This test compares rank-ordered logistic models of the 8-page and 12-page surveys. The LRT calculated statistic is 0.0325 which is lower than chi-square statistic at 95% level, and this leads to result that restriction does not make any difference in our models.

WTP for Biochar Management Options

Table 4.4 presents the results of the rank ordered logit model, Table 4.5 and Table 4.6 present pooled rank ordered and pooled conditional logit models. In the rank-ordered logit, we asked the participants to select their most preferred and least preferred management option. Using that information on the three alternative management options we ranked their selected option. The rank-ordered logit cost coefficient is negative as expected, and significant. The estimated WTP is $508, which is the ratio of option3dummy divided by cost coefficient. The cost coefficient for burn on site was not significant, so we have not calculated the WTP.

The demographic characteristic was included in the conditional logit model, but it did not improve the results and made the results worse. This suggests the rank order logit, by utilizing more information per respondent, as a statistically more efficient estimate with our data.

V. CONCLUSION

Based on our calculations and the level of significance for cost coefficients, we were able to choose our rank-ordered logit model WTP calculations as our best estimate for the biochar option. The reason behind that is the cost coefficients for conditional logit was not significant which does not make sense to calculate WTP. We did not use any information criteria test such as BIC or AIC to choose the best model, since the cost coefficient in the conditional logit model was not significant, so we only ended up with one model. We found that the WTP for biochar using rank ordered logit is $508 per household.

TABLES

TABLE 4.1: DESCRIPTIVE STATICS FOR RANK ORDERED LOGIT AND CONDITIONAL LOGIT

Variable	Obs	Mean	Std. Dev.	Dummy Definition
Gender	368	0.60	0.489	1 if female, 0 otherwise
Rural	362	0.276	0.447	1 if resides in rural,0 otherwise
Visitfor	368	0.848	0.359	1 if visitfor,0 otherwise
Forthgrade	1096	0.0055	0.0738	1 if edyears<=4
Fiftheight	1096	0.0027	0.052	1 if edyears>=5 & edyears<=8
Nintheleventh	1096	0.0137	0.116	1 if edyears>=9 & edyears<=11
Nohsdiploma	1096	0.115	0.319	1 if edyears==12
Hsdiploma	1096	0	0	1 if edyears>12& edyears<13
Somecollege	1096	0.208	0.406	1 if edyears==13
Associatedegree	1096	0.091	0.288	1 if edyears==14
College	1096	0.290	0.454	1 if edyears==16
Graduate or Professional Degree	1096	0.273	0.446	1 if edyears>16
Youngadult	1096	0.0273	0.163	1 if ageyears>=20 & ageyears<=24
Adult	1096	0.284	0.451	1 if ageyears>=25 & ageyears<=44
Middleage	1096	0.432	0.495	1 if ageyears>=45 & ageyears<=64
Senior	1096	0.774	0.418	1 if ageyears<=65
Lowerclass	1096	0.079	0.27	1 if income<=22000
Midlowerclass	1096	0.199	0.40	1 if income>22000 & income<=45500
Middleclass	1096	0.377	0.485	1 if income>45500 & income<=117450
Uppermiddleclass	1096	0.292	0.455	1 if income>117450 & income<=500000

TABLE 4.2: RESPONDENT CHOICE BY MANAGEMENT OPTIONS; BURN ON SITE VERSUS BIOCHAR FOR POOLED BEST-WORST SURVEY

Option	% Respondents chose the management option
Current Management	16.54%
Burn on Site	32.52%
Convert Beetle Killed Trees to Biochar	50.94%

TABLE 4.3: SAMPLE DATA

ID	Option	Most Preferred	Least Preferred	Selected Option	Rank
1017	1	3	1	0	1
1017	2	3	1	0	2
1017	3	3	1	1	3
1021	1	3	1	0	1
1021	2	3	1	0	2
1021	3	3	1	1	3
1025	1	2	3	0	2
1025	2	2	3	1	1
1025	3	2	3	0	3

TABLE 4.4: RANK-ORDERED LOGISTIC FOR BEST-WORST SURVEYS

	Burn on Site			Move offsite and Convert to Biochar		
	Coefficient.	Std. Err.	P>|z|	Coefficient.	Std. Err.	P>|z|
Cost	.0006	.0003	.061	-.00132	.00039	.001
Option2dummy	-.89	.101	0			
Option3dummy				.67	.099	0
Sample Size	1092			1095		
Log Likelihood	-608.32			-629.69		
LR chi2	88.56			45.82		
Prob>chi2	0			0		
WTP	NA			$508		

TABLE 4.5: POOLED RANK ORDERED LOGIT

	Burn on Site			Move offsite and Convert to Biochar		
	Coefficient.	Std. Err.	P>|z|	Coefficient.	Std. Err.	P>|z|
Stackedcost	-.0028	0.00043	0	-.00132	0.00039	0.001
Option2dummy	-0.358	0.083	0			
Option3dummy				0.67*	0.99	0
Sample Size	1095			1095		
Log Likelihood	-772.93			-629.69		
Prob>chi2	0			0		
WTP	NA			$508		

TABLE 4.6: POOLED CONDITIONAL LOGISTIC FOR BEST-WORST SURVEY

	Burn on Site			Move offsite and Convert to Biochar		
	Coefficient.	Std. Err.	P>|z|	Coefficient.	Std. Err.	P>|z|
Cost	.00549	.00097	0	.00214	.00088	.0016
Option2dummy	0.0039	.11	.972			
Option3dummy				.728	.125	0
Sample Size	1092			1092		
Log Likelihood	-374.83			-358.55		
LR chi2	50.13			82.69		
Prob>chi2	0			0		
WTP	NA			NA		

FIGURES

	Option 1: Current Management	Option 2: Burn Beetle Killed Trees on Site	Option 3: Convert Beetle Killed Trees to Biochar
Pine Beetle Killed Trees (Acres Infested)			
% Forest Burned Every 10 Years	20%	10%	10%
Forest Fire Frequency	More frequent, intense wildfires	Less frequent, less intense wildfires	Less frequent, less intense wildfires
Air Pollution from Fire Smoke (# Average Days)	High Air Pollution 10 Unhealthy days	Low Air Pollution 4 Unhealthy days	Very Low Air Pollution 2 Unhealthy days
Greenhouse Gas Emissions	High	Medium	Low
Water Quality in Streams and Lakes in Areas Burned	Frequently Muddy	Rarely Muddy	Rarely Muddy
# Of Months Recreation Areas are closed	6 Months	2 Months	1 Month
Annual Cost to Taxpayers			

1. Using the information provided in the table above which option is your **Most** Preferred? (Check one)

   Option 1 ☐ Option 2 ☐ Option 3 ☐

2. Using the information provided in the table above which option is your **Least** Preferred? (Check one)

   Option 1 ☐ Option 2 ☐ Option 3 ☐

FIGURE 4.1: BEST- WORST RANK SURVEY SAMPLE

CHAPTER FIVE
Concluding Remarks

I have applied different econometric methods to secondary data of dairy prices, and primary data that have been collected from color mail surveys. I have learned that different characteristics of data require different econometric methods. In the second chapter we have stationary versus non-stationary data which requires time series modeling in order to forecast the dairy prices for out of sample January 2010 to December 2013. We discovered that VAR (2) has the best forecasting results with lowest RMSE for later months in the forecast, and AR (2) has the lowest RMSE for first two months. In the third and fourth chapters we were dealing with primary data that we have collected from color mail surveys that were sent to a random sample of residents of Larimer County. The dependent variable in the non-market section is dichotomous which utilizes non-parametric and fully parametric models (maximum likelihood estimators (MLE)) which were consistent with economic theory.

We applied a non-parametric model to our repeated CVM surveys and fully parametric models to best-worst surveys in which respondents rank the suggested management options from the most preferred to least preferred option. The WTP for two suggested management options of burning onsite (Option2) and move the dead trees to an offsite area and converting the dead trees into biochar (Option 3) were calculated. We discovered that there is a substantial WTP of Larimer County resident to avoid the forest fires, and there was a 15% difference of what management actions to use to avoid the forest fires and their consequences. The WTP for Option 2 is $411, and Option 3 is $470 per household.

For the last chapter, two versions of best-worst stated preference studies have been sent to the Larimer County and participants were asked to choose their worst and best management options. We applied rank-ordered logit and conditional logit models to calculate the WTP for the Larimer County residents. Ranking the management options uses more information and the rank-ordered logit model outperformed conditional logit model, however we could only calculate WTP for moving the dead branches to offsite and converting them into biochar management, and the WTP for Option 3 is $508 per household.

The magnitude of WTP per household for the biochar option in the non- parametric ($470), and rank ordered logit model ($508) are quite similar. One reason is that Turnbull is lower bound, if the respondent says yes to $25; their WTP is considered only at $25, not in between $25 and next highest Bid amount. If the respondent says "no" to the lowest bid amount, then Turnbull says WTP is zero.

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APPENDIX: SURVEY INSTRUMENT

Colorado State University

How should Your Forests be managed in Colorado?

What do you think?

Please read the following information before answering the survey questions.

What are the Problems facing Colorado Forests?

Colorado forests are on private land, state lands (state forests and parks), and federal lands (National Parks and National Forests). Being in a hot and dry area, Colorado has frequent wildfires on forest land. One result of 100 years of fighting forest fires and reducing logging over the last 25 years is that forests in the Colorado are overgrown and vulnerable to catastrophic wildfire and attack by insects and disease. Making matters worse over the last several years has been a large outbreak of mountain pine beetle. Pine beetles are native to Colorado and have always been around, but weather and drought and densely packed forests have made this recent outbreak much larger and more severe than in previous years. Those conditions generally make forest fires larger, burn hotter and longer, and cause more severe damage. Most of the trees are so small in diameter that they are neither suitable nor profitable to turn into lumber, paper or other commercially valuable products.

One question we face as citizens is how to deal with all these dead trees, especially given their contribution to unusually damaging forest fires. In particular, one of the contributing factors to the intensity and rapid spread of fires in 2012 is that the region contained about 70 percent beetle-killed pine trees. The High Park Fire near Fort Collins burned an estimated 87,250 acres. Smoke from the fires made the area unhealthy for several days. Soil erosion resulting from the burned area muddied the Poudre River. The Waldo Canyon fire near Colorado Springs burned 18,247 acres.
A total of 35 large wildfires occurred in Colorado in 1989, 1990, 1994, 1996, 2000, 2002, 2003, and 2012.

What Can be Done?

One approach to reduce the fire hazard and slow the spread of pine beetles is to remove the dead and dying trees and cut some live trees to thin the forest to reduce spread of pine beetles. Thinning the forests to clear out insect and disease-killed trees is expensive.

Two approaches have been suggested to deal with the disposal problem:

1. Collect and pile the dead and dying trees and burn them on the forest when it is safe to do so. This solves the disposal problem at a low cost but contributes to smoke, air pollution, and greenhouse gas emissions; and has a small risk of burning out of control and spreading. Even without pine beetles there will be a need to do forest thinning and some amount of timber harvest. Thus, there will always be residual material to dispose of.

2. Collect the dead and dying trees and move them to an area off the forest where they can be converted into a product called ***"biochar*."** Biochar is a charcoal-like material that can be produced from wood (including beetle-killed trees) by heating the wood in a closed chamber with a low oxygen level. Biochar is useful as a soil amendment and can be used in forest soil restoration and home gardens. This solves the disposal problem at a higher cost. However, emissions are controlled to meet pollution standards and most of the carbon is captured in the biochar; it also creates a useful product from waste material taken off the forest. Even without pine beetles there will be needs to do forest thinning and some amount of timber harvest. Thus, there will always be residual material to dispose of.

You will be asked later in the survey to choose between three alternative options for dealing with the problems faced by Colorado Forests. Each alternative will be described, but first we want to ask you about some other things.

Several objectives are used in deciding how to manage forests, particularly forests on public lands. There might be tradeoffs between some of those objectives such that one objective must be given priority over others. Please tell us how important you think the following objectives are for deciding management priorities.

Circle one number for each objective.

Objective	Not Important	A Little Important	Moderately Important	Important	Very Important
Provide opportunities for high quality recreational use of the forest.	1	2	3	4	5
Provide high water quality in streams and rivers.	1	2	3	4	5
Provide high air quality.	1	2	3	4	5
Contribute to managing climate change since trees absorb and store carbon.	1	2	3	4	5
Improve forest health.	1	2	3	4	5
Control soil erosion.	1	2	3	4	5

Please answer each of the following questions.

Q1. Have you ever been affected by a wildland fire? (*Circle all that apply)*.

1. Smelled smoke from wildland fire.
2. Seen a wildland fire.
3. Been notified to prepare to evacuate your house as a result of a wildland fire.
4. Evacuate your home as a result of a wildland fire.
5. Suffered property loss or damage from a wildland fire.
6. Friends, relatives, or acquaintances of mine have either been evacuated or told to be prepared to be evacuated from their homes.

Resource managers seek ways to allow fires to burn more naturally and less dangerously. This can involve thinning forests using different methods. There are advantages and disadvantages associated with both of these methods, and we are interested in your opinions about using them.

- **Prescribed fire** –This involves letting a naturally-caused fire burn under close watch or intentionally setting fires in ways that can be controlled to produce the desired forest conditions.
- **Mechanical vegetation removal** – Using chainsaws or other specialized logging equipment to remove trees and other forest vegetation to produce the desired forest conditions.

Please answer the next 3 questions by circling the number next to the response that most closely matches your opinion. There are no right or wrong answers. We want to know what you think.

Q2. In my opinion, intentionally setting prescribed fires on public forests and rangelands is: (*Circle One)*

1. A legitimate tool that resource managers should be able to use as needed.
2. Something that should be done only infrequently, in carefully selected areas.
3. A practice that should not be used because it creates too many negative impacts
4. An unnecessary practice.
5. I know too little to make a judgment about this topic.

Q3. In my opinion, mechanical vegetation removal on public forests and rangelands is: (*Circle One)*

1. A legitimate tool that resource managers should be able to use as needed.
2. Something that should be done only infrequently, in carefully selected areas.
3. A practice that should not be used because it creates too many negative impacts.
4. An unnecessary practice.
5. I know too little to make a judgment about this topic.

Q4. Please indicate your preference for treating the existing buildup of dead trees in Colorado. (*Circle One)*

1. Use mechanical removal only.
2. Use prescribed fire only.
3. Do nothing; let nature take its course.
4. Remove trees useful for wood products, lumber, or firewood; then follow with prescribed fire as needed.
5. None of the above. What would you do? ____

Next we present information on three different options to deal with pine beetle killed trees and forest fires in Colorado. After reading this, we will ask you which option you would choose.

For each of the following questions, circle the number that best matches your opinion.

	Strongly Disagree	*Somewhat disagree*	*Neutral*	*Somewhat agree*	*Strongly Agree*	*Don't know*
Prescribed or controlled burning is too risky to be used for public forest management.	-2	-1	0	1	2	X
I am opposed to cutting trees on public forests.	-2	-1	0	1	2	X
If there were a way to use all the dead trees removed from the forest, I would be more favorable toward cutting trees on public forests.	-2	-1	0	1	2	X
We need to cut trees on public forests to decrease the risk of catastrophic wildfire.	-2	-1	0	1	2	X
We should let fires burn and let nature take its course.	-2	-1	0	1	2	X
The most important role for public forests is providing jobs and income for local people.	-2	-1	0	1	2	X
If people choose to live in or next to public forests, they must be willing to accept the risk of wildfire and damage to their property.	-2	-1	0	1	2	X
It's OK to use tax dollars to protect homes of people who choose to live in or next to public forests.	-2	-1	0	1	2	X
Thinning public forests to decrease the risk of catastrophic wildfire is too expensive. We should let fires burn.	-2	-1	0	1	2	X
Fighting wildfires on public forests is too expensive. We should let them burn.	-2	-1	0	1	2	X
It is ecologically beneficial to the forest to allow wildfires to burn.	-2	-1	0	1	2	X
We should harvest trees on public forests as long as we maintain forest health.	-2	-1	0	1	2	X

1. First Option/ Current Management:

Current Management Actions:

- *Continue the current level of forest management activity*
- *Selectively remove dead and dying trees only in high hazard areas (for example, around houses, campgrounds, highways, etc).*

Effects of Current Management:

1. 70 percent of forest has beetle killed trees.
2. 20 percent of forest burns every 10 years.
3. ***High*** amounts of air pollution from fires resulting in ***10 unhealthy days*** from fire smoke.
4. ***High*** amounts of greenhouse gases are produced, worsening climate change.
5. When it rains after a fire, flash floods and erosion bring soil into streams and reduce water quality. This can result in fish kills and higher water treatment costs.
6. If there is a fire, forest recreations areas and trails burned and closed to public for ***6 months***.

Picture to Illustrate the First Option/ Current Management:

Pine Beetle Killed Trees
Combined with Healthy Trees

Forest Fires

Burnt Forest

Second Option: Clear more forests of pine beetle killed trees and burn them on the forest

Management Actions:

- *Harvest dead and dying beetle-killed trees throughout the forest*
- *Selectively thin out trees throughout the forest*
- *Burn collected dead trees and residual materials on the forest where harvested*

Effects of Option 2:

1. 25 percent of forest has beetle-killed trees; thinned areas have fewer trees.
2. 10 percent of forest burns every 10 years. Fires that do occur are less intense than in unthinned areas.
3. Minimal smoke from wildfires. ***Some*** air pollution from burning on-site. ***4 unhealthy days*** from fire smoke.
4. ***Medium*** amounts of greenhouse gases are produced which slightly worsens climate change.
5. Less flash flooding and soil erosion, resulting in less dirt entering streams, thus protecting existing water quality. There is a reduced chance of fish kills, and no increase in water treatment costs or minimal.
6. Forest recreation areas are closed for cutting dead trees and during burning on site for ***2 months***.

Picture to Illustrate the Second Option/ Clear more forests of pine beetle killed trees and burn them on the forest

Pine Beetle Killed Trees

Piles of Pine Beetle
Killed Trees

Burning Pine Beetle
Killed Trees

3. Third Option: Clear more forests of pine beetle killed trees and convert to biochar

Management Actions:

- *Harvest dead and dying beetle-killed trees throughout the forest*
- *Selectively thin out trees throughout the forest.*
- *Move these cut trees off the forest*
- *Convert these trees into Biochar by burning in an enclosed unit*

Effects of Option 3:

1. 25 percent of forest has beetle killed trees; thinned areas have fewer trees.
2. 10 percent of forest burns every 10 years. Fires that do occur are less intense.
3. Minimal smoke from wildfires. ***Very low*** air pollution as tree burning takes place in enclosed chambers. ***2 unhealthy days*** from fire smoke.
4. ***Low*** amounts of greenhouse gases are emitted from the chamber, therefore minimal effect on climate change.
5. Less flash flooding and erosion, resulting in less soil entering streams, thus protecting existing water quality. There is a reduced chance of fish kills, and no increase in water treatment costs or minimal.
6. Forest recreation areas are closed for cutting dead trees for **1 month**.

Picture to Illustrate the Third Option/ Clear more forests of pine beetle killed trees and convert biochar

Pine Beetle Killed Trees

Piles of Pine Beetle Killed Trees

Wood Chips

Biochar

In order to compare the three options, we want to describe the possible forest conditions with each option. The following symbols will be used to represent the level of the effect of each management alternative on forest conditions. More symbols displayed indicate more of whatever the symbol represents—more healthy trees, more beetle-killed trees, etc. In the case of recreation, more symbols indicate greater negative effect on recreation.

Resource Descriptions

 Healthy trees: better able to withstand fire and attacks by beetles.

 Pine beetle killed trees: dead and dying trees infested by pine beetles.

 Frequency of wildfires: The number and intensity of forest fires that do occur.

 Unhealthy air quality days: everyone experiences some undesirable health effects. People with lung and heart disease as well as young children and senior citizens might need to avoid going outside.

 Clean River/Lake: when water is suitable for all fish, recreational activities such as swimming, kayaking, and only minimal treatment is needed for purifications for drinking water.

 Muddy River/Lake: when ashes from forest fire and dirt is in the river. The river is unsuitable for recreational activities, is harmful for fish, and extra treatments needed to purify for drinking water.

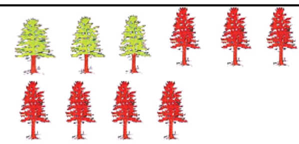
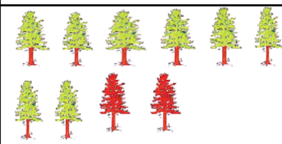
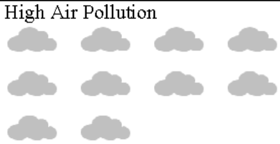
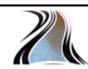
 Closed recreation areas: number of months that hiking trails, and camping areas are closed due to forest fire, and cleanup activities.

Paying for Increased Forest Management

Because there is a large amount of federal land such as National Forests in Colorado, cost of reducing the wildfire hazard will be shared between all U.S. taxpayers and Colorado taxpayers. Two combined federal and state taxes would increase, with the amount of the increase depending on the management option selected.

The Federal tax would be in the form of an increase in income tax. Colorado state taxes would combine an increase in sales tax with an increase in state income tax. These annual tax amounts would be for 10 years, taking effect in 2014 and expiring in 2024. The money would go in a separate and dedicated fund for pine beetle and forest treatments that would be monitored by a citizen advisory panel.

In this table two alternatives policy scenarios are provided. Please read carefully and choose your option below.

	Option 1: Current Management	Option 2: Burn Beetle Killed Trees on Site
Pine Beetle Killed Trees (Acres Infested)		
% Forest Burned Every 10 Years	20%	10%
Forest Fire Frequency	 More frequent, intense wildfires	 Less frequent, less intense wildfires
Air Pollution from Fire Smoke (# Average Days)	High Air Pollution  10 Unhealthy days	Low Air Pollution  4 Unhealthy days
Greenhouse Gas Emissions	High	Medium
Water Quality in Streams and Lakes in Areas Burned	 Frequently Muddy	 Rarely Muddy
# Of Months Recreation Areas are closed	 6 Months	 2 Months
Annual Cost to Taxpayers		

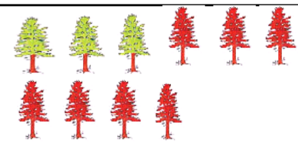
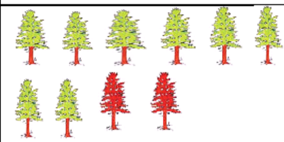
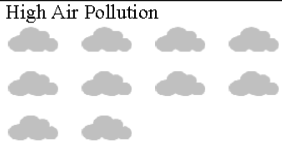
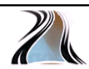
1. Using the information provided in the table above, which option would you choose? (*Check one box).*

Option 1 ☐ Option 2 ☐

There are no right or wrong answers. We are just interested in your honest opinions. Why did you select the alternative that you did? ____

____

In this table two alternatives policy scenarios are provided. Please read carefully and choose your option below.

	Option 1: Current Management	Option 3: Convert Beetle Killed Trees to Biochar
Pine Beetle Killed Trees (Acres Infested)		
% Forest Burned Every 10 Years	20%	10%
Forest Fire Frequency	 More frequent, intense wildfires	 Less frequent, less intense wildfires
Air Pollution from Fire Smoke (# Average Days)	High Air Pollution  10 Unhealthy days	Very Low Air Pollution  2 Unhealthy days
Greenhouse Gas Emissions	High	Low
Water Quality in Streams and Lakes in Areas Burned	 Frequently Muddy	 Rarely Muddy
# Of Months Recreation Areas are closed	 6 Months	 1 Month
Annual Cost to Taxpayers		

1. Using the information provided in the table above, which option would you choose? (*Check one box*).

Option 1 ☐ Option 3 ☐

There are no right or wrong answers. We are just interested in your honest opinions. Why did you select the alternative that you did?

____

____

Please tell us something about yourself.

The last few questions will help us in evaluating how well our sample represents residents of Larimer County. **Your answer will be kept confidential and will only be used for the analysis of this study. Results will only be reported as group averages, you will not be identified in any way.**

1. Before this survey, had you ever heard of "Biochar?" ☐ Yes ☐ No
2. How far is your house from the area of the High Park Fire? (*Check one box*)
   ☐ 1-10 miles ☐ 11-19 miles ☐ 20-39 miles ☐ 40-59 miles ☐ more than 60 miles
3. Do you or anyone in your household have respiratory problems? ☐ Yes ☐ No
4. Did you evacuate your house during the High Park fire? ☐ Yes ☐ No
5. What is your gender? ☐ Male ☐ Female
6. What is your age? ________ years
7. How many individuals live in your household, including yourself? ______
8. Are you Hispanic or Latino? ☐ Yes ☐ No
9. With which racial group(s) do you most closely identify? (*Circle all that apply*).
   1 American Indian/Alaska Native
   2 Asian
   3 Black/African American
   4 Native Hawaiian or other Pacific Islander
   5 White
10. What is the highest level of schooling you have completed? (*Circle one number*).
    1 Fourth grade or less
    2 Fifth through eighth grades
    3 Ninth through eleventh grades
    4 Twelfth grade, no diploma
    5 High school graduate (including GED)
    6 Some college
    7 Associates degree
    8 Bachelor's degrees
    9 Graduate or professional degree
11. Do you live in a ☐ Rural area ☐ Urban area?
12. I live in ☐ A Rented Property ☐ A Property I Own
13. Did you visit Colorado forests in the last 12 months for…
    No, I did not visit any Colorado forests in the last 12 months.
    Yes, I did visit a Colorado forest and I did the following activities: (*Check all that apply*)
    ☐ Camping ☐ Hiking ☐ Mountain Biking ☐ Bird Watching
    ☐ Snow Skiing ☐ Backpacking ☐ Other (please list): ____________
14. How much was your household income from all sources (before taxes) last year? (*Check one*)
    _____ Less than $10,000
    _____ $10,000-$19,999
    _____ $20,000-$29,999
    _____ $30,000-$39,999
    _____ $40,000-$49,999
    _____ $50,000-$59,999
    _____ $60,000-$69,999
    _____ $70,000-$79,999
    _____ $80,000-$89,999
    _____ $90,000-$99,999
    _____ $100,000-$149,999
    _____ $150,000-$199,999
    _____ $200,000 or more
15. How many household members contributed to this income? ____________

Thank you very much for completing the survey!

Forest Management Survey in the State of Colorado

Is there anything else that you would like to tell us about the forest management? If so, please feel free to write any thoughts or comments you have regarding forest management in Colorado, here.

When done please put this completed survey in the enclosed stamped return envelope.

Fold here for mailing

Fold here for mailing

Department of Agricultural and Resource Economics
Colorado State University
Fort Collins, Colorado 80523-1172

Colorado State University

How should Your Forests be managed in Colorado?

What do you think?

Please read the following information before answering the survey questions.

What are the Problems facing Colorado Forests?

Colorado forests are on private land, state lands (state forests and parks), and federal lands (National Parks and National Forests). Being in a hot and dry area, Colorado has frequent wildfires on forest land. One result of 100 years of fighting forest fires and reducing logging over the last 25 years is that forests in the Colorado are overgrown and vulnerable to catastrophic wildfire and attack by insects and disease. Making matters worse over the last several years has been a large outbreak of mountain pine beetle. Pine beetles are native to Colorado and have always been around, but weather and drought and densely packed forests have made this recent outbreak much larger and more severe than in previous years. Those conditions generally make forest fires larger, burn hotter and longer, and cause more severe damage. Most of the trees are so small in diameter that they are neither suitable nor profitable to turn into lumber, paper or other commercially valuable products.

One question we face as citizens is how to deal with all these dead trees, especially given their contribution to unusually damaging forest fires. In particular, one of the contributing factors to the intensity and rapid spread of fires in 2012 is that the region contained about 70 percent beetle-killed pine trees. The High Park Fire near Fort Collins burned an estimated 87,250 acres. Smoke from the fires made the area unhealthy for several days. Soil erosion resulting from the burned area muddied the Poudre River. The Waldo Canyon fire near Colorado Springs burned 18,247 acres. *A total of 35 large wildfires occurred in Colorado in 1989, 1990, 1994, 1996, 2000, 2002, 2003, and 2012.*

What Can be Done?

One approach to reduce the fire hazard and slow the spread of pine beetles is to remove the dead and dying trees and cut some live trees to thin the forest to reduce spread of pine beetles. Thinning the forests to clear out insect and disease-killed trees is expensive.

Two approaches have been suggested to deal with the disposal problem:

1. Collect and pile the dead and dying trees and burn them on the forest when it is safe to do so. This solves the disposal problem at a low cost but contributes to smoke, air pollution, and greenhouse gas emissions; and has a small risk of burning out of control and spreading. Even without pine beetles there will be a need to do forest thinning and some amount of timber harvest. Thus, there will always be residual material to dispose of.

2. Collect the dead and dying trees and move them to an area off the forest where they can be converted into a product called ***"biochar*****.**" Biochar is a charcoal-like material that can be produced from wood (including beetle-killed trees) by heating the wood in a closed chamber with a low oxygen level. Biochar is useful as a soil amendment and can be used in forest soil restoration and home gardens. This solves the disposal problem at a higher cost. However, emissions are controlled to meet pollution standards and most of the carbon is captured in the biochar; it also creates a useful product from waste material taken off the forest. Even without pine beetles there will be needs to do forest thinning and some amount of timber harvest. Thus, there will always be residual material to dispose of.

You will be asked later in the survey to choose between three alternative options for dealing with the problems faced by Colorado Forests. Each alternative will be described, but first we want to ask you about some other things.

Several objectives are used in deciding how to manage forests, particularly forests on public lands. There might be tradeoffs between some of those objectives such that one objective must be given priority over others. Please tell us how important you think the following objectives are for deciding management priorities.

Circle one number for each objective.

Objective	Not Important	A Little Important	Moderately Important	Important	Very Important
Provide opportunities for high quality recreational use of the forest.	1	2	3	4	5
Provide high water quality in streams and rivers.	1	2	3	4	5
Provide high air quality.	1	2	3	4	5
Contribute to managing climate change since trees absorb and store carbon.	1	2	3	4	5
Improve forest health.	1	2	3	4	5
Control soil erosion.	1	2	3	4	5

Please answer each of the following questions.

Q1. Have you ever been affected by a wildland fire? (*Circle all that apply*).

1. Smelled smoke from wildland fire.
2. Seen a wildland fire.
3. Been notified to prepare to evacuate your house as a result of a wildland fire.
4. Evacuate your home as a result of a wildland fire.
5. Suffered property loss or damage from a wildland fire.
6. Friends, relatives, or acquaintances of mine have either been evacuated or told to be prepared to be evacuated from their homes.

Resource managers seek ways to allow fires to burn more naturally and less dangerously. This can involve thinning forests using different methods. There are advantages and disadvantages associated with both of these methods, and we are interested in your opinions about using them.

- **Prescribed fire** –This involves letting a naturally-caused fire burn under close watch or intentionally setting fires in ways that can be controlled to produce the desired forest conditions.
- **Mechanical vegetation removal** – Using chainsaws or other specialized logging equipment to remove trees and other forest vegetation to produce the desired forest conditions.

Please answer the next 3 questions by circling the number next to the response that most closely matches your opinion. There are no right or wrong answers. We want to know what you think.

Q2. In my opinion, intentionally setting prescribed fires on public forests and rangelands is: (Circle One)

1. A legitimate tool that resource managers should be able to use as needed.
2. Something that should be done only infrequently, in carefully selected areas.
3. A practice that should not be used because it creates too many negative impacts
4. An unnecessary practice.
5. I know too little to make a judgment about this topic.

Q3. In my opinion, mechanical vegetation removal on public forests and rangelands is: (Circle One)

1. A legitimate tool that resource managers should be able to use as needed.
2. Something that should be done only infrequently, in carefully selected areas.
3. A practice that should not be used because it creates too many negative impacts.
4. An unnecessary practice.
5. I know too little to make a judgment about this topic.

Q4. Please indicate your preference for treating the existing buildup of dead trees in Colorado. (Circle One)

1. Use mechanical removal only.
2. Use prescribed fire only.
3. Do nothing; let nature take its course.
4. Remove trees useful for wood products, lumber, or firewood; then follow with prescribed fire as needed.
5. None of the above. What would you do? ____

Next we present information on three different options to deal with pine beetle killed trees and forest fires in Colorado.

After reading this, we will ask you which option you would choose.

For each of the following questions, circle the number that best matches your opinion.

	Strongly Disagree	*Somewhat disagree*	*Neutral*	*Somewhat agree*	*Strongly Agree*	*Don't know*
Prescribed or controlled burning is too risky to be used for public forest management.	-2	-1	0	1	2	X
I am opposed to cutting trees on public forests.	-2	-1	0	1	2	X
If there were a way to use all the dead trees removed from the forest, I would be more favorable toward cutting trees on public forests.	-2	-1	0	1	2	X
We need to cut trees on public forests to decrease the risk of catastrophic wildfire.	-2	-1	0	1	2	X
We should let fires burn and let nature take its course.	-2	-1	0	1	2	X
The most important role for public forests is providing jobs and income for local people.	-2	-1	0	1	2	X
If people choose to live in or next to public forests, they must be willing to accept the risk of wildfire and damage to their property.	-2	-1	0	1	2	X
It's OK to use tax dollars to protect homes of people who choose to live in or next to public forests.	-2	-1	0	1	2	X
Thinning public forests to decrease the risk of catastrophic wildfire is too expensive. We should let fires burn.	-2	-1	0	1	2	X
Fighting wildfires on public forests is too expensive. We should let them burn.	-2	-1	0	1	2	X
It is ecologically beneficial to the forest to allow wildfires to burn.	-2	-1	0	1	2	X
We should harvest trees on public forests as long as we maintain forest health.	-2	-1	0	1	2	X

1. First Option/ Current Management:

Current Management Actions:

- *Continue the current level of forest management activity*
- *Selectively remove dead and dying trees only in high hazard areas (for example, around houses, campgrounds, highways, etc).*

Effects of Current Management:

1. 70 percent of forest has beetle killed trees.
2. 20 percent of forest burns every 10 years.
3. ***High*** amounts of air pollution from fires resulting in ***10 unhealthy days*** from fire smoke.
4. ***High*** amounts of greenhouse gases are produced, worsening climate change.
5. When it rains after a fire, flash floods and erosion bring soil into streams and reduce water quality. This can result in fish kills and higher water treatment costs.
6. If there is a fire, forest recreations areas and trails burned and closed to public for ***6 months***.

Picture to Illustrate the First Option/ Current Management:

Pine Beetle Killed Trees Combined with Healthy Trees

Forest Fires

Burnt Forest

Second Option: Clear more forests of pine beetle killed trees and burn them on the forest

Management Actions:

- *Harvest dead and dying beetle-killed trees throughout the forest*
- *Selectively thin out trees throughout the forest*
- *Burn collected dead trees and residual materials on the forest where harvested*

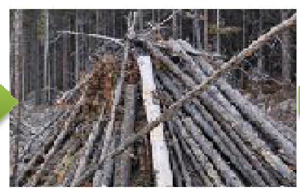
Effects of Option 2:

1. 25 percent of forest has beetle-killed trees; thinned areas have fewer trees.
2. 10 percent of forest burns every 10 years. Fires that do occur are less intense than in unthinned areas.
3. Minimal smoke from wildfires. *Some* air pollution from burning on-site. *4 unhealthy days* from fire smoke.
4. *Medium* amounts of greenhouse gases are produced which still slightly worsen climate change.
5. Less flash flooding and soil erosion, resulting in less dirt entering streams, thus protecting existing water quality.

   There is a reduced chance of fish kills, and no increase in water treatment costs or minimal.
6. Forest recreation areas are closed for cutting dead trees and during burning on site for *2 months*.

Picture to Illustrate the Second Option/ Clear more forests of pine beetle killed trees and burn them on the forest

Pine Beetle Killed Trees



Piles of Pine Beetle Killed Trees

Burning Pine Beetle Killed Trees

3. Third Option: Clear more forests of pine beetle killed trees and convert to biochar
Management Actions:

- *Harvest dead and dying beetle-killed trees throughout the forest*
- *Selectively thin out trees throughout the forest*
- *Move these cut trees off the forest*
- *Convert these trees into Biochar by burning in an enclosed unit*

Effects of Option 3:

1. 25 percent of forest has beetle killed trees; thinned areas have fewer trees.
2. 10 percent of forest burns every 10 years. Fires that do occur are less intense than in unthinned areas.
3. Minimal smoke from wildfires. ***Very low*** air pollution as tree burning takes place in enclosed chambers.

   2 unhealthy days from fire smoke.
4. ***Low*** amounts of greenhouse gases are emitted from the chamber, therefore minimal effect on climate change.
5. Less flash flooding and erosion, resulting in less dirt entering streams, thus protecting existing water quality.

   There is a reduced chance of fish kills, and no increase in water treatment costs or minimal.
6. Forest recreation areas are closed for cutting dead trees for **1 month**.

Picture to Illustrate the Third Option/ Clear more forests of pine beetle killed trees and convert biochar

Pine Beetle Killed Trees

Piles of Pine Beetle Killed Trees

Wood Chips

Biochar

In order to compare the three options, we want to describe the possible forest conditions with each option. The following symbols will be used to represent the level of the effect of each management alternative on forest conditions. More symbols displayed indicate more of whatever the symbol represents—more healthy trees, more beetle-killed trees, etc. In the case of recreation, more symbols indicate greater negative effect on recreation.

Resource Descriptions

 Healthy trees: better able to withstand fire and attacks by beetles.

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 Frequency of wildfires: The number and intensity of forest fires that do occur.

 Unhealthy air quality days: everyone experiences some undesirable health effects. People with lung and heart disease as well as young children and senior citizens might need to avoid going outside.

 Clean River/Lake: when water is suitable for all fish, recreational activities such as swimming, kayaking, and only minimal treatment is needed for purifications for drinking water.

 Muddy River/Lake: when ashes from forest fire and dirt is in the river. The river is unsuitable for recreational activities, is harmful for fish, and extra treatments needed to purify for drinking water.

 Closed recreation areas: number of months that hiking trails, and camping areas are closed due to forest fire, and cleanup activities.

Paying for Increased Forest Management

Because there is a large amount of federal land such as National Forests in Colorado, cost of reducing the wildfire hazard will be shared between all U.S. taxpayers and Colorado taxpayers. Two combined federal and state taxes would increase, with the amount of the increase depending on the management option selected.

The Federal tax would be in the form of an increase in income tax. Colorado state taxes would combine an increase in sales tax with an increase in state income tax. These annual tax amounts would be for 10 years, taking effect in 2014 and expiring in 2024. The money would go in a separate and dedicated fund for pine beetle and forest treatments that would be monitored by a citizen advisory panel.

In this table three alternatives policy scenarios are provided. Please read carefully and choose your options below.

	Option 1: Current Management	Option 2: Burn Beetle Killed Trees on Site	Option 3: Convert Beetle Killed Trees to Biochar
Pine Beetle Killed Trees (Acres Infested)			
% Forest Burned Every 10 Years	20%	10%	10%
Forest Fire Frequency	More frequent, intense wildfires	Less frequent, less intense wildfires	Less frequent, less intense wildfires
Air Pollution from Fire Smoke (# Average Days)	High Air Pollution 10 Unhealthy days	Low Air Pollution 4 Unhealthy days	Very Low Air Pollution 2 Unhealthy days
Greenhouse Gas Emissions	High	Medium	Low
Water Quality in Streams and Lakes in Areas Burned	Frequently Muddy	Rarely Muddy	Rarely Muddy
# Of Months Recreation Areas are closed	6 Months	2 Months	1 Month
Annual Cost to Taxpayers			

1. Using the information provided in the table above which option is your **Most** Preferred? (Check one)

   Option 1 ☐ Option 2 ☐ Option 3 ☐

2. Using the information provided in the table above which option is your **Least** Preferred? (Check one)

   Option 1 ☐ Option 2 ☐ Option 3 ☐

Please tell us something about yourself.

The last few questions will help us in evaluating how well our sample represents residents of Larimer County. **Your answer will be kept confidential and will only be used for the analysis of this study. Results will only be reported as group averages, you will not be identified in any way.**

1. Before this survey, had you ever heard of "Biochar?" ☐ Yes ☐ No
2. How far is your house from the area of the High Park Fire? (*Check one box*)

   ☐ 1-10 miles ☐ 11-19 miles ☐ 20-39 miles ☐ 40-59 miles ☐ more than 60 miles
3. Do you or anyone in your household have respiratory problems? ☐ Yes ☐ No
4. Did you evacuate your house during the High Park fire? ☐ Yes ☐ No
5. What is your gender? ☐ Male ☐ Female
6. What is your age? ________ years
7. How many individuals live in your household, <u>including yourself</u>? ______
8. Are you Hispanic or Latino? ☐ Yes ☐ No
9. With which racial group(s) do you most closely identify? (*Circle all that apply*).

   1 American Indian/Alaska Native
   2 Asian
   3 Black/African American
   4 Native Hawaiian or other Pacific Islander
   5 White
10. What is the highest level of schooling you have completed? (*Circle one number*).

    1 Fourth grade or less
    2 Fifth through eighth grades
    3 Ninth through eleventh grades
    4 Twelfth grade, no diploma
    5 High school graduate (including GED)
    6 Some college
    7 Associates degree
    8 Bachelor's degrees
    9 Graduate or professional degree
11. Do you live in a ☐ Rural area ☐ Urban area?
12. I live in ☐ A Rented Property ☐ A Property I Own
13. Did you visit Colorado forests in the last 12 months for….

    No, I did not visit any Colorado forests in the last 12 months.

    Yes, I did visit a Colorado forest and I did the following activities: (*Check all that apply*)

    ☐ Camping ☐ Hiking ☐ Mountain Biking ☐ Bird Watching

    ☐ Snow Skiing ☐ Backpacking ☐ Other (please list): ___________
14. How much was your household income from all sources (before taxes) last year? (*Check one*)

    _____ Less than $10,000
    _____ $10,000-$19,999
    _____ $20,000-$29,999
    _____ $30,000-$39,999
    _____ $40,000-$49,999
    _____ $50,000-$59,999
    _____ $60,000-$69,999
    _____ $70,000-$79,999
    _____ $80,000-$89,999
    _____ $90,000-$99,999
    _____ $100,000-$149,999
    _____ $150,000-$199,999
    _____ $200,000 or more
15. How many household members contributed to this income? ___________

Thank you very much for completing the survey!

Forest Management Survey in the State of Colorado

Is there anything else that you would like to tell us about the forest management? If so, please feel free to write any thoughts or comments you have regarding forest management in Colorado, here.

When done please put this completed survey in the enclosed stamped return envelope.

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