

MANAGING RISK AND UNCERTAINTY IN AGRICULTURAL PRODUCTION

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To my father

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Abstract of Dissertation Presented to the Graduate School
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MANAGING RISK AND UNCERTAINTY IN AGRICULTURAL PRODUCTION

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This dissertation includes three essays on the general topic of risk in agricultural production under global competition, trade negotiations, and environmental policies. The studies address the need for developing a more comprehensive methodology to examine viable options for agricultural production given competitive / regulatory pressures. Investment, production, and/or institutional risks are examined for two important Florida vegetable crops – winter tomato and potato. The first essay focuses on market risk and analyzes the consumer perceptions of imported and domestic greenhouse tomatoes. Differential demand models are estimated. The results indicate a boom phase of growth in the U.S. greenhouse tomato market, leading to the increase in sales of both U.S. and Mexico produced tomato.

The second essay comprehensively identifies and characterizes the risks involved in greenhouse tomato investment decisions. In addition to market risks, the outcomes of the investments are affected by the uncertainty in cost and yield. To examine the risks, net present value models with Monte Carlo simulation are used to analyze the viability of greenhouse investment decisions. The analysis is further extended by utilizing real option method. The results indicate that a grower would

choose to continue with field-grown tomato production due to high option value and risk aversion. These results are consistent with what has been witnessed in tomato production in Florida. However, policies or market conditions such increase credit availability, increase interest rates, decrease energy prices, stabilize high tomato prices would make the greenhouse production more preferable.

Finally, the third essay examines the production risk and the choices of fertilizer application rates by Florida potato producers. Nitrogen fertilizer is commonly used as a strategy to manage production risks; however, excessive nitrogen application has the potential to impact surface water quality. Using county-level data, the study explores the economically optimal nitrogen fertilizer rate by explicitly considering the production risks and producers' risk perceptions. The results show that no single fertilizer BMP can be recommended for all growers and all market conditions. Overall, the three essays contribute to the economic literature on agricultural risk management, and generate information to assist agricultural producers and policy makers.

CHAPTER 1 INTRODUCTION

The weather conditions, fluctuation in yields and prices, the change in government policies, severity of international competition, and new trade agreements have significant impact on agribusiness profits (Harwood et al. 1999). All these factors are combined in the notions of risk and uncertainty. Risk management is a critical component in the agricultural management. Farmers make decisions by selecting one among many alternatives to diminish the negative economic effects of risk factors.

Risk usually refers to the situation when alternative outcomes or conditions have known probabilities. In turn, uncertainty refers to the outcomes and conditions with unknown probability distribution. However, these terms are often used interchangeably (Roberts, Osteen and Soule, 2004). All risk factors are categorized in literature as production risk, price risk, financial risk, institutional risk, and human risk (Moss, 2010). Uncertainty in weather and climate, disease and pests create production risk by affecting both the yield and quality of commodities produced (i.e., production risks). Output prices received by farmers or input prices can fluctuate unpredictably for agricultural producers (i.e., price risks). Price risk and production risks can be related, since prices can depend on total yield and quality of the produce. However, prices depend on many other variables like global market and competition. In turn, financial risk is caused by credit availability and the change in interest rate that affect the farm business borrowing money. Institutional risk is related with the government policies on taxes, environmental regulations, and agricultural subsidies that can have a crucial impact both on the agricultural firm and the environment (Roberts, Osteen and Soule,

2004). At last, human factors such as accidents and illness can also create unpredictable situations and risks affecting the agricultural enterprises.

Additional information about uncertain factors and effective risk management strategies help producers to make better decisions. Risk management tools include enterprise diversification, vertical integration, contracts, hedging, options, liquidity, insurance, and off-farm employment (Harwood et al. 1999). The use of alternative risk management strategies depends on the farmer's risk perception, information availability, and government farm programs.

The three essays in this dissertation focus on risk management in agricultural production given global competition and changing environmental regulations. The first and second essays focus on the diversification of production practices as a risk management strategy. Specifically, the study examines the adoption of greenhouse technology to mitigate Florida tomato producers' profit losses associated with the increasing competition with Mexican tomato imports. Tomato sales from Florida have dropped almost 50% in the last decade, from as much as \$500 million/year to \$250 million/year in market value. At the same time, the Mexican import (and primarily, greenhouse tomatoes) increased significantly in the last years. Florida producers have begun to consider greenhouse tomato production as a way to regain competitiveness. However, the adoption rate of this new production technology is still low, offering a good opportunity for researchers to analyze the risks and opportunities associated with potential expansion in Florida greenhouse tomato production. Since the viability of new investment depends on the consumer perceptions of greenhouse tomato and the market risk, in the first essay, consumer demand for greenhouse tomatoes is examined

by using differential models. The second essay aims at investigating the viability of greenhouse investment decisions, taking energy use as a price (cost) risk component for decision-making, and using net present value and real option approach.

The third essay focuses on institutional risk and examines the producers' choice of fertilizer rate given changing water quality regulations. Specifically, the development of nitrogen fertilizer best management practice (BMP) is examined for Florida potato production. BMPs are being developed to improve and protect water quality in Florida; however, the economic factors affecting the adoption of these BMP by the producers have not yet been examined. The nitrogen fertilizer use decisions are commonly made by farmers to address production risks, including the risks associated with adverse weather events. At the same time, nutrient leaching from agricultural fields has the potential to impact surface water quality. In Florida, mandatory limits on nitrogen fertilizer application rates are proposed as a strategy to address water quality issues in several regions, including the northern potato-producing region of Florida. This study explores the economic viability of the proposed nitrogen BMPs. County level data are used, and stochastic production functions are estimated. Farmers' fertilizer use choices are examined using Monte Carlo simulations, expected profit maximization, and stochastic ranking methods.

Overall, the three essays contribute to the economic literature on agricultural risk management and environmental policy, and generate information to assist agricultural producers and policy makers.

CHAPTER 2 THE PERCEPTION OF U.S. AND MEXICAN GREENHOUSE TOMATOES IN THE U.S. MARKET

Introductory Remarks

The United States (U.S.) winter fresh tomato industry, especially from the beginning of December to the end of April in Figure 2-1, consists predominantly of Florida field-grown (24%), Mexican field-grown (27%), and Mexican greenhouse tomatoes (27%). Mexican and Floridian producers have engaged in a trade conflict since the early 1970s (Bredahl, Schmitz and Hillman, 1987; Vansickle, Evans and Emerson, 2003). Many U.S. producers believe that their industry is vulnerable to excessive imports and low prices. Further, some states in the U.S., such as California and Arizona, have started producing greenhouse tomatoes during the winter season. This response puts downward pressure on winter tomato prices and also makes the market more prone to new conflicts between the Mexican and Florida producers. Therefore, it is important to assess both import and domestic greenhouse production to address potential trade conflicts. We start the analysis by studying the substitution and complimentary relationships between imported and domestically produced tomatoes. These relationships are referred to as consumer perception of the product. For example, if two goods are substitutes, consumers perceive them as similar products, whereas, two compliments are perceived as non-competitive consumption goods.

The U.S. is the second largest fresh tomato producer in the world with 33.5 million cwt in 2010, and the fresh tomato industry is the highest valued fresh vegetable industry in the nation (FAOSTAT, 2013; USDA-ERS, 2013b). Florida (12.3 million cwt) and California (10.4 million cwt) are the largest tomato producing states in the U.S. (USDA-ERS, 2012c). Fresh field-grown tomatoes are harvested in California

during all seasons except winter, while in Florida they are harvested from October to June with peak production from November to January. Recently, however, California and Arizona have become key states for U.S. greenhouse production transforming California and Arizona into winter tomato producers when prices are at peak levels.

Most of Florida's winter production is shipped to the eastern U.S. while Mexico provides fresh tomatoes more for the western part (VanSickle, Evans and Emerson, 2003). More than half of the fresh tomatoes consumed in the U.S. are imported from Mexico and Canada, and half of these tomatoes come from greenhouse production (Figure 2-2). The U.S. imported nearly 35 million cwt of fresh tomatoes in 2011, of which Mexico accounted for 11.5 million cwt with greenhouse tomatoes and Canada accounted for 3 million cwt with greenhouse tomatoes (USDA-FAS, 2013). Other countries like the Netherlands and Spain also export greenhouse tomatoes to the U.S. but in much smaller quantities. U.S. greenhouse tomato production was 5.4 million cwt in 2011, a 16% share of total U.S. fresh tomato production. Growth trends indicate there is still potential to expand this industry (USDA-ERS, 2013a).

Florida producers historically got higher prices for their tomatoes. The average grower's price of fresh tomatoes was \$72.50 per cwt in 2010 in Florida, while the average price in California was \$33.10 per cwt (USDA-ERS, 2013c). However, with the growth in the U.S. greenhouse industry and increased imports in the winter market, average U.S. grower prices fell from \$48.4 in 2010 to \$31.3 in 2012 (USDA-ERS, 2013a). Yield per acre of greenhouse tomatoes can be up to twenty-fold that of field-grown tomatoes and this helps imported greenhouse tomatoes have opportunities to

increase their share in the U.S. by offering lower prices and better quality product (Cantliffe and VanSickle, 2009).

In this paper, we analyze U.S. demand for domestic and imported tomatoes, and evaluate consumer preferences for the greenhouse and field-grown tomatoes as well as cross-price effects on demand for those commodities (i.e., consumer perceptions). To do so, tomato demand can be estimated by four differential demand systems (Rotterdam, AIDS, CBS and NBR) and a synthetic model that nests the four demand systems (Barten, 1993). The domestic demand includes the shipments of U.S. products and the imported fresh tomatoes because the tomato market in the nation is assumed to be inseparable in this study (Winters, 1984). The demand analysis is completed in two parts. The first aggregated part provides us a general perspective of the tomato market in the U.S. while the disaggregated data in the second part enable the comparison among the U.S. and Mexican tomato categories.

In the aggregated analysis, none of the four tested demand systems fits the data as well as the synthetic one. In the second analysis, the Rotterdam model fits the data best for evaluating domestic and import demand. The expenditure elasticity of aggregated U.S. tomatoes is greater than unity in the aggregated analysis while those of other imported tomatoes are less than unity. The results from the disaggregated analysis show that Mexican greenhouse tomatoes also have a conditional expenditure elasticity greater than unity. The own-price elasticities indicate that tomato demand is inelastic. Results also signify that U.S. tomatoes are substitutes with the imported tomatoes at the aggregate level. This indicates that imported and domestic tomatoes are perceived as a similar product. However, results for the disaggregated analysis

indicates that U.S. field-grown and other tomatoes compete with both U.S. and Mexican greenhouse tomatoes, but that U.S. greenhouse tomatoes do not compete with Mexican greenhouse tomatoes.

As fresh tomatoes are the highest valued fresh vegetable in the U.S., the fresh tomato market in the U.S. is an open market for rent seeking actions of importers and domestic producers. While importers try to increase their shares in this market by lowering their prices, domestic producers want to keep it a high-valued market and avoid any costly investment in production practices (such as investment in greenhouse production). The results of this study are exceptional for those interested in international trade and for policy makers. Finding out how Mexican greenhouse tomatoes are perceived is a helpful tool for designing future policies for dealing with potential trade conflicts. Overall, the main goal of this study is to examine tomato demand in the U.S. and to evaluate consumer preferences for the domestic greenhouse, domestic field-grown, imported, and Mexican greenhouse tomatoes and as well as cross-price effects on demand for these goods. The paper is organized as follows. The next section presents and discusses the differential demand systems. A later section describes the data sources and discusses the data used in this study. The third section demonstrates the results of tomato demand in the U.S. and wraps up the results for disaggregated tomato demand analysis, particularly for the greenhouse tomatoes. Finally, we summarize the findings and indicate possible future direction for study.

Import Demand Model

The first differential demand system known as the Rotterdam model was developed by Barten (1964) and Theil (1965). In 1980, Deaton and Muellbauer (1980) developed the Almost Ideal Demand System (AIDS). Later, Keller and Van Driel (1985),

and Clements (1987) developed the Central Bureau of Statistics (CBS) model, combining these two parameterizations. The contribution of the CBS is that its marginal shares are not constant as they are in the Rotterdam model. Neves (1987) developed a fourth model, called the National Bureau of Research (NBR) model. Finally, Barten (1993) developed a synthetic model that nested all four differential systems.

One of the first applications of these demand systems to import demand was for an agricultural commodity by Seale, Sparks and Buxton (1992) who applied the differential demand systems to the imports of U.S. fresh apples. More recently, Schmitz and Seale (2002) used this methodology to estimate the demand for fresh fruit imports into Japan. Our analysis utilizes the methodologies above. We extend the methodology to demand for imported tomatoes, both greenhouse and field-grown. We also fit the models to monthly data, not previously used in other studies.

Let the utility function take the general form of $U = U(q_1, \dots, q_n)$ of a finite number of commodities. We assume twice differentiability and non-saturation so that $\partial U / \partial q_i > 0$. The generalized diminishing marginal utility requires that the Hessian matrix of the utility function, $U = [\partial^2 U / \partial q_i \partial q_j]$, is negative definite and symmetric $n \times n$ matrix. We can derive demand equations by maximizing the utility function subject to the consumer's budget constraint $\sum_i p_i q_i = M$, where p_i is the price, q_i is quantity, and M is the total budget so that $\sum_i p_i \frac{\partial q_i}{\partial p_j} = -q_j$ and $\sum_i p_i \frac{\partial q_i}{\partial M} = 1$.

$$\text{Max } U(q_i) - \mu(\sum_i p_i q_i - M) \quad (2-1)$$

Differentiating equation (2-1) proportionality with respect to q_i , p_j , and M and utilizing Barten's Fundamental matrix (Barten, 1964) eventually yields the differential demand equation. The well-known parameterization of this equation gives us the Rotterdam demand system:

$$w_i d(\ln q_i) = \theta_i d(\ln Q) + \sum_{j=1}^n \pi_{ij} d(\ln p_j) \quad (2-2)$$

In this equation, w_i represents the average budget share of good i while the parameter θ_i is the marginal budget share of good i and π_{ij} is a compensated price effect for commodity i with respect to the price of commodity j . There are three constraints for demand theory: adding-up ($\sum_i \theta_i = 1$, $\sum_i \pi_{ij} = 0$); homogeneity ($\sum_j \pi_{ij} = 0$); and Slutsky symmetry ($\pi_{ij} = \pi_{ji}$).

The expenditure elasticity (η_i) of import demand for good i , and the Slutsky price elasticity (η_{ij}) and Cournot¹ price elasticity (c_{ij}) of good i with respect to price j respectively, are calculated by the following equations:

$$\eta_i = \frac{\theta_i}{w_i}; \quad (2-3)$$

$$\eta_{ij} = \frac{\pi_{ij}}{w_i}; \text{ and} \quad (2-4)$$

$$c_{ij} = \frac{\pi_{ij} - \theta_i w_j}{w_i}. \quad (2-5)$$

¹ Cournot price elasticities are calculated but the results are not included in this study. These elasticities reflect both price and income effects of the demand with respect to a change in the prices of the goods. In theory, cournot own-price elasticities are lower than the slusky own-price elasticities.

Replacing θ_i with $w_i + \beta_i$ in the equation (2-2) and rearranging the terms lead us to the CBS model (Keller and Van Driel, 1985):

$$w_i d(\ln q_i - d(\ln Q)) = \beta_i d(\ln Q) + \sum_{j=1}^n \pi_{ij} d(\ln p_j). \quad (2-6)$$

Substituting π_{ij} by $\gamma_{ij} = \pi_{ij} + w_i \delta_{ij} - w_i w_j$ in the equation (2-6) gives us the (differential)

AIDS equation (Barten, 1993):

$$d(w_i) = \beta_i d(\ln Q) + \sum_{j=1}^n \gamma_{ij} d(\ln p_j). \quad (2-7)$$

Additionally, the NBR is generated by replacing β_i with $\theta_i - w_i$ in the equation (2-7) (Neves, 1987).

$$d(w_i) + w_i d(Q) = \theta_i d(\ln Q) + \sum_{j=1}^n \gamma_{ij} d(\ln p_j). \quad (2-8)$$

The synthetic or general model, proposed by Barten (1993), is shown in equation (2-9) below and has two additional parameters, δ_1 and δ_2 :

$$w_i d(\ln q_i) = (d_i + \delta_1 w_i) d(\ln Q) + \sum_{j=1}^n e_{ij} d(\ln p_j) + \delta_1 w_i d(\ln Q) - \delta_2 w_i (d \ln p_i - d \ln P) \quad (2-9)$$

where $d_i = \delta_1 \beta_i + (1 - \delta_1) \theta_i$ and $e_{ij} = \delta_2 \gamma_{ij} + (1 - \delta_2) \pi_{ij}$. The constraints on the model are:

adding-up $\sum_i d_i = 1 - \delta_1$, $\sum_i e_{ij} = 0$; homogeneity $\sum_j e_{ij} = 0$; and Slutsky symmetry

$e_{ij} = e_{ji}$. The expenditure elasticity, the Slutsky price elasticity and Cournot price

elasticities are found respectively by $\eta_i = (d_i + \delta_1 w_i) / w_i$; $\eta_{ij} = (e_{ij} - \delta_2 w_i (\delta_{ij} - w_j)) / w_i$; and

$c_{ij} = (e_{ij} - \delta_2 w_i (\delta_{ij} - w_j)) - (d_i + \delta_1 w_i) w_j / w_i$ where δ_{ij} represents Kronecker delta equal to

unity if $i=j$ and zero otherwise. The parameters, δ_1 and δ_2 , give us the information about

the best demand system that fits the data. Equation (2-9) becomes Rotterdam when $\delta_1 = 0$ and $\delta_2 = 0$, CBS when $\delta_1 = 1$ and $\delta_2 = 0$, AIDS when $\delta_1 = 1$ and $\delta_2 = 1$, and NBR when $\delta_1 = 0$ and $\delta_2 = 1$.

Data

Monthly imports and domestic fresh tomato shipments data are used in this study. The tomato import data are found at Global Agricultural Trade Systems (GATS) of Foreign Agricultural Service, United States Department of Agriculture (USDA-FAS, 2013). The Harmonized Commodity Description and Coding System (HS) is used at the 10 digits level. Import values and quantity data are collected for Mexico (field-grown and greenhouse tomatoes), Canada (almost all greenhouse tomatoes), Netherland (all greenhouse tomatoes), and other countries (mainly greenhouse tomatoes) from January 1989 to June 2012 (USDA-FAS, 2013). Expenditure on U.S. tomatoes is approximated from the shipping points' data of the U.S. tomato statistics charts of Economic Research Service (USDA-ERS, 2013c). The monthly movement data and shipping prices are collected from January 1978 to June 2010 from an ERS dataset (USDA-ERS 2013c). The monthly data are extended to August 2012 by using the summation of daily movements and the average of daily shipping point prices reported by Agricultural Marketing Service (AMS), U.S. Department of Agriculture (USDA-AMS, 2013). Therefore, the time frame of the analysis is from January 1989 to August 2012 with 270 observations.

Disaggregated data that allow us to compare field-grown and greenhouse-produced tomatoes of the U.S. and Mexico are collected from the daily AMS reports for quantity movements from shipping points, shipping point prices and terminal point

prices that cover the time period from October 2004 to August 2012 with 94 total observations (USDA-AMS, 2013).

Monthly prices from daily reports are calculated from the simple average of the daily shipping point prices. The weighted average cannot be calculated since the price data are not reported with the quantity sold. Monthly quantities are found at daily movements reported from the shipping points for each tomato category: field-grown, greenhouse, plum, cherry and grape tomatoes. The greenhouse tomatoes category does not include plum, cherry and grape tomatoes produced in greenhouses. U.S. greenhouse tomato prices are only found at the terminal points. Therefore, the terminal point prices for greenhouse tomatoes are scaled by the ratio of the shipping point to the terminal point prices for field-grown tomatoes.

Results

Tomato Import Demand

The parameters are calculated using Time Series Processor (TSP - version 5.0). The equations are estimated by iterative seemingly unrelated regressions (SUR). One equation is dropped during estimation to comply with the adding up condition (Barten, 1993). Log differences and average shares are calculated by taking a 12-month difference to account for seasonality. The Hildreth-Lu procedure is applied to test for autocorrelation of the system of equations and GARCH is used to test for homoscedasticity. The parameter rho, the autocorrelation parameter as a fraction, is chosen by transforming both dependent and independent variables by

$X_1 = X_1 \cdot \sqrt{1 - \rho^2}$ and $X_i = X_i - \rho \cdot X_{i-1}$ for $(i=2, \dots, n)$ at the highest log-likelihood level of the multivariate regression. When the model without rho is taken as a base model, the

log-likelihood ratio (LR) test rejects that rho is equal to zero at the 5% level. When the GARCH parameters are tested for homoscedasticity, they are not found different from zero at the 5% level. Therefore, we reject the null hypothesis of homoscedasticity. The robust (White) standard errors are calculated and given in parenthesis for each coefficient and elasticity.

Homogeneity and symmetry are imposed on the unrestricted demand systems and these restrictions are tested with LR tests. Table 2-1 illustrates the results of the LR test in which θ^R is the vector of parameter estimates of the restricted model, θ^U is the vector of parameter estimates of the unrestricted model, and $L(.)$ is the log-likelihood value. When the homogeneity restriction is compared with the critical value of a χ^2 distribution at 5% significance level, we fail to reject the homogeneity hypothesis in CBS demand system and the symmetry in Rotterdam, AIDS and NBR. Therefore, the augmented chi-square, described by Laitenen (1978), is used for the homogeneity restriction. Since the symmetry restriction is barely rejected, we accept the restriction by referring to Meisner (1979) who showed the sad fate of symmetry test. The augmented chi-square (T^2) is calculated by $(n-1)(N-n-1)/(N-2n+1) \cdot F((N-2n+1), (n-1))$, where n is the number of commodities in the equations, and N is the number of observations. F values are found for homogeneity as $F(261,4) = 5.63$. Thus, we fail to reject homogeneity hypothesis at the 5% significance level.

Estimating the synthetic model allows us to select among the four demand systems of this analysis. We find that δ_1 and δ_2 coefficients are respectively 0.441 and 0.317 and statistically significant at the 1% level. Since both of the values are close to be 0.5, we could not detect the best demand system that fits the data for tomato import

demand analysis. Additionally, LR tests are conducted for the same purpose. Table 2-2 shows the comparison of the four demand systems to the synthetic model with homogeneity and symmetry imposed. In all cases, we reject the four models in comparison to the synthetic model at the 5% significance level. Accordingly, we only discuss the results of the synthetic model.

Parameter estimation

Parameter estimates with homogeneity and symmetry restrictions are provided for all the parameterizations in Table 2-3, Table 2-4, Table 2-5, Table 2-6 and Table 2-7. All the expenditure coefficients for the synthetic model, used since the other models are rejected, are positive but only the coefficients for the U.S. and the Rest of the World (ROW) are statistically significant at the 5% level. The own-price coefficients for all the goods are negative and statistically significant at the 1% level except for the U.S. and Mexican tomato price coefficients. Three out of ten cross-price coefficients are statistically significant at the 10% level. It is important to note that the expenditure and price coefficients of the synthetic model do not give any information on the income elasticity or on the substitution effect like the other demand systems.

Elasticity estimation

The conditional expenditure and Slutsky price elasticities for the U.S and each importer country are presented in Table 2-8, Table 2-9, Table 2-10, Table 2-11 and Table 2-12. All the elasticity values are calculated at the sample mean from 1990:1 to 2012:08. The individual parameter estimates, showed in previous tables, are used to calculate the elasticities.

All of the expenditure elasticities are statistically significant at the 5% level. The point estimates of the expenditure elasticities of U.S. tomatoes and ROW tomatoes are

greater than unity. This indicates that if the expenditure on tomatoes increases by 1%, the expenditure on these products increase by more than 1%. The results show that a 1% increase in the expenditure for tomato creates a 1.32% increase in U.S. and a 1.16% increase in the ROW tomatoes, respectively, while the demand for Mexican, Canadian and Dutch tomatoes only increases 0.56%, 0.55% and 0.58%, respectively. These results indicate that U.S. consumers prefer U.S. and ROW tomatoes as total expenditure for fresh tomatoes increase allowing for no price changes.

The Slutsky own-price elasticity designates the percentage change in quantity demanded resulting from a percentage change in price, holding real expenditure constant. All own-price elasticities are negative and significant at the 1% level except for ROW. Results indicate that the demand for tomatoes is inelastic since all estimated own-price elasticities are less than unity in absolute terms. The own-price elasticity of U.S. tomatoes is one of the lowest elasticities followed by Mexican tomatoes, and then by Canadian tomatoes. The results also indicate that these products have relative competitiveness power in the market. For instance, a 1% increase in the price of U.S. tomatoes decreases, the quantity demanded only by 0.16%, whereas, the same increase in Mexican tomato price decreases the demand by 0.24%, *ceteris paribus*. Although the difference is not large, it still shows that U.S. tomatoes have a price advantage in the market if prices rise. However, a 1% decrease in Mexican tomato price increases the demand for Mexican tomatoes more than the same price decrease on U.S. tomatoes would increase demand for U.S. tomatoes.

Cross-price elasticity shows the response in demanded quantity to price changes of other tomatoes. For example, the cross-price elasticity of U.S. tomatoes with respect

to Mexican tomatoes reveals the percentage change in the quantity demanded for U.S. tomatoes resulting from a percentage change in the Mexican tomatoes price. A positive and statistically significant cross-price elasticity indicates substitute goods while the negative price elasticity indicates complement goods. The analysis shows that 16 out of 20 cross-price elasticities are statistically significant at the 10% level, and all the U.S. cross-price elasticities are positive and statistically significant at the 1% level. U.S. tomatoes are substitutes with the all imported tomatoes. The largest cross-price elasticity is for U.S. tomatoes relative to Mexican tomatoes with a value of 0.12. The other cross-price elasticities of the U.S. with respect to the other tomatoes are 0.03, 0.01 and 0.01, respectively, for Canadian, Dutch and ROW tomatoes. These elasticities indicate the percentage change in the quantity demanded for U.S. tomatoes resulting from a percentage change in the other tomatoes prices. In turn, a 1% increase in the price of U.S. tomatoes increases, *ceteris paribus*, the quantity demanded for Mexican, Canadian, Dutch and ROW tomatoes by 0.21%, 0.23%, 0.25% and 0.48%, respectively. Moreover, a price change in Mexican tomatoes strongly affects the quantity demanded for the U.S. tomatoes, and a price increase in the U.S. tomatoes has a large effect on the quantity demanded for the other tomatoes.

Disaggregated Tomato Import Demand

The analysis is further expanded to evaluate disaggregated tomato product categories according to production techniques and the types of tomatoes. The aim of the disaggregation is to explore the consumption preferences of U.S. consumers and to analyze the demand for U.S. greenhouse tomatoes. Since we aim to compare field-grown and greenhouse-produced tomatoes of the U.S. and Mexico, we aggregated plum, cherry and grape tomatoes as U.S. other tomatoes, and all the other tomato

importers (i.e. Canada, the Netherlands, Spain) as ROW while keeping the total tomato expenditure the same as in the previous section.

All the statistical tests described in the previous section for import demand are applied in this analysis. We reject the hypothesis of autocorrelation by using log-likelihood test for the rho obtained from Hildreth-Lu procedure. Homoscedasticity is tested by GARCH and we reject the null hypothesis of homoscedasticity at the 5% significance level. The robust (White) standard errors are used to control for heteroscedasticity.

Homogeneity and symmetry restrictions are tested by the log-likelihood ratio test. Table 2-13 indicates that homogeneity restrictions are rejected for CBS, AIDS and NBR models at the 5% significance level. We fail to reject the symmetry hypothesis at the 5% significance level for all the demand systems. The augmented chi-square (T^2) is calculated for F values of $F(83,5)=4.42$ for homogeneity. The results showed that we fail to reject homogeneity at the 5% significance level for all of the demand systems except barely for AIDS model.

The coefficients of the synthetic model are estimated and the two coefficients that can restrict the synthetic model to the other four demand systems are $\delta_1 = -0.037$ and $\delta_2 = 0.056$. Neither is statistically different from zero. These coefficients indicate that the Rotterdam demand system fits the data better than the other demand systems for the disaggregated tomato analysis. LR tests also confirm our finding. Table 2-14 shows that we can only fail to reject the Rotterdam model at the 5% significance level when the four demand systems are compared with the synthetic model with

homogeneity and symmetry imposed results. Therefore, the results are presented only for the Rotterdam demand system for this section.

Parameter estimation

The Rotterdam estimates for parameters with homogeneity and symmetry restrictions are presented in Table 2-15, Table 2-16, Table 2-17, Table 2-18 and Table 2-19. Estimated expenditure coefficients are all positive and statistically significant at the 1% level except for Mexico field-grown, greenhouse and ROW tomatoes. All the statistically significant Slutsky own-price coefficients are negative. The U.S. and the Mexican greenhouse tomato own-price coefficients are not statistically different than zero while the others are statistically significant at the 5% level. Nine out of 15 cross-price coefficients are statistically significant at the 10% level. The results signify that U.S. field-grown tomatoes are substitute with Mexican field-grown and greenhouse tomatoes as well as U.S. other tomatoes. For instance, a 1% increase (decrease) in the U.S. field-grown tomato price raises (diminishes) the quantity demanded for Mexican field-grown and greenhouse tomatoes 0.05% and 0.03%, respectively. Interestingly, we find that U.S. greenhouse tomatoes are complementary with Mexican greenhouse tomatoes. U.S. consumers seemingly do not differentiate between U.S. and Mexican greenhouse tomatoes. In other words, a switch in consumers' demand into Mexican greenhouse tomatoes would increase the demand of U.S. greenhouse tomatoes. Mexican field tomatoes are also complements with Mexican greenhouse tomatoes. It signifies that these goods would benefit from an increase of U.S. consumers' demand for other Mexican tomatoes. For instance, a price decrease in Mexican field-grown or greenhouse tomatoes raises the quantity demanded of both goods.

Elasticity estimation

Conditional expenditure and Slutsky price elasticities of disaggregated tomato demand are provided in Table 2-20, Table 2-21, Table 2-22, Table 2-23 and Table 2-24. All the elasticity values for the Rotterdam demand systems are calculated at the sample mean from 2005:10 to 2012:08. Elasticities are calculated from individual parameter estimates presented in previous tables.

The expenditure elasticities of U.S. field-grown, U.S. greenhouse, U.S. others and Mexican greenhouse tomatoes are greater than unity and statistically significant at the 1% level. Thus, the disaggregated data analysis shows us that Mexican greenhouse tomato demand response is also similarly to that of U.S. tomatoes in the market when total expenditure for fresh tomatoes changes. The expenditure elasticity for Mexican field-grown and ROW are not statistically different from zero.

The statistically significant own-price elasticities are all negative and less than unity in absolute terms similar to the results in the previous section. Four out of six own-price elasticities are statistically significant at the 5% level in the Rotterdam demand system. The largest (-.09) is that of U.S. field-grown tomatoes while those of U.S. others, Mexican field-grown, and Mexican greenhouse tomatoes are of similar size of around -.03.

The interpretation of cross-price elasticities shows us essentially the substitution effect of U.S. tomatoes by categories. We find that U.S. field-grown and U.S. other tomatoes are substitutes with Mexican field-grown and Mexican greenhouse tomatoes. A 1% increase in the price of Mexican field-grown (greenhouse) tomatoes, *ceteris paribus*, increases the demand of U.S. field-grown tomatoes by 0.12% (0.11%). However, a 1% increase in the price of U.S. field-grown tomatoes increases the

Mexican field-grown or greenhouse tomato demand by 0.17% and 0.22%, respectively. Accordingly, the quantity demanded of U.S. field-grown tomatoes is more sensitive to the price changes of imported tomatoes than the quantity demanded of imported tomatoes is to price changes in U.S. field-grown tomatoes. U.S. other tomatoes are found to be less sensitive to the price change in the Mexican tomatoes because a 1% increase in the U.S. other tomatoes increases the demand for the Mexican field-grown or greenhouse tomatoes demand by 0.07% and 0.11%, respectively, while this price increase in the Mexican field-grown or greenhouse tomatoes will result in a 0.15% and 0.16% increases in U.S. other tomatoes demand.

We conclude that the demand of tomatoes is significantly affected by the price change of the U.S. and Mexican tomatoes. Surprisingly, the cross-price elasticity between the U.S. and Mexican greenhouse tomatoes is negative and statistically significant at the 5% level indicating they are complements. This result supports our discussion in the introduction that imports of Mexican greenhouse tomatoes stimulate investment in U.S. greenhouse tomatoes. Results also show that the Mexican field tomatoes are complements with Mexican greenhouse tomatoes. The findings in this section suggest that the growth of greenhouse tomatoes will continue until their market share reaches a maturation stage.

Summary and Discussion

The trade conflict between the U.S. and Mexico tomato producers is still a great concern for the winter tomato market. In 1996, the U.S. established a fixed entrance price for Mexican tomatoes as part of a complex arrangement in 1996. Nevertheless, the Executive Vice President of the Florida Tomato Exchange pointed out that “tomato sales have dropped as low as \$250 million annually, from as much as \$500 million, ...,

which has led to a push to rescind the agreement” (Strom and Malkin, 2012). This conflict is often mentioned by producer and importer groups as farmers and policy makers continue searching for alternative ways to deal with this issue (Malkin, 2012).

The renegotiated suspension agreement for the antidumping investigation raises the reference prices of Mexican tomatoes ranging from 50% to 300% from the previous agreement depending on their category (US-DC, 2013). This agreement distinctively covers four different tomato categories including open area, controlled environment, specialty loose and specialty packed categories. Although this study confirms the importance of categorizing tomatoes, it also emphasizes the significant effect of the substitution and complementary linkage between these categories. The analysis of these linkages between the U.S. and Mexican tomatoes helps policy makers to understand the market and to choose the right policies.

The results suggest that demand for U.S. tomatoes is more sensitive to change in total expenditure for field-grown tomatoes than the demand for imported tomatoes. However, the disaggregated analysis shows that the demand for Mexican greenhouse tomatoes responds similarly to that of U.S. field-grown tomatoes. We find that U.S. tomatoes are perceived as a similar product to imported tomatoes by consumers, which indicates the strong competition among these goods in the market. Furthermore, the tomato demand is not sensitive to the price changes in U.S. greenhouse tomatoes while the price changes in U.S. field-grown and other tomatoes affects the demand significantly.

Although U.S. field-grown tomatoes compete with Mexican field-grown tomatoes and all sources of greenhouse tomatoes, there is a synergistic relationship between

imported and domestically grown greenhouse tomatoes. Since the beginning of the 21st century, we have witnessed a large increase in the production and marketing of greenhouse tomatoes, taking market share away from field-grown tomato producers. Mexican greenhouse tomatoes are competing with and taking market share from U.S. field-grown tomatoes but have led to a growth in production of U.S. greenhouse tomatoes. When a sector is in a boom phase of growth (as has been the greenhouse tomato market), it appears that competitive products are complimentary in the market. This will in fact continue until the market matures and it moves into the bust side of the boom-bust business cycle in sector analysis (Schmitz 1995). When the market matures we hypothesize U.S. and imported greenhouse tomatoes will shift from complementary products to substitutes in the market. Until then, the investment of greenhouse tomatoes will continue to grow in the U.S. while demand for field-grown tomatoes continues to shrink.

Table 2-1. The log-likelihood ratio tests for homogeneity and symmetry ^a

	Log-likelihoods	$-2[L(\theta^R)-L(\theta^U)]$	$\chi^2(0.05)$	$T^2(0.05)$
Synthetic Model				
Unrestricted Model (26)	2883.43			
Homogeneity (22)	2878.42	10.02	9.49	22.77
Homogeneity + Symmetry (16)	2871.62	13.60	12.59	
Rotterdam				
Unrestricted Model (24)	2858.71			
Homogeneity (20)	2851.96	13.50	9.49	22.77
Homogeneity + Symmetry (14)	2845.88	12.16	12.59	
CBS				
Unrestricted Model (24)	2833.30			
Homogeneity (20)	2828.99	8.62	9.49	22.77
Homogeneity + Symmetry (14)	2821.51	14.96	12.59	
AIDS				
Unrestricted Model (24)	2854.43			
Homogeneity (20)	2848.27	12.32	9.49	22.77
Homogeneity + Symmetry (14)	2842.58	11.38	12.59	
NBR				
Unrestricted Model (24)	2827.90			
Homogeneity (20)	2822.41	10.98	9.49	22.77
Homogeneity + Symmetry (14)	2817.57	9.68	12.59	

Notes: ^a Number of parameters estimated is given in parenthesis.

Table 2-2. Test results for the log-likelihood ratio tests ^a

	Log-likelihoods	$-2[L(\theta^R)-L(\theta^U)]$	$\chi^2(0.05)$
Synthetic Model (16)	2871.62		
Rotterdam (14)	2845.88	51.48 ^b	5.99
CBS (14)	2821.51	100.22 ^b	5.99
AIDS (14)	2842.58	58.08 ^b	5.99
NBR (14)	2817.57	108.10 ^b	5.99

Notes: ^a Number of parameters estimated is given in parenthesis.

^b LR values of tested model against synthetic model, homogeneity and symmetry imposed on both.

Table 2-3. Parameter estimation of import demand, synthetic model, 1989 – 2012.

	Slutsky Price Coefficients (e_{ij})					Expenditure Coefficients (d_i)	δ_1	δ_2
	U.S.	Mexico	Canada	Netherlands	ROW			
U.S.	-0.017 (0.020)	0.011 (0.020)	0.003 (0.002)	0.001 (0.001)	0.002** (0.001)	0.504*** (0.128)	0.441*** (0.121)	0.317*** (0.061)
Mexico		-0.011 (0.020)	-0.002 (0.002)	0.002 (0.002)	0.001 (0.001)	0.040 (0.089)		
Canada			-0.008*** (0.003)	0.006*** (0.002)	0.001 (0.001)	0.007 (0.005)		
Netherlands				-0.008*** (0.001)	-0.001* (0.001)	0.002 (0.004)		
ROW					-0.003*** (0.001)	0.005** (0.003)		

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world.

Table 2-4. Parameter estimation of import demand, Rotterdam model, 1989 – 2012.

	Slutsky Price Coefficients (π_{ij})					Marginal Income Share (θ_i)
	U.S.	Mexico	Canada	Netherlands	ROW	
U.S.	-0.088*** (0.017)	0.070*** (0.017)	0.011*** (0.002)	0.003*** (0.001)	0.003*** (0.001)	0.749*** (0.083)
Mexico		-0.074*** (0.017)	0.000 (0.003)	0.003 (0.002)	0.002* (0.001)	0.205** (0.081)
Canada			-0.017*** (0.004)	0.006*** (0.002)	0.000 (0.001)	0.028*** (0.008)
Netherlands				-0.010*** (0.001)	-0.002** (0.001)	0.009** (0.005)
ROW					-0.004*** (0.001)	0.009*** (0.003)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world.

Table 2-5. Parameter estimation of import demand, CBS model, 1989 – 2012.

	Slutsky Price Coefficients (π_{ij})					Marginal Income Share (β_i)
	U.S.	Mexico	Canada	Netherlands	ROW	
U.S.	-0.084*** (0.018)	0.066*** (0.018)	0.012*** (0.002)	0.003*** (0.001)	0.003*** (0.001)	0.185* (0.097)
Mexico		-0.067*** (0.019)	-0.003 (0.003)	0.003 (0.002)	0.002 (0.001)	-0.174* (0.100)
Canada			-0.015*** (0.004)	0.005*** (0.002)	0.001 (0.001)	-0.010 (0.008)
Netherlands				-0.009*** (0.001)	-0.002** (0.001)	-0.004 (0.005)
ROW					-0.004*** (0.001)	0.003 (0.003)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world.

Table 2-6. Parameter estimation of import demand, AIDS model, 1989 – 2012.

	Slutsky Price Coefficients (γ_{ij})					Marginal Income Share (β_i)
	U.S.	Mexico	Canada	Netherlands	ROW	
U.S.	0.128*** (0.017)	-0.109*** (0.017)	-0.015*** (0.003)	-0.004*** (0.001)	0.000 (0.001)	0.189** (0.090)
Mexico		0.118*** (0.017)	-0.006** (0.003)	-0.001 (0.002)	-0.002 (0.001)	-0.160* (0.090)
Canada			0.011*** (0.004)	0.007*** (0.001)	0.002* (0.001)	-0.020** (0.008)
Netherlands				-0.002 (0.001)	0.000 (0.001)	-0.008** (0.004)
ROW					0.000 (0.001)	-0.001 (0.003)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world.

Table 2-7. Parameter estimation of import demand, NBR model, 1989 – 2012.

	Slutsky Price Coefficients (γ_{ij})					Marginal Income Share (θ_i)
	U.S.	Mexico	Canada	Netherlands	ROW	
U.S.	0.124*** (0.016)	-0.105*** (0.016)	-0.015*** (0.004)	-0.003*** (0.001)	0.000 (0.001)	0.753*** (0.076)
Mexico		0.111*** (0.017)	-0.003 (0.004)	-0.001 (0.002)	-0.001 (0.001)	0.219*** (0.072)
Canada			0.009** (0.004)	0.007* (0.002)	0.002 (0.001)	0.018* (0.010)
Netherlands				-0.003** (0.001)	-0.001 (0.001)	0.005 (0.004)
ROW					0.000 (0.001)	0.005* (0.003)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world.

Table 2-8. Conditional expenditure and Slutsky price elasticities of import demand, synthetic model, 1989 – 2012.

	U.S.	Mexico	Canada	Netherlands	ROW	Expenditure Elasticity
U.S.	-0.16*** (0.03)	0.12*** (0.03)	0.03*** (0.004)	0.01*** (0.002)	0.01*** (0.002)	1.32*** (0.15)
Mexico	0.21*** (0.05)	-0.24*** (0.05)	0.02* (0.009)	0.01* (0.005)	0.005 (0.003)	0.56** (0.26)
Canada	0.23*** (0.03)	0.07* (0.04)	-0.41*** (0.06)	0.09*** (0.02)	0.02 (0.02)	0.55*** (0.13)
Netherlands	0.25*** (0.07)	0.21** (0.11)	0.42*** (0.10)	-0.80*** (0.10)	-0.08* (0.05)	0.58** (0.28)
ROW	0.48*** (0.15)	0.21 (0.15)	0.18 (0.16)	-0.18* (0.11)	-0.05 (0.13)	1.16*** (0.40)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world.

Table 2-9. Conditional expenditure and Slutsky price elasticities of import demand, Rotterdam model, 1989 – 2012.

	U.S.	Mexico	Canada	Netherlands	ROW	Expenditure Elasticity
U.S.	-0.15*** (0.03)	0.12*** (0.03)	0.02*** (0.00)	0.01*** (0.00)	0.01*** (0.00)	1.30*** (0.14)
Mexico	0.21*** (0.05)	-0.23*** (0.05)	0.00 (0.01)	0.01 (0.01)	0.01* (0.00)	0.62** (0.24)
Canada	0.16*** (0.03)	0.00 (0.04)	-0.24*** (0.05)	0.08*** (0.02)	0.00 (0.02)	0.39*** (0.11)
Netherlands	0.21*** (0.07)	0.18 (0.12)	0.36*** (0.10)	-0.63*** (0.09)	-0.11** (0.05)	0.60** (0.29)
ROW	0.47*** (0.16)	0.28* (0.16)	0.04 (0.16)	-0.25** (0.11)	-0.55*** (0.13)	1.25*** (0.42)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world.

Table 2-10. Conditional expenditure and Slutsky price elasticities of import demand, CBS model, 1989 – 2012.

	U.S.	Mexico	Canada	Netherlands	ROW	Expenditure Elasticity
U.S.	-0.15*** (0.03)	0.11*** (0.03)	0.02*** (0.00)	0.01*** (0.00)	0.01*** (0.00)	1.32*** (0.17)
Mexico	0.20*** (0.05)	-0.20*** (0.06)	-0.01 (0.01)	0.01 (0.01)	0.01 (0.00)	0.47 (0.30)
Canada	0.17*** (0.03)	-0.04 (0.05)	-0.22*** (0.06)	0.08*** (0.02)	0.01 (0.02)	0.86*** (0.11)
Netherlands	0.18*** (0.07)	0.16 (0.11)	0.34*** (0.10)	-0.57*** (0.09)	-0.11** (0.05)	0.77** (0.31)
ROW	0.44*** (0.16)	0.24 (0.15)	0.11 (0.16)	-0.25** (0.11)	-0.54*** (0.12)	1.49*** (0.38)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world.

Table 2-11. Conditional expenditure and Slutsky price elasticities of import demand, AIDS model, 1989 – 2012.

	U.S.	Mexico	Canada	Netherlands	ROW	Expenditure Elasticity
U.S.	-0.20*** (0.03)	0.14*** (0.03)	0.05*** (0.01)	0.01*** (0.00)	0.01*** (0.00)	1.33*** (0.16)
Mexico	0.25*** (0.05)	-0.31*** (0.05)	0.05*** (0.01)	0.01** (0.00)	0.00 (0.00)	0.52* (0.27)
Canada	0.37*** (0.04)	0.25*** (0.04)	-0.78*** (0.05)	0.12*** (0.02)	0.04** (0.02)	0.72*** (0.11)
Netherlands	0.33*** (0.07)	0.25** (0.10)	0.53*** (0.09)	-1.08*** (0.07)	-0.02 (0.04)	0.50** (0.25)
ROW	0.52*** (0.13)	0.07 (0.17)	0.41** (0.18)	-0.05 (0.09)	-0.95*** (0.10)	0.85** (0.37)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world.

Table 2-12. Conditional expenditure and Slutsky price elasticities of import demand, NBR model, 1989 – 2012.

	U.S.	Mexico	Canada	Netherlands	ROW	Expenditure Elasticity
U.S.	-0.21*** (0.03)	0.15*** (0.03)	0.05*** (0.01)	0.01*** (0.00)	0.01*** (0.00)	1.31*** (0.13)
Mexico	0.26*** (0.05)	-0.33*** (0.05)	0.06*** (0.01)	0.01** (0.01)	0.00 (0.00)	0.66*** (0.22)
Canada	0.36*** (0.05)	0.29*** (0.05)	-0.81*** (0.06)	0.12*** (0.02)	0.03* (0.02)	0.25* (0.14)
Netherlands	0.36*** (0.07)	0.26** (0.11)	0.54*** (0.11)	-1.15*** (0.07)	-0.02 (0.04)	0.33 (0.27)
ROW	0.56*** (0.13)	0.12 (0.17)	0.34* (0.18)	-0.06 (0.09)	-0.97*** (0.10)	0.63* (0.38)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world.

Table 2-13. The log-likelihood ratio tests for homogeneity and symmetry a

	Log-likelihoods	$-2[L(\theta^R)-L(\theta^U)]$	$\chi^2(0.05)$	$T^2(0.05)$
Rotterdam				
Unrestricted Model (35)	923.73			
Homogeneity (30)	918.24	10.98	11.07	23.16
Homogeneity + Symmetry (20)	913.94	8.60	18.31	
CBS				
Unrestricted Model (35)	915.10			
Homogeneity (30)	908.90	12.40	11.07	23.16
Homogeneity + Symmetry (20)	904.38	14.96	18.31	
AIDS				
Unrestricted Model (35)	890.61			
Homogeneity (30)	878.10	25.02	11.07	23.16
Homogeneity + Symmetry (20)	874.92	6.36	18.31	
NBR				
Unrestricted Model (35)	887.18			
Homogeneity (30)	876.20	21.96	11.07	23.16
Homogeneity + Symmetry (20)	872.80	6.80	18.31	

Notes: ^a Number of parameters estimated is given in parenthesis.

Table 2-14. Test results for the log-likelihood ratio tests ^a

	Log-likelihoods	$-2[L(\theta^R)-L(\theta^U)]$	$\chi^2(0.05)$
Synthetic Model (22)	914.18		
Rotterdam (20)	913.94	0.46 ^b	5.99
CBS (20)	904.38	19.60 ^b	5.99
AIDS (20)	874.92	78.52 ^b	5.99
NBR (20)	872.80	82.76 ^b	5.99

Notes: ^a Number of parameters estimated is given in parenthesis.

^b LR values of tested model against synthetic model, homogeneity and symmetry imposed on both.

Table 2-15. Parameter estimation of disaggregated import demand, synthetic model, 2004 – 2012.

	U.S. Field-grown	U.S. Greenhouse	Slutsky Price Coefficients (e_{ij})				Marginal Income Share (d_i)	δ_1	δ_2
			U.S. Others	Mexico Field-grown	Mexico Greenhouse	ROW			
U.S. Field-grown	-0.081*** (0.021)	0.005 (0.013)	-0.007 (0.007)	0.049*** (0.014)	0.028*** (0.010)	0.007* (0.03)	0.372*** (0.129)	-0.037 (0.205)	0.056 (0.084)
U.S. Greenhouse		0.035 (0.022)	-0.006 (0.010)	-0.011 (0.012)	-0.033* (0.019)	0.010 (0.009)	0.128** (0.050)		
U.S. Others			-0.027** (0.010)	0.015** (0.006)	0.017** (0.008)	0.007 (0.006)	0.144*** (0.049)		
Mexico Field-grown				-0.029 (0.022)	-0.036*** (0.011)	0.012** (0.006)	0.128 (0.099)		
Mexico Greenhouse					-0.042** (0.017)	-0.017** (0.008)	0.248*** (0.054)		
ROW						-0.019 (0.009)	0.018 (0.025)		

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world. "U.S. Others" includes plum, cherry and grape tomatoes.

Table 2-16. Parameter estimation of disaggregated import demand, Rotterdam model, 2004 – 2012.

	Slutsky Price Coefficients (π_{ij})						Marginal Income Share (θ_i)
	U.S. Field- grown	U.S. Greenhouse	U.S. Others	Mexico Field- grown	Mexico Greenhouse	ROW	
U.S. Field- grown	-0.092*** (0.014)	0.006 (0.013)	-0.005 (0.006)	0.053*** (0.012)	0.030*** (0.009)	0.008* (0.004)	0.361*** (0.091)
U.S. Greenhouse		0.030 (0.022)	-0.005 (0.010)	-0.010 (0.011)	-0.032* (0.019)	0.010 (0.009)	0.124** (0.049)
U.S. Others			-0.032*** (0.008)	0.016*** (0.005)	0.018** (0.008)	0.007 (0.006)	0.141*** (0.036)
Mexico Field- grown				-0.039*** (0.016)	-0.033*** (0.011)	0.013** (0.006)	0.122 (0.102)
Mexico Greenhouse					-0.035** (0.016)	-0.017** (0.008)	0.240*** (0.048)
ROW						-0.021** (0.009)	0.012 (0.017)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world. "U.S. Others" includes plum, cherry and grape tomatoes.

Table 2-17. Parameter estimation of disaggregated import demand, CBS model, 2004 – 2012.

	Slutsky Price Coefficients (π_{ij})						Marginal Income Share (β_i)
	U.S. Field- grown	U.S. Greenhouse	U.S. Others	Mexico Field- grown	Mexico Greenhouse	ROW	
U.S. Field- grown	-0.091*** (0.014)	0.006 (0.013)	-0.005 (0.006)	0.052*** (0.013)	0.031*** (0.009)	0.007 (0.005)	0.041 (0.104)
U.S. Greenhouse		0.028 (0.022)	-0.003 (0.010)	-0.010 (0.011)	-0.031* (0.018)	0.010 (0.010)	0.032 (0.050)
U.S. Others			-0.033*** (0.008)	0.017*** (0.006)	0.017** (0.008)	0.006 (0.006)	0.030 (0.038)
Mexico Field- grown				-0.042*** (0.016)	-0.030*** (0.010)	0.014** (0.006)	-0.093 (0.113)
Mexico Greenhouse					-0.024 (0.015)	-0.011 (0.009)	0.077* (0.045)
ROW						-0.025** (0.010)	-0.087*** (0.022)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world. "U.S. Others" includes plum, cherry and grape tomatoes.

Table 2-18. Parameter estimation of disaggregated import demand, AIDS model, 2004 – 2012.

	Slutsky Price Coefficients (γ_{ij})						Marginal Income Share (β_i)
	U.S. Field- grown	U.S. Greenhouse	U.S. Others	Mexico Field- grown	Mexico Greenhouse	ROW	
U.S. Field- grown	0.110*** (0.016)	-0.025** (0.012)	-0.038*** (0.006)	-0.022 (0.013)	-0.017** (0.009)	-0.008 (0.006)	0.037 (0.100)
U.S. Greenhouse		0.107*** (0.021)	-0.008 (0.012)	-0.031*** (0.011)	-0.051*** (0.017)	0.007 (0.010)	0.040 (0.051)
U.S. Others			0.052*** (0.010)	-0.006 (0.006)	0.012 (0.009)	-0.012* (0.007)	0.014 (0.037)
Mexico Field- grown				0.130*** (0.018)	-0.069*** (0.012)	-0.001 (0.007)	-0.117 (0.106)
Mexico Greenhouse					0.130*** (0.016)	-0.005 (0.009)	0.109** (0.045)
ROW						0.020* (0.011)	-0.082*** (0.025)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world. "U.S. Others" includes plum, cherry and grape tomatoes.

Table 2-19. Parameter estimation of disaggregated import demand, NBR model, 2004 – 2012.

	Slutsky Price Coefficients (γ_{ij})						Marginal Income Share (θ_i)
	U.S. Field- grown	U.S. Greenhouse	U.S. Others	Mexico Field- grown	Mexico Greenhouse	ROW	
U.S. Field- grown	0.107*** (0.015)	-0.025** (0.012)	-0.038*** (0.006)	-0.020 (0.013)	-0.018* (0.010)	-0.006 (0.006)	0.346*** (0.091)
U.S. Greenhouse		0.110*** (0.021)	-0.011 (0.012)	-0.030*** (0.011)	-0.052*** (0.018)	0.008 (0.010)	0.128** (0.051)
U.S. Others			0.054*** (0.009)	-0.008 (0.006)	0.011 (0.009)	-0.008 (0.007)	0.124*** (0.036)
Mexico Field- grown				0.134*** (0.018)	-0.072*** (0.013)	-0.004 (0.006)	0.095 (0.099)
Mexico Greenhouse					0.146*** (0.017)	-0.014 (0.009)	0.269*** (0.057)
ROW						0.024** (0.010)	0.038** (0.023)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world. "U.S. Others" includes plum, cherry and grape tomatoes.

Table 2-20. Conditional expenditure and Slutsky price elasticities of disaggregated import demand, synthetic model, 2004 – 2012.

	U.S. Field-grown	U.S. Greenhouse	U.S. Others	Mexico Field-grown	Mexico Greenhouse	ROW	Expenditure Elasticity
U.S. Field-grown	-0.30*** (0.06)	0.02** (0.01)	-0.02* (0.01)	0.17*** (0.02)	0.10*** (0.01)	0.03*** (0.01)	1.16*** (0.21)
U.S. Greenhouse	0.07** (0.03)	0.32 (0.23)	-0.05 (0.10)	-0.10 (0.12)	-0.34* (0.20)	0.11 (0.17)	1.31** (0.52)
U.S. Others	-0.05* (0.03)	-0.05 (0.09)	-0.29*** (0.07)	0.15*** (0.05)	0.17** (0.08)	0.07 (0.09)	1.28*** (0.33)
Mexico Field-grown	0.24*** (0.03)	-0.04 (0.05)	0.07*** (0.02)	-0.17** (0.07)	-0.15*** (0.05)	0.06 (0.06)	0.54 (0.46)
Mexico Greenhouse	0.19*** (0.03)	-0.21* (0.12)	0.12** (0.05)	-0.21*** (0.07)	-0.22** (0.11)	-0.11 (0.09)	1.54*** (0.31)
ROW	0.08*** (0.03)	0.10 (0.15)	0.07 (0.09)	0.13 (0.13)	-0.16 (0.13)	-0.13 (0.29)	0.13 (1.23)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world. "U.S. Others" includes plum, cherry and grape tomatoes.

Table 2-21. Conditional expenditure and Slutsky price elasticities of disaggregated import demand, Rotterdam model, 2004 – 2012.

	U.S. Field-grown	U.S. Greenhouse	U.S. Others	Mexico Field-grown	Mexico Greenhouse	ROW	Expenditure Elasticity
U.S. Field-grown	-0.30*** (0.05)	0.02 (0.04)	-0.02 (0.02)	0.17*** (0.04)	0.10*** (0.03)	0.03* (0.01)	1.16*** (0.29)
U.S. Greenhouse	0.07 (0.14)	0.32 (0.23)	-0.05 (0.10)	-0.10 (0.12)	-0.34* (0.20)	0.11 (0.09)	1.31** (0.52)
U.S. Others	-0.05 (0.06)	-0.05 (0.09)	-0.29*** (0.07)	0.15*** (0.05)	0.16** (0.07)	0.07 (0.05)	1.29*** (0.33)
Mexico Field-grown	0.24*** (0.05)	-0.04 (0.05)	0.07*** (0.02)	-0.17** (0.07)	-0.15*** (0.05)	0.06** (0.02)	0.55 (0.46)
Mexico Greenhouse	0.19*** (0.06)	-0.21* (0.12)	0.11** (0.05)	-0.21*** (0.07)	-0.22** (0.10)	-0.11** (0.05)	1.53*** (0.31)
ROW	0.07* (0.04)	0.10 (0.08)	0.07 (0.05)	0.12** (0.05)	-0.16** (0.08)	-0.20** (0.08)	0.12 (0.16)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world. "U.S. Others" includes plum, cherry and grape tomatoes.

Table 2-22. Conditional expenditure and Slutsky price elasticities of disaggregated import demand, CBS model, 2004 – 2012.

	U.S. Field-grown	U.S. Greenhouse	U.S. Others	Mexico Field-grown	Mexico Greenhouse	ROW	Expenditure Elasticity
U.S. Field-grown	-0.29*** (0.05)	0.02 (0.04)	-0.02 (0.02)	0.17*** (0.04)	0.10*** (0.03)	0.02 (0.02)	1.13*** (0.34)
U.S. Greenhouse	0.06 (0.13)	0.30 (0.23)	-0.03 (0.11)	-0.11 (0.12)	-0.33* (0.19)	0.11 (0.10)	1.34** (0.52)
U.S. Others	-0.04 (0.06)	-0.03 (0.09)	-0.30*** (0.07)	0.16*** (0.05)	0.16** (0.07)	0.05 (0.06)	1.27*** (0.34)
Mexico Field-grown	0.23*** (0.06)	-0.05 (0.05)	0.08*** (0.02)	-0.19*** (0.07)	-0.14*** (0.04)	0.06** (0.03)	0.58 (0.51)
Mexico Greenhouse	0.20*** (0.06)	-0.20* (0.12)	0.11** (0.05)	-0.19*** (0.06)	0.16 (0.10)	-0.07 (0.06)	1.49*** (0.29)
ROW	0.07 (0.04)	0.10 (0.09)	0.05 (0.06)	0.13** (0.06)	-0.11 (0.08)	-0.24** (0.09)	0.17 (0.21)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world. "U.S. Others" includes plum, cherry and grape tomatoes.

Table 2-23. Conditional expenditure and Slutsky price elasticities of disaggregated import demand, AIDS model, 2004 – 2012.

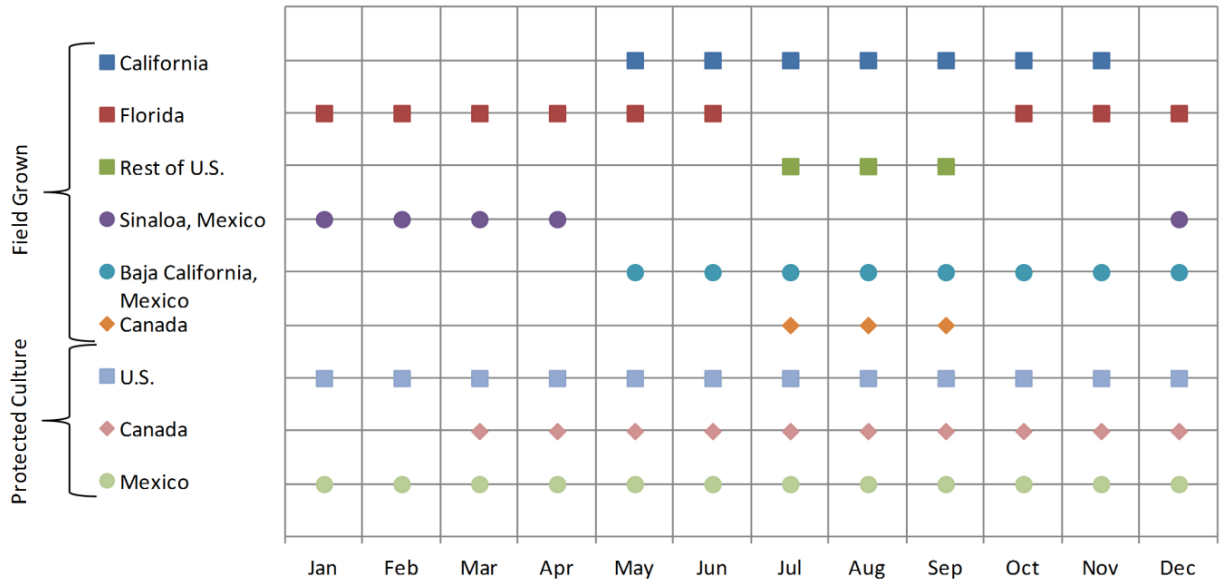
	U.S. Field-grown	U.S. Greenhouse	U.S. Others	Mexico Field-grown	Mexico Greenhouse	ROW	Expenditure Elasticity
U.S. Field-grown	-0.34*** (0.05)	0.02 (0.04)	-0.01 (0.02)	0.15*** (0.04)	0.10*** (0.03)	0.08*** (0.02)	1.12*** (0.32)
U.S. Greenhouse	0.05 (0.12)	0.23 (0.22)	0.02 (0.13)	-0.10 (0.12)	-0.38** (0.18)	0.18* (0.11)	1.42*** (0.54)
U.S. Others	-0.03 (0.06)	0.02 (0.11)	-0.41*** (0.09)	0.17*** (0.05)	0.26*** (0.08)	-0.01 (0.06)	1.13*** (0.34)
Mexico Field-grown	0.21*** (0.06)	-0.04 (0.05)	0.08*** (0.03)	-0.19** (0.08)	0.21*** (0.04)	0.10*** (0.03)	0.48** (0.47)
Mexico Greenhouse	0.20*** (0.06)	-0.23** (0.11)	0.18*** (0.06)	-0.22*** (0.08)	-0.02 (0.10)	0.07 (0.06)	1.69*** (0.29)
ROW	0.23*** (0.06)	0.16* (0.10)	-0.01 (0.07)	0.21*** (0.06)	0.11 (0.09)	-0.72*** (0.07)	0.22 (0.24)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world. "U.S. Others" includes plum, cherry and grape tomatoes.

Table 2-24. Conditional expenditure and Slutsky price elasticities of disaggregated import demand, NBR model, 2004 – 2012.

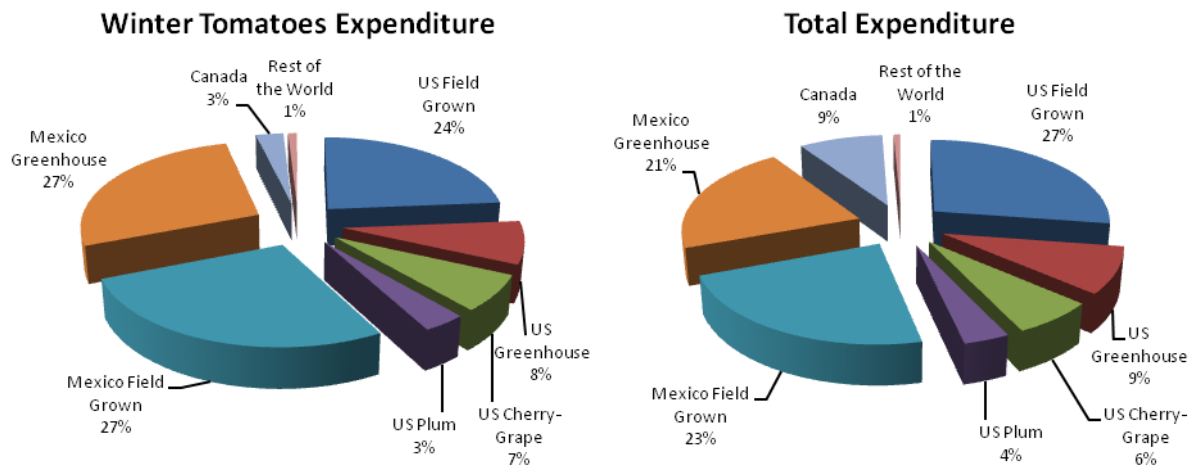
	U.S. Field-grown	U.S. Greenhouse	U.S. Others	Mexico Field-grown	Mexico Greenhouse	ROW	Expenditure Elasticity
U.S. Field-grown	-0.34*** (0.05)	0.02 (0.04)	-0.01 (0.02)	0.16*** (0.04)	0.10*** (0.03)	0.09*** (0.02)	1.11*** (0.29)
U.S. Greenhouse	0.05 (0.12)	0.25 (0.22)	-0.01 (0.12)	-0.09 (0.12)	-0.39** (0.19)	0.19* (0.11)	1.35** (0.54)
U.S. Others	-0.04 (0.06)	-0.01 (0.11)	-0.40*** (0.08)	0.15*** (0.05)	0.26*** (0.08)	0.04 (0.06)	1.14*** (0.33)
Mexico Field-grown	0.22*** (0.06)	-0.04 (0.05)	0.07*** (0.02)	-0.17** (0.08)	0.21*** (0.04)	0.09*** (0.03)	0.42 (0.44)
Mexico Greenhouse	0.19*** (0.06)	-0.23** (0.11)	0.18*** (0.06)	-0.24*** (0.09)	0.09 (0.11)	0.01 (0.06)	1.71 (0.36)
ROW	0.25*** (0.06)	0.17* (0.10)	0.04 (0.07)	0.19*** (0.06)	0.02 (0.09)	-0.69*** (0.07)	0.36 (0.22)

Notes: Asterisks (*, **, ***) represent significant at the 10%, 5% and 1% level, respectively. ROW=rest of the world. "U.S. Others" includes plum, cherry and grape tomatoes.



Source: Adopted from USDA-ERS North American Fresh-Tomato Market Report (USDA-ERS 2013a)

Figure 2-1. Field-grown and protected-culture fresh market tomato shipments by month.



Source: Calculated by Authors from Fresh-Tomato Shipments (USDA-AMS 2013)

Figure 2-2. U.S. share of winter (December-April) and total tomato expenditure in the last 5 years, 2007- 2012

CHAPTER 3 THE POTENTIAL FOR GREENHOUSE TOMATO PRODUCTION EXPANSION IN FLORIDA

Introductory Remarks

Among all the vegetable crops in the U.S., the total value of production is the highest for tomato production (USDA-ERS 2013a). Tomato demand in the U.S. is high during all 12 months of the year (USDA-ERS 2013b). During the summer season most of U.S. states, Mexico and Canada produce tomatoes so the supply is high and prices are relatively low. However, the dynamics are different during the winter season since the main tomato suppliers are the state of Florida and Mexico only. Florida produces field-grown tomatoes, while Mexico ships more greenhouse tomatoes every year to the U.S. Figure 3-1 shows the disaggregation of tomato imports from Mexico by field grown and greenhouse tomatoes. The composition of Mexican imports has been significantly enhanced by greenhouse production and it has been observed that the increase in Mexican tomato imports is associated with the increase in greenhouse tomato imports specifically.

Due to the demand for high quality tomato by U.S. consumers and the reference price applied on Mexican tomato import (US-DC, 2013), Mexican producers are increasingly able to offer greenhouse tomatoes with higher quality and lower prices than the Florida field-grown winter tomatoes. Additionally, Mexico greenhouse production acreage increased to 30,000 acres in 2012 and 70% of this acreage is devoted to tomato production (SAGARPA 2013). Tomato production in Florida has fallen from 55,000 acres in 1990 to 30,000 acres in 2012 (USDA-ERS 2013b). Overall, competition with Mexican producers affects the profits of Florida tomato producers that have traditionally benefited from higher prices in the winter market. Figure 3-2 demonstrates

the last 10 years of domestic and import tomatoes in the U.S. market. Domestic fresh tomatoes supply went down 25% from the peak level in 2005. The supply of fresh tomatoes imported from Mexico almost doubled in the last ten years, surpassing US domestic tomatoes in the last two years.

The increase in Mexican tomato imports created a trade conflict with the U.S. fresh winter tomato industry. The international competition has been an issue in the industry since the early 1970s. Given that tomatoes are the highest valued fresh vegetable crop, the U.S. fresh tomato market is favored by importers and domestic producers alike. While importers try to increase their shares with low prices, domestic producers attempt to keep their share in the tomato market without any costly investment in production practices. However, the competition with Mexican greenhouse tomato producers pushed winter tomato producers (particularly, in Florida) to search for new investment opportunities like greenhouse tomato production.

There are advantages and disadvantages to greenhouse production. For instance, the controlled environment of greenhouse production gives high and stable yields. It also enables farmers to perfect crop timing and to supply winter markets when fresh market prices are at a premium. On the other hand, the disadvantages are high initial investment costs, high operating costs, and energy-intensive production practices.

This paper aims to incorporate risk into the net present value and real option analysis to investigate whether it is beneficial for Florida tomato producers to invest in greenhouse production methods. Feasibility of the greenhouse investment opportunities is evaluated given decision maker's risk aversion and the different revenue and cost structures of tomato production technologies. Therefore, the study also investigates

whether the investment in greenhouse technology can allow Florida producers to increase their per unit revenue or reduce their production costs, and to keep their market share.

Tomato Production in the US

Fresh tomatoes are harvested in California during all seasons except winter, while in Florida tomatoes are harvested from October to June with peak production from November to January. Most of Florida's production is shipped to the eastern U.S. while Mexico provides fresh tomatoes for the western part of U.S. (VanSickle et al. 2003). Overall, almost one-third of the total U.S. fresh tomato consumption is imported from Mexico and Canada during the off-season period, and around 40% of Mexican and the large majority of Canadian tomatoes are produced in greenhouses (USDA-FAS 2012). Other countries like the Netherlands and Spain also export greenhouse tomatoes to the U.S. in smaller quantities.

In the last decade, U.S. greenhouse tomato production increased two-fold (from 2.7 million cwt in 2000 to 5.4 million cwt in 2011), although its share in the total fresh tomato market is still relatively low at approximately 15 percent (Figure 3-3). However, for the retail market specifically, more than 40% of domestic tomatoes are produced using greenhouse technologies (USDA-ERS 2013b). California and Arizona have become the key states for greenhouse production since the competition with Mexican greenhouse tomato producers drove them to switch into their niche market during the winter season when the tomato price is at peak level.

Florida supplies tomatoes largely for the winter market while California field-grown production supplies in spring and summer. Florida producers get higher prices for their product because they produce in the off-season, when lower winter supplies result

in higher prices. The average price of fresh tomatoes was \$72.50 per cwt in 2010 in Florida, while the average price in California was \$33.10 per cwt (USDA ERS, 2012b). However, fresh tomato prices are known to be sensitive to the instabilities of supply that lead to price volatility. Florida's biggest winter tomato competitor, Mexican greenhouse production, has anywhere between three-fold and twenty-fold more yield (on per-acre basis) than Florida field production. Although greenhouse production cost is high, it is competitive in revenue and the quality can be better than that of field-grown tomatoes. Hence, imported greenhouse tomatoes have more opportunities to increase their market share in the U.S. (Cantliffe and VanSickle, 2009). Overall, the increased interest in greenhouse tomato production in Southwestern states, as well as increasing competition from imported Mexican greenhouse tomatoes can subsequently decrease winter tomato prices, and hence the profits of Florida producers.

As mentioned above, investment and operating costs for greenhouse tomato production are higher than those of field production, and as a result, greenhouse production is often perceived by Florida producers as more risky (Cook and Calvin, 2005). The main risk parameters for tomato production could be identified as market, yield, price, and cost risks (Table 3-1). The source of market risk is the perception of products. For instance, greenhouse tomatoes might be perceived as a different product than field grown tomatoes, influencing the demand and supply relationships. This type of risk is not considered in this study (see chapter 2 for the discussion about the consumer perception).

Controlled atmosphere almost eliminates the yield risk in greenhouse production whereas yield risk is high for field grown production. An industry survey indicates that

tomatoes yield varies from 20 to 32 lbs (9-14.5 kg) per plant space per year in the regular greenhouses while yield can range from 46 to 50 lbs (21-23 kg) per plant space under the best greenhouse technology (Pena 2005). Furthermore, a field grown trial showed that per plant tomato yield generally ranges from 6 to 15 lbs (3-7 kg) per plant space in Florida (UF-IFAS, 2013).

The source of price risk is the supply and demand relationship. Stabilized greenhouse production (i.e. the ability to target harvesting time to the periods when the prices are high) reduces this price risk. Moreover, low priced imported tomatoes increase price risk for domestic greenhouse and field-grown producers. Finally, cost risk comes from inputs, energy and labor expenses. High operating costs and energy intensive production processes increase the chances of negative profits for greenhouse production although there are some technological improvements to reduce this risk. However, cost risk is relatively low in field grown production. Nevertheless, the investment in greenhouse production systems may be a viable option for growers in Florida, since this technology results in much greater yields, higher quality products, and a more stable market demand and/or prices than the current field-grown production technology.

Literature Review: Risk in Investment Decision Making

To explore investment decisions made by growers, the risk-based model is widely used by academics and business consultants. In this study, a comprehensive investment decision model is developed, and then a simulation approach for including risk is employed to examine the decision to invest in the greenhouse production systems in Florida. Below, existing studies are reviewed focusing on (a) agricultural

decision-making under risk and uncertainty, and (b) application of simulation methods for risk-based analysis, and (c) real option value for investing in a new technology.

There are numerous empirical studies of risk and agricultural decision-making. The risk analysis methodologies proposed in the studies can be summarized chronologically as follows. Initially, risk programming was applied by Hazell (1971) to examine risky decisions; later, Anderson et al. (1977) focused on the role of producers' risk attitudes; further, an empirical analysis of effective educational programs to facilitate risky decision-making was provided by Nelson and Harris (1978). Then, Young (1984) improved the methods of measuring risk. More general efficiency criteria for ordering risky choices were introduced by King and Robison (1981), and stochastic simulation was proposed by Mapp and Helmers (1984). More applications of risk analysis in production, marketing, and finance are also published by various researchers (Robison and Brake 1979; Sonka and Patrick 1984).

Collins and Barry (1986) evaluated two approaches for using a single-index model in portfolio analysis for agricultural firms. The single-index model offers a summary measure of risk for individual assets or enterprises that accounts for the combined effects of the asset's own variance, as well as covariance with other assets. When used in portfolio analysis to derive risk-efficient sets of decision choices, the single-index model offers a computationally efficient way to use quadratic programming that accounts for a full constraint set and for the covariance relationships among the decision choices.

Williams et al. (1990) examined risk-based decisions in the context of stochastic dominance between two tillage systems, conventional tillage and no-tillage, for five crop

rotations, wheat-fallow, grain sorghum-fallow, continuous wheat, continuous grain sorghum, and wheat-grain sorghum-fallow. Their results showed that risk-averse managers prefer a conventional tillage wheat-sorghum-fallow system.

Simulation is a widely covered subject; however, most of the existing studies are not written for agricultural economists and do not relate to agricultural firm-level models. Simulation as a tool for analyzing risky decisions was suggested by Anderson et al. (1977). The various types of equations and identities used to construct the Farm Level Income and Policy Simulation Model in these studies, described in Richardson and Nixon (1986; 1999); however, the methods for simulating the random variables were not discussed.

Risk analysis for adopting any of four commonly used zero runoff sub-irrigation systems in greenhouse operations was described on different crop categories by Uva et al. (2000) with a Monte Carlo simulation approach. Richardson et al. (2000) developed a procedure for estimating and simulating probability distributions in farm-level risk assessment and clearly describe the procedure on how to analyze risk by this method. Iwai and Emerson (2008) combined risk analysis with a Monte Carlo simulation by calculating NPV and the real options price to assess sugarcane mechanization investment in Florida. In lieu of previous studies, the goal of this paper is to examine agricultural decision-making under risk and uncertainty, and to apply simulation methods for risk based analysis on greenhouse tomato investment decisions in Florida.

Data and Models

The financial models to analyze tomato production in Florida are built on three different production budgets. The first budget set is called the patriot model based on high technology greenhouse tomato production system (Greenhouse-HT) which has

higher cost but in turn higher yield than the typical Florida greenhouse production (VanSickle, 2011). The second set is for the typical greenhouse tomato production in Florida (Greenhouse-FL); this set relies on the enterprise budget information from the University of Florida's Small Farm and Alternative Enterprises project team (Smith et al. 2006). This budget was updated as of 2013 by UF extension agents. The last budget contains the field grown tomato production budget provided as interactive budget tables for Florida field grown tomato by University of Florida, Food and Resource Economics Department (UF-FRED 2013). The first two sets use different greenhouse sizes (patriot model is based on 120,000 square meters (29.7 acres) greenhouse area and the Florida greenhouse budget is based on 30'-120' dimensions). For this analysis, all the budget sets are adjusted to a one acre basis to make a relevant comparisons between field grown and greenhouse production systems.

The budget data are inserted into pro-forma financial statements, namely the income statement, cash flow statement and balance sheet, for each production technology. The financial model is constructed in Excel add-in Simetar©, a simulation and risk analysis software (Richardson, Schumann and Feldman, 2008). The data include expected yield, expected unit price, variable cost, fixed cost, construction cost, and durables expense. The initial equity (IE) requirement for field-grown production (fg) is assumed to be zero while it is set to \$35,000.00/acre for greenhouse production. The operations are assumed to be owned by 100% equity holder (i.e., by the producer). Working capital loans are provided for 90% of the annual variable production at an interest rate of 5%.

It is further assumed that 80% of the equipment and durables costs for greenhouse tomato production are funded with a seven year loan at 8% interest. The rate of return to investment is assumed to be 10%, which is used as a discount rate for the Net Present Value (NPV) analysis. Financial model assumptions are presented in Table 3-2, and the budget summaries in Table 3-3.

Table 3-3 indicates that greenhouse production requires approximately from 15 to 30 times more start-up cash than the field production. The largest expense for greenhouse production is growing cost since the high yield requires high seedlings and chemicals expenses. Labor cost for Florida greenhouse production accounts for the big portion of total expense. It is observed that the higher yield in greenhouse production leads to lower per-unit sales costs, as compared with the field grown production. The budget summaries reveal that greenhouse production is an energy intense technology because energy cost accounts for a significant portion of the total production cost.

Table 3-4 presents the net income statements (NIs) of all three tomato production technologies for 2014. Revenue is found by multiplying production volume and product price at the expected level when the simulated variables are non-stochastic. We find that the break-even production points are 22 lbs per plant (or 26 kg per square meter, assuming 10,650 plants per acre) and 38 lbs per plant (or 52 kg per square meter, assuming 12,141 plants per acre) for Florida greenhouse (fl) and high-tech greenhouse (ht), respectively. Therefore, these levels are used for the rest of the analysis. The tax rate on earnings before tax (EBT) is taken as 25%, based on the average tax rate of agricultural production firms as calculated from corporate tax data

for the last ten years (IRS, 2012). Straight-line depreciation is applied for all equipment.

Gross profit, earnings before tax (EBT) and net income are computed as follows:

$$\text{Gross Profit} = \text{Revenue} - \text{Cost} \quad (3-1)$$

$$\text{EBT} = \text{Gross Profit} - \text{Depreciation} - \text{Administration Cost} - \text{Interest} \quad (3-2)$$

$$\text{Net Income} = \text{EBT} - \text{Tax} \quad (3-3)$$

The net present value (NPV) framework is commonly used to evaluate agricultural investment. In this analysis, expected present values (PV) of NI are calculated for the span of ten years and discounted to the starting period. NPV was obtained by subtracting the initial investment amount from the present value of the enterprise.

$$NPV_0 = -(\text{Start-up Equity Value}) + \sum_{t=1}^{10} \frac{PV_t}{(1+r)^t} + \frac{\text{Terminal Value}}{(1+r)^{10}} \quad (3-4)$$

where start-up equity value is added manually to prevent firms from running out of cash during the financial year, PV is the present value at the time t for ten years of analysis, terminal value is the value of the firm at the end of ten years, and r is the after tax discount rate.

Simulation model

The objective of this study is to incorporate yield, price and cost risks in the NPV analysis. This objective is achieved by simulating the risk parameters for 10 years. A Monte Carlo simulation model of tomato production is based on the framework presented by Richardson, Lemmer and Outlaw (2007). Risk parameters are the correlated tomato yield and sales prices used in the financial statement analysis. Data were collected from USDA-ERS annual field-grown price and yield data from 1990 to 2012 for Florida, and from USDA-AMS monthly terminal point greenhouse prices in the

eastern states from January 2004 to December 2012. Time series tomato price/yield data sets are used to assess price/yield correlation and volatility. Specifically, USDA-ERS data are used to analyze the price/yield correlation of field-grown methods; the correlation is used in price simulations, which is then applied to all financial analysis. We assume no fluctuations in greenhouse tomato yield. Moreover, the USDA-AMS data are used to calculate the premium received by greenhouse tomatoes. End-user fuel prices are used for estimating the increase in the energy cost. The risk on cost is accounted for in the model by using the fuel/liquid petroleum gas and electricity price relationship. The gas and electricity prices data are collected from 1990 to 2011 (US-EIA 2013). The price change in the simulated prices is inserted as the stochastic growth rate for annual fuel and electricity expenses, which is used to generate the stochastic energy cost. All simulated stochastic components are iterated simultaneously in the model and the key components of the financial model are simulated 500 times for each production technology to estimate the probability density functions (PDF) and cumulative distribution functions (CDF). The distribution of yield, revenue, cost and net present values (NPV) are obtained (Figure 3-4). The NPV distributions are ranked using Simetar© software tools such as mean variance method, first and second degree stochastic dominance, stochastic dominance with respect to a function (SDRF) and stochastic efficiency with respect to a function (SERF) to incorporate risk aversion (Hardaker et al. 2004).

The stochastic variables are selected as the tomato yield, sale prices, fuel/lpg gas price and electricity price. The multivariate empirical (MVE) probability distribution is used for the simulation of these variables (Richardson, Klose and Gray 2000) where

yield and sale prices correlation and, gas and electricity price correlation are utilized.

The methodology of MVE is summarized below. Non-random components are found as a function of linear trend:

$$\hat{X}_{it} = \hat{a} + \hat{b} \cdot Trend_t \quad (3-5)$$

Then, random components are calculated by the difference of actual and predicted values ($\hat{X}_{it}$).

$$\hat{e}_{it} = X_{it} - \hat{X}_{it} \quad (3-6)$$

Relative variability of observations is measured as a fraction of random components to predicted values.

$$D_{it} = \frac{\hat{e}_{it}}{\hat{X}_{it}} \quad (3-7)$$

After the relative variability is sorted for each observation, correlation matrix is calculated by the probabilities of occurrence for these variables. The intra-temporal correlation matrix for price and yield variables is found as follows:

$$\rho_{ij} = \begin{bmatrix} 1 & \rho(\hat{e}_{it}, \hat{e}_{jt}) \\ & 1 \end{bmatrix} \quad (3-8)$$

Correlated standard normal deviates ($CSND_{ik}$) are found by using this correlation matrix and independent standard normal deviates (R_{ik}) for ten-year simulation time span (with years indexed by k). Thus, the empirical distribution for each variable is estimated using correlated uniform deviates:

$$CUD_{ik} = normdist(R_{ik} \cdot CSND_{ik}) \rightarrow CFD_{ik} \quad (3-9)$$

At last, stochastic simulation ($\tilde{X}_{ik}$) is found by the multiplication of predicted values and the MVE distribution. The relative risk expansion in the model is given as (E_{ik}) which is selected as unity in this analysis.

$$\tilde{X}_{ik} = \hat{X}_{ik} \cdot (1 + CFD_{ik} \cdot E_{ik}) \quad (3-10)$$

The stochastic variables, summarized in Table 3-5, are inserted into financial models for the iteration of NPV to evaluate the economic risk for the tomato investment decision.

Ranking risky assets

Mean variance method, first and second degree stochastic dominance, SDRF and SERF are used to rank the risky production technology alternatives. Mean variance method simply looks for less variance and higher mean for ranking the risky alternatives. First degree stochastic dominance compares CDFs of the NPVs for the risky alternatives. If CDFs of two alternatives are represented as $F(x)$ and $G(x)$, and $F(x)$ dominates $G(x)$, then $\sum F(x) \leq \sum G(x)$ for all x . CDFs of the two alternatives compared should not cross each other (Richardson and Outlaw 2008). If they cross, one could use second degree stochastic dominance for ranking the risky alternatives. Using this criterion, if $F(x)$ dominates $G(x)$ when we obtain $\sum F(x) - \sum G(x) \leq 0$ for all x . Finally, SDRF is applied to incorporate known risk aversion coefficients (RAC) into ranking of risky alternatives. SDRF can be described as follows:

$$\sum U(x, r_i(x))F(x) \leq \sum U(x, r_i(x))G(x) \quad (3-11)$$

where $F(x)$ is preferred to $G(x)$ under given risk aversion coefficient ($r_i(x)$) of the decision maker where i refers to the upper and lower limits of risk aversion coefficients

(Richardson and Outlaw 2008). At last, SERF examines the range of producers' risk aversion for which the certainty equivalent (CE) is calculated to determine the ranking of risky alternatives (Hardaker et al. 2004).

$$CE(x_{ij}, r_i(x))_{ij} = U^{-1}(x_{ij}, r_i(x)) \quad (3-12)$$

where $U^{-1}(\dots)$ is the inverse utility function and CE values are calculated for j risky alternatives between upper and lower limits of risk aversion coefficients, respectively, represented as $(r_U(x))$ and $(r_L(x))$.

Real option approach

The NPV analysis has the following limitations: (1) only current information available at the time of the decision is used, (2) after the initial investment decision is made, the future decisions cannot be analyzed; and (3) just a single discount rate is used to calculate NPV (as opposed to allowing the rate to change over time). Hence, the analysis of NPV using criteria discussed above may be incomplete, and it may not be sufficient to explain why U.S. growers still do not switch to the greenhouse tomato production. The next step in this research is to use real options approach (ROA) to evaluate viability of greenhouse tomato production in Florida. ROA has several advantages. First, ROA allows including the future value of agricultural investment into current investment decision analysis. Secondly, ROA controls for the irreversibility of investment in analysis. Thirdly, ROA allows modeling dynamic decision making process while NPV models for the current decision. Fourth, ROA allows for the flexibility of agricultural investment by including the non-linear distribution of the cash flow or the eventual risk profile changes. The main difference in the concept of NPV and ROA could be shown as follows:

$$NPV : MAX (at \ t = 0)[0, E_0(V_t - X)] \quad (3-13)$$

$$ROA : E_0 MAX (at \ t = T)[0, V_t - X] \quad (3-14)$$

where $V_t - X$ represents the comparison of the possible values to choose the best among the possible alternatives (Copeland and Antikarov, 2003). ROA uses expectation of maximum values where the decision is made after the information is revealed (maximize at $t=T$). In contrast, NPV assign the decision for today by looking at the maximum of the expectations (maximize at $t=0$). Real option value is calculated by using the binomial decision tree procedure expressed by Copeland and Antikarov (2003) and followed Iwai and Emerson (2008). The details of the calculation and the assumptions are summarized in the result section.

Results

The non-stochastic NPVs can be computed when all assumptions are substituted into the financial model at the mean values. Table 3-6 presents forecasted present firm values and net incomes for field grown and greenhouse tomato production for ten-year periods. We use equation (3-4) to separately calculate NPVs for each technology.

Table 3-7 suggests that high-tech greenhouse production is the most feasible investment opportunity. Florida greenhouse technology is the second best investment (given the assumptions made). The NPV results presented in Table 3-7 are not sufficient to explain the greenhouse investment decision given by Florida tomato producers. Therefore, to explain the producers' choices, NPV values are simulated using Monte Carlo method applied to the financial model in Simetar© add-in to Excel. Simulations are completed for the stochastic components which represents the risk associated with the tomato production technologies considered (i.e., yield, sale prices,

gas price and electricity price). The simulation results are summarized in Table 3-8. “Greenhouse-HT” has the largest mean; however, “Field-grown” has the lowest standard deviation. Therefore, we cannot rank the investment decision by using the mean variance method only.

The cumulative distribution function (CDF) of NPV values for alternative production technologies are illustrated in Figure 3-5. CDFs cross each other, and hence, the technologies cannot be ranked using the first order stochastic dominance criterion (Table 3-9 and Figure 3-5).

In turn, the second order stochastic dominance criterion suggests that “Greenhouse-HT” dominates both “Greenhouse-FL” and “Field-grown”. Further, “Greenhouse-FL” dominates “Field-grown”. This result indicates that “Greenhouse-HT” is the most preferred investment option, and “Greenhouse-FL” is the second-best choice, among the three technologies considered.

Risk aversion of the decision maker is taken into consideration when we rank the investment alternatives with stochastic dominance with respect to a function (SDRF) analysis. The first preferred set based on SDRF at the lower risk aversion coefficient (RAC=0) shows the ranking for a risk neutral producer (Table 3-10). The ranking for risk neutral producer suggest that “Greenhouse-HT” is the first preferred alternative and it is followed by “Greenhouse-FL” and “Field-grown” technologies, which is consistent with the second degree stochastic dominance result. However, the investment preference among the alternative options changes for the extremely risk-averse producer. The absolute risk aversion coefficient is calculated by $a(w) = (r(w) / w) = (4 / 100,000) = 0.00004$ where w represents wealth and the relative risk aversion coefficients are

classified from zero to four representing, respectively, from the risk neutral to the extremely risk-averse person (Richardson and Outlaw 2008). Thus, extremely risk-averse decision makers prefer field-grown tomato production over both greenhouse technologies.

The SDRF results also show that “Greenhouse-FL” dominates “Greenhouse-HT” when the decision maker is extremely risk-averse (Table 3-10). To explain this result, one can search for the cases where “Greenhouse-FL” might dominate all other alternatives with stochastic efficiency with respect to a function (SERF). SERF provides us a broad overview of the risky alternatives over a range of absolute risk aversion coefficients (ARAC). Figure 3-6 illustrates the certainty equivalent of the alternative technologies for a range of producers’ risk-aversion levels (i.e., from risk neutral to extremely risk-averse). The figure indicates that “Greenhouse-HT” dominates for the RAC values from 0 to 2.6, and “Greenhouse-FL” dominates from 2.6 to 3.5 and “Field-grown” dominates at the rest. This result implies that “Greenhouse-HT” is the preferred technology for the risk neutral and normally risk-averse producer. In turn, “Greenhouse-FL” is the preferred risky alternative for moderately risk-averse producer, and finally, “Field-grown” is only preferred by an extremely risk-averse producer.

Finally, binomial decision tree for field-grown tomato production is illustrated in figure 3-7. Field-grown tomato production is taken as a base production technique for Florida, and the investment option for greenhouse tomato is investigated. The procedure described by Copeland and Antikarov (2003) is followed for the multiplicative stochastic process to calculate ROA. The uncertainty in field-grown production is estimated by generating 500 sets of net income based on the simulating cost and

revenue terms. We obtain the volatility from the standard deviation of the simulated annual rate of return defined as $z = (PV_{2014}^{fg} + NI_{2014}^{fg}) / \ln(PV_{2013}^{fg}) - 1$ where PV_1 and NI_1 represent the net income and present value of field grown production, respectively, for 2014 season and PV_0 is the fixed present value at \$16,855.19 for 2013 season. The mean (μ_z) and the standard deviation (σ_z) of the annual rate of return are found as 0.16 and 0.92, respectively. The standard deviation indicates the high volatility for the field grown production; therefore, we expect high option value to keep the option alive which incentivize growers to postpone the new investment (Dixit and Pindyck, 1994).

The present value for 2014 season (\$14,405) is the forecasted present value for the field-grown technology (see table 3-6), and NPV for 2014 is calculated by adding net income (\$992) to the present value of the same year, yielding \$15,397. The upper and lower values for 2015 are calculated by using the annual volatility of the field-grown production, 0.92; therefore, NPV for 2015 would either be \$35,954 ($PV_{2014}^{fg} \cdot e^{(\sigma_z \sqrt{dt})}$) or \$5,771 ($PV_{2014}^{fg} \cdot e^{(-\sigma_z \sqrt{dt})}$) where $dt=1$. Then, we could find PVs for the 2015 season by discounting the calculated NPVs with the ratio calculated as $NI_{2015}^{fg} / (PV_{2015}^{fg} + NI_{2015}^{fg})$. This procedure is followed for the all the years until we calculate all branches in the decision tree.

As described in the Copeland and Antikarov (2003), we analyze the optimal execution of real options starting at the end of the tree when the option expires. We analyze two different investment options for the field-grown producer: (1) investment in Florida greenhouse; (2) investment in high-tech greenhouse. The final nodes of the option calculation are chosen as the maximum of the three values from the present value of the final year, present value of high-tech greenhouse in 2023 minus discounted

initial equity for 2023, and present value of Florida greenhouse in 2023 minus discounted initial equity for 2023 as $MAX(PV_{2023}^{fg}, PV_{2023}^{fl} - IE_{2023}^{fl}, PV_{2023}^{ht} - IE_{2023}^{ht})$. For instance, the top node of the end of three is the maximum value of comparing present value \$36,799,192 from binomial tree, the value given from Florida greenhouse as $\$308,825 - \$35,000 / (1 + 0.3)^{10}$, and the value given from Florida greenhouse as $\$558,720 - \$35,000 / (1 + 0.3)^{10}$.

After we fill the values at the end of the tree, the remaining nodes are calculated by replicating portfolio approach. Following Iwai and Emerson (2008), one can derive the equation for holding option value (C_t) at time t as $C_t = [qC_{t+1}^u + (1 - q)C_{t+1}^d] / (1 + r_f)$ where q is the risk neutral probability ($q = ((1 + r_f) - e^{-\sigma_z}) / (e^{\sigma_z} - e^{-\sigma_z})$), risk free rate of return is taken as 3% calculated from ten year Treasury bills and, C^u and C^d denote the up and down state of the option values, respectively. Next, we compare the holding option value with the investment options as $MAX(C_t, PV_t^{fl} - IE_t^{fl}, PV_t^{ht} - IE_t^{ht})$ and repeat the procedure for the all the remaining nodes (Figure 3-8). Finally, we compute NPV with option value as \$421,240 and option value is simply calculated by subtracting NPV value from the NPV with option value which is $\$421,240 - \$15,397 = \$405,843$. This option value indicates how much a farmer loses when the investment option is exercised.

Table 3-11 summarizes the NPV results for each tomato production technologies with the option value. The results suggest that a farmer in field-grown production still has a high option value to invest in greenhouse technology given assumed production information. The results explain why we may not see greenhouse investment in Florida, yet.

Discussion

Florida tomato growers have lost market share in the last decade to the increasing Mexican greenhouse tomato imports. Although Florida producers achieved an agreement with Mexican producers for a fixed floor price for Mexican tomatoes in 1996, domestic tomato sales continue to decline in the winter season. The renegotiated antidumping investigation suspension agreement came into force in the summer of 2013. This agreement could help Florida growers, but the lower-priced imported field-grown tomatoes will still be a threat for the market share of the domestic growers.

The regular NPV analysis results suggest that investment in tomato production with the high technology greenhouse is preferred over regular Florida greenhouse and field-grown production (assuming per-plant crop yield for each technology is at the break-even point). Moreover, the investment decision preferences changes with an increase in the risk aversion coefficient of the decision-maker. Stochastic efficiency ranking of the investment decision shows that the high technology greenhouse is preferred by risk neutral and normally risk-averse decision makers. However, moderately risk-averse decision makers may invest in a regular Florida greenhouse technology, while extremely risk-averse growers will continue to produce field-grown tomatoes. These results are consistent with what has been witnessed in tomato production in Florida. The increase in greenhouse investment shows that some growers are beginning to take more risk because they find greenhouse investment as a way to compete better in the market.

The strength of this study lays in the examination of all possible tomato production alternatives for Florida producers by incorporating risk into the decision making analysis. However, the analysis depends on the budget data prepared by

experts and university researchers as a representative farm, rather than actual budget data. Although the budgets are prepared for representative farms, we updated the budget items with the experts' recommendations to better reflect farm production simulation.

Table 3-1. Risk identification for greenhouse and field grown tomato productions

Risk parameters	Risk source	Greenhouse	Field-grown
Market Risk	Product Perception		
Yield Risk	Weather	Low	High
Price Risk	Supply/ Demand relationship	Relatively low	High
Cost Risk	Input – Energy – Labor expense variability	High	Relatively low

Source: Prepared by author based on the expert opinions and literature.

Table 3-2. Key assumptions used in greenhouse tomato financial model

Variable	Unit	Value
Ownership	Per cent	100%
Operating Loan Length	Years	1
Operating Loan Interest Rate	Per cent	5.0
Long Term Loan Length	Years	7
Long Term Loan Interest Rate	Per cent	8.0
Interest on equity invested	Per cent	10.0
Corporate tax rate	Per cent	25.0
Inflation rate	Per cent	2.0
Increase in Energy Prices	Per cent	7.0

Table 3-3. Tomato budget for three production technologies (in dollars per acre)

	Field-grown	Greenhouse – FL	Greenhouse - HT	Production Cost Share		
Initial Equity	\$ -	\$ 35,000.00	\$ 35,000.00			
Start-up Cash	\$ 13,150.00	\$ 196,322.35	\$ 389,055.81			
Construction	\$ -	\$ 459,596.72	\$ 945,236.68			
Cost & Durables						
Growing Costs	\$ 7,218.09	\$ 27,043.08	\$ 170,147.20	41.20%	11.48%	33.41%
Energy Costs	\$ -	\$ 58,040.68	\$ 93,297.17	0.00%	24.64%	18.32%
Labor Costs	\$ 354.92	\$ 74,653.13	\$ 131,167.23	2.03%	31.69%	25.76%
Sales Costs	\$ 5,815.80	\$ 53,005.56	\$ 80,520.31	33.19%	22.50%	15.81%
Administrative	\$ 4,132.85	\$ 22,852.22	\$ 34,151.64	23.59%	9.70%	6.71%
Total Production Cost	\$ 17,521.66	\$ 235,594.67	\$ 509,283.54	100.00%	100.00%	100.00%
(w/o initial investment)						

Source: Based on three budget sets (see Appendix B).

Table 3-4. Net income statements for alternative tomato production technologies, 2014 (\$/acre)

	Field-grown	Greenhouse – FL	Greenhouse - HT
Expected Production Amount	40,500 lbs	244,950 lbs	473,499 lbs
Expected Revenue	\$ 19,501.47	\$ 338,458.85	\$ 666,456.25
Energy Cost	\$ -	\$ 58,040.68	\$ 93,297.17
Other Costs	\$ 7,573.01	\$ 101,696.21	\$ 301,314.43
Gross Profit	\$ 11,928.46	\$ 194,106.46	\$ 289,382.97
Sales and Administrative Cost	\$ 9,948.65	\$ 75,857.79	\$ 114,671.94
Depreciation	\$ -	\$ 61,121.85	\$ 79,953.60
Interest Payment	\$ 657.06	\$ 40,015.95	\$ 83,412.91
EBT	\$ 1,322.75	\$ 1,726.38	\$ (6,193.80)
Tax on EBT (%25)	\$ 330.69	\$ 431.60	\$ -
Net Income	\$ 992.06	\$ 1,294.79	\$ (6,193.80)

Table 3-5. Stochastic variables used in financial model of tomato production investment decision

Variable	Unit	Value
Tomato Yield (Field Grown)	cwt/acre	Mean Yield ^k * [1 + MVE (S _i , F(S _i), CUSD ₁)]
Sale Prices	\$/cwt	Mean Price ^k * [1 + MVE (S _i , F(S _i), CUSD ₂)]
Electricity Price	\$/KW	Mean Price ^k * [1 + MVE (S _j , F(S _j), CUSD ₁)]
Gas/Liquid Petroleum Gas Price	\$/Gallon	Mean Price ^k * [1 + MVE (S _j , F(S _j), CUSD ₂)]

Table 3-6. Forecasted present values and net incomes for field-grown and greenhouse tomato productions (\$/acre)

Years	Field-grown		Greenhouse - FL		Greenhouse - HT	
	PV	Net Incomes	PV	Net Incomes	PV	Net Incomes
2014	\$ 14,404.89	\$ 992.06	\$226,838.19	\$ 2,478.53	\$394,471.53	(\$ 6,193.80)
2015	\$ 15,654.05	\$ 981.08	\$257,196.79	\$ 5,290.71	\$400,997.94	\$ 1,002.08
2016	\$ 16,892.13	\$ 964.64	\$287,299.40	\$ 8,245.50	\$406,864.84	\$ 6,923.71
2017	\$ 18,113.69	\$ 942.65	\$261,829.38	\$10,299.70	\$402,877.48	\$12,977.68
2018	\$ 19,313.16	\$ 914.97	\$277,034.58	\$13,328.65	\$406,776.82	\$19,539.92
2019	\$ 20,484.85	\$ 881.52	\$252,064.54	\$15,890.36	\$409,288.96	\$26,473.89
2020	\$ 21,622.99	\$ 842.15	\$151,496.24	\$18,725.42	\$255,378.75	\$33,679.74
2021	\$ 22,721.66	\$ 796.77	\$199,911.79	\$21,934.31	\$303,641.17	\$40,144.11
2022	\$ 23,774.85	\$ 745.24	\$277,684.01	\$21,639.57	\$436,434.02	\$39,720.92
2023	\$ 24,776.40	\$ 687.45	\$308,825.43	\$20,603.35	\$558,720.30	\$38,998.94

Table 3-7. Net present values per acre field grown and greenhouse tomato productions

	Present Value	Initial Equity	NPV
Field-grown	\$3,705.19	-	\$3,705.19
Greenhouse - FL	\$74,130.33	\$35,000.00	\$39,130.33
Greenhouse - HT	\$105,289.52	\$35,000.00	\$70,289.52

Table 3-8. Summary statistics of Monte Carlo simulation for alternative technologies

	Greenhouse-HT	Greenhouse-FL	Field-grown
Mean	57,494.36	30,204.39	320.34
Standard Deviation	60,035.25	37,676.04	4,130.99
Coefficient of Variation	104.42	124.74	1,289.58
Minimum	(122,421.19)	(85,587.57)	(14,079.44)
Maximum	222,902.09	126,208.66	10,434.16

Table 3-9. First and second order stochastic dominance results for alternative technologies

	Greenhouse-HT	Greenhouse-FL	Field-grown	Approximate Area
First Degree Dominance				
Greenhouse-HT FDD:	-	-	-	
Greenhouse-FL FDD:	-	-	-	
Field-grown FDD:	-	-	-	
Second Degree Dominance				
Greenhouse-HT SDD:	-	Dominates	Dominates	167,059.7
Greenhouse-FL SDD:	-	-	Dominates	194,511.2
Field-grown SDD:	-	-	-	224,362.5

Table 3-10. Stochastic dominance with respect to a function results

Ranking	Name	Level of Preference
Lower Risk Aversion Coefficient: 0 (Risk-neutral)		
1	Greenhouse-HT	Most Preferred
2	Greenhouse-FL	2nd Most Preferred
3	Field-grown	3rd Most Preferred
Upper Risk Aversion Coefficient: 0.00004 (Extremely Risk-averse)		
1	Field-grown	Most Preferred
2	Greenhouse-FL	2nd Most Preferred
3	Greenhouse-HT	3rd Most Preferred

Table 3-11. Net present values with option value for field grown and greenhouse tomato production (\$/acre)

	Present Value	Initial Equity	NPV	Option Value
Field-grown	\$3,705.19	-	\$3,705.19	
Greenhouse – FL	\$74,130.33	\$35,000.00	\$39,130.33	\$405,842.66
Greenhouse – HT	\$105,289.52	\$35,000.00	\$70,289.52	\$405,842.66

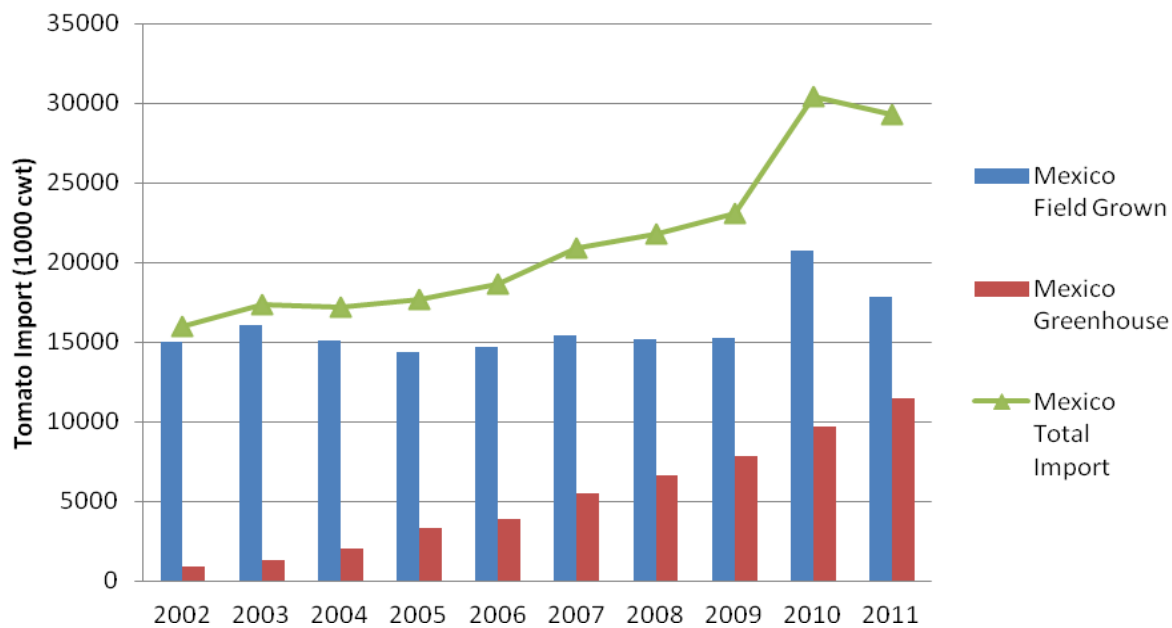


Figure 3-1. Tomato imports from Mexico by technology

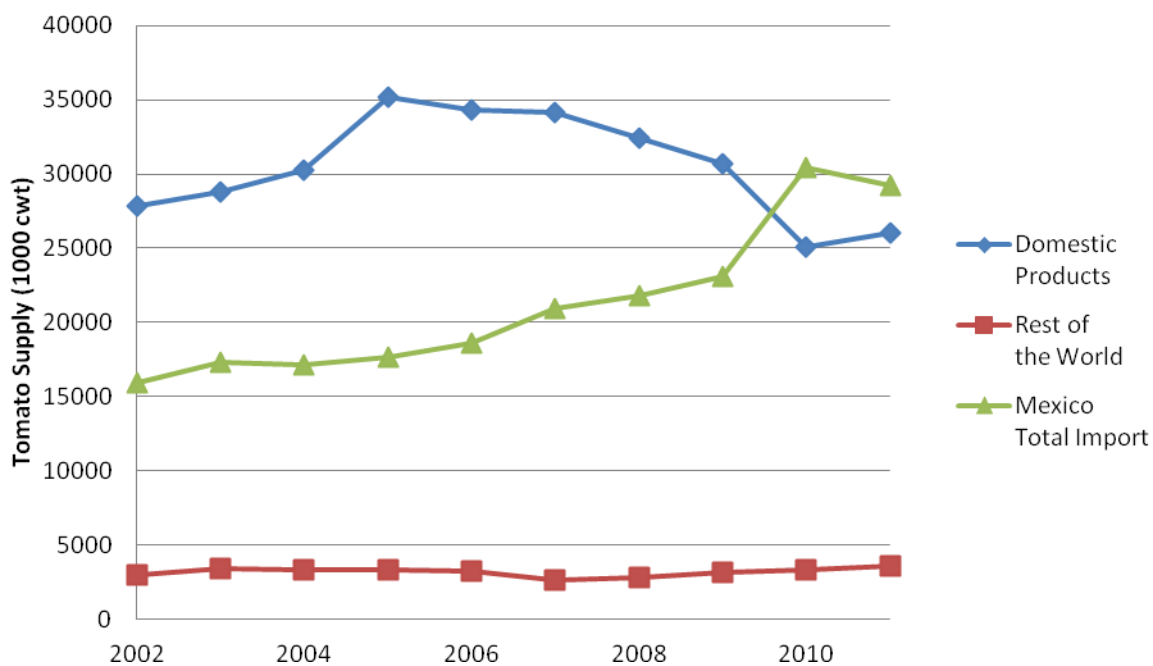


Figure 3-2. Fresh tomato supply in the U.S. market

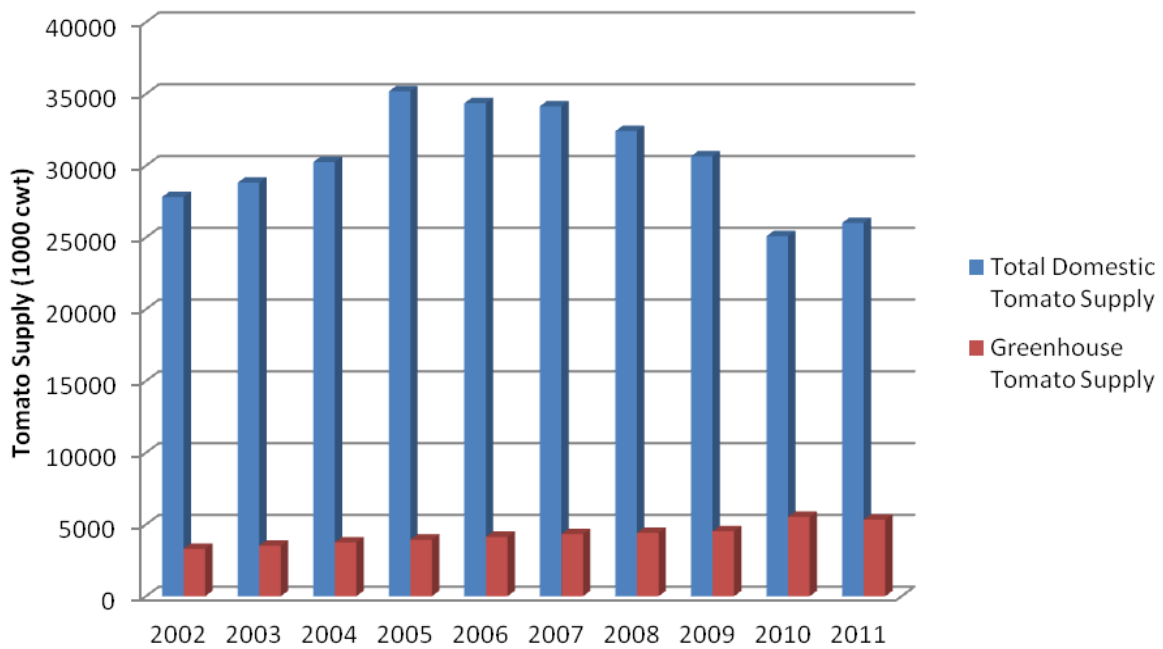
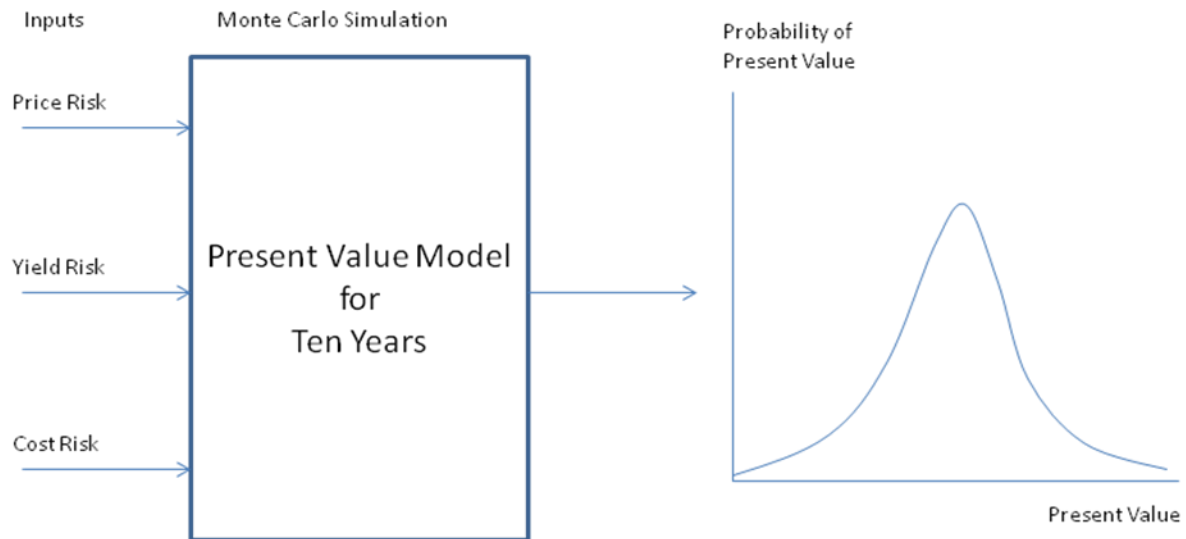


Figure 3-3. Domestic fresh tomato market in the U.S.



Source: Adapted from Copeland and Antikarov (2003)

Figure 3-4. Risk modeling in the net present value analysis

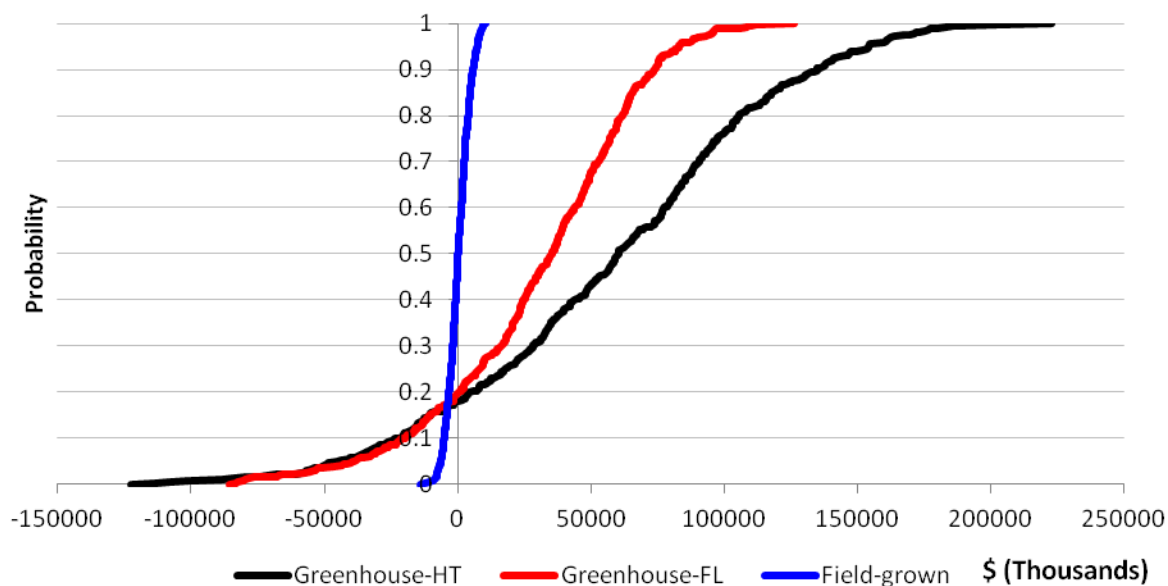


Figure 3-5. CDFs of simulated NPVs for alternative technologies

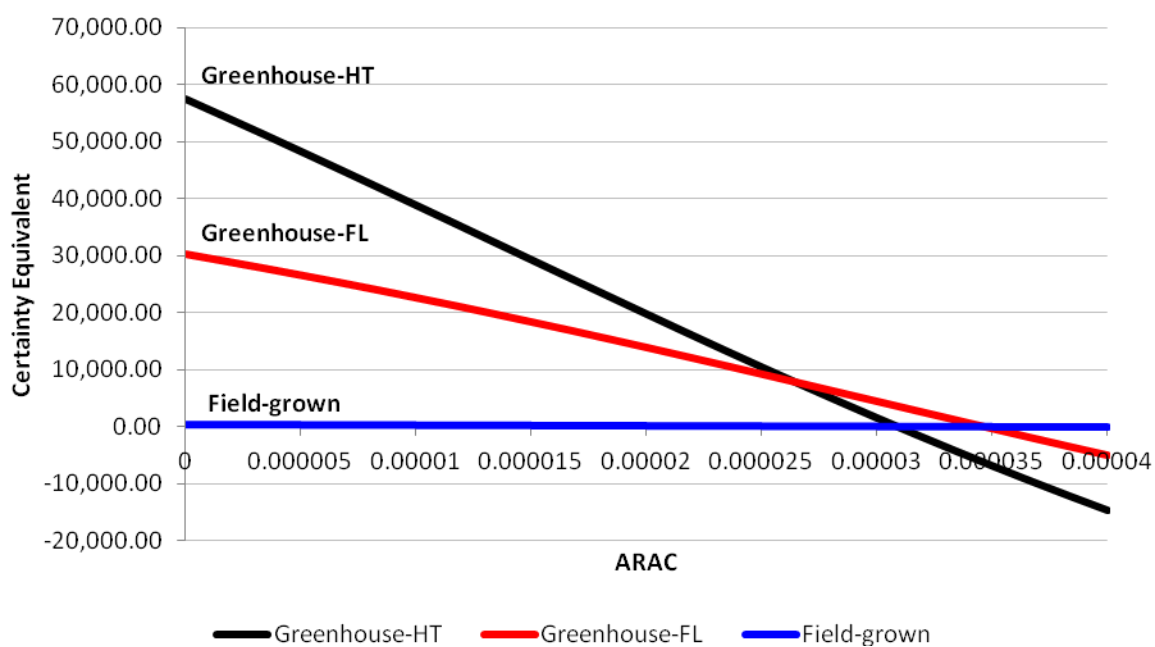


Figure 3-6. Stochastic efficiency with respect to a function under a negative exponential utility function

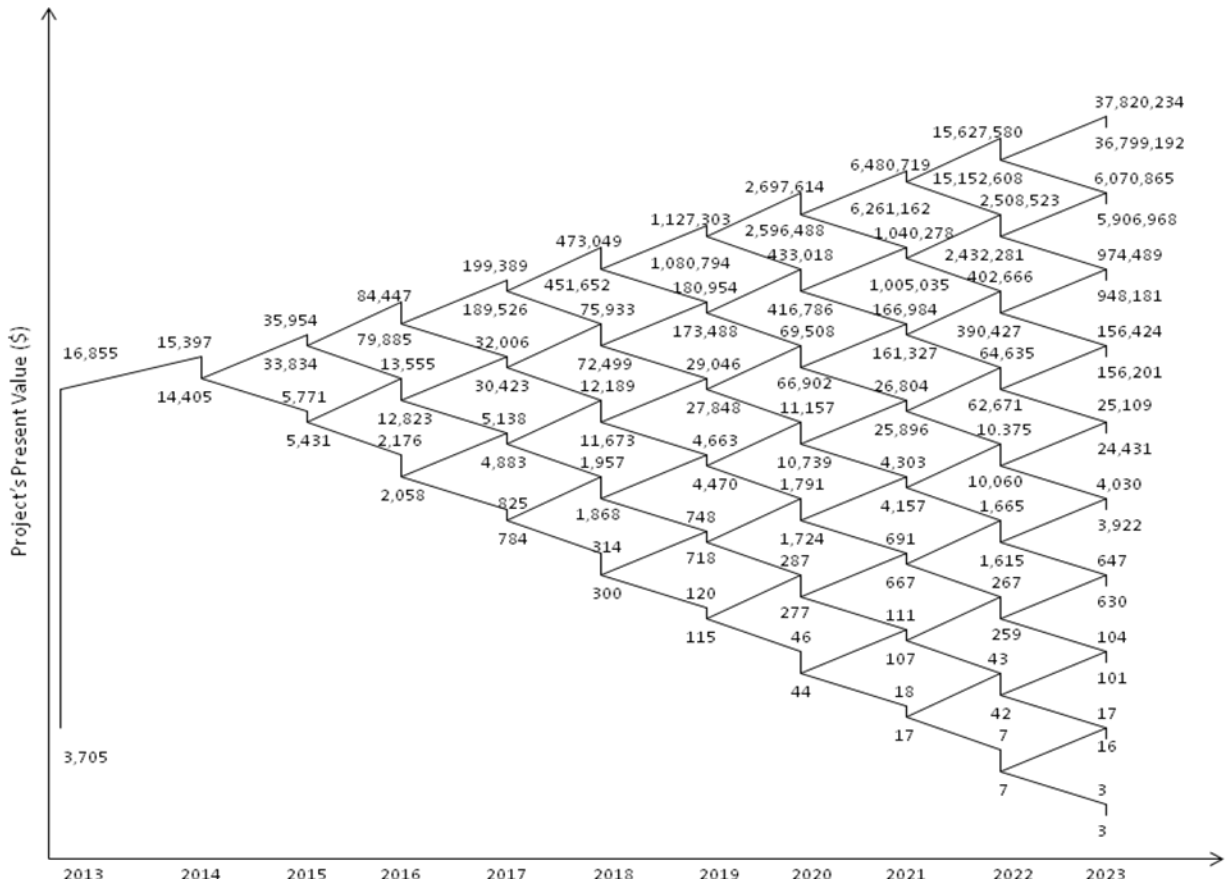


Figure 3-7. Present value binomial tree for field-grown tomato production

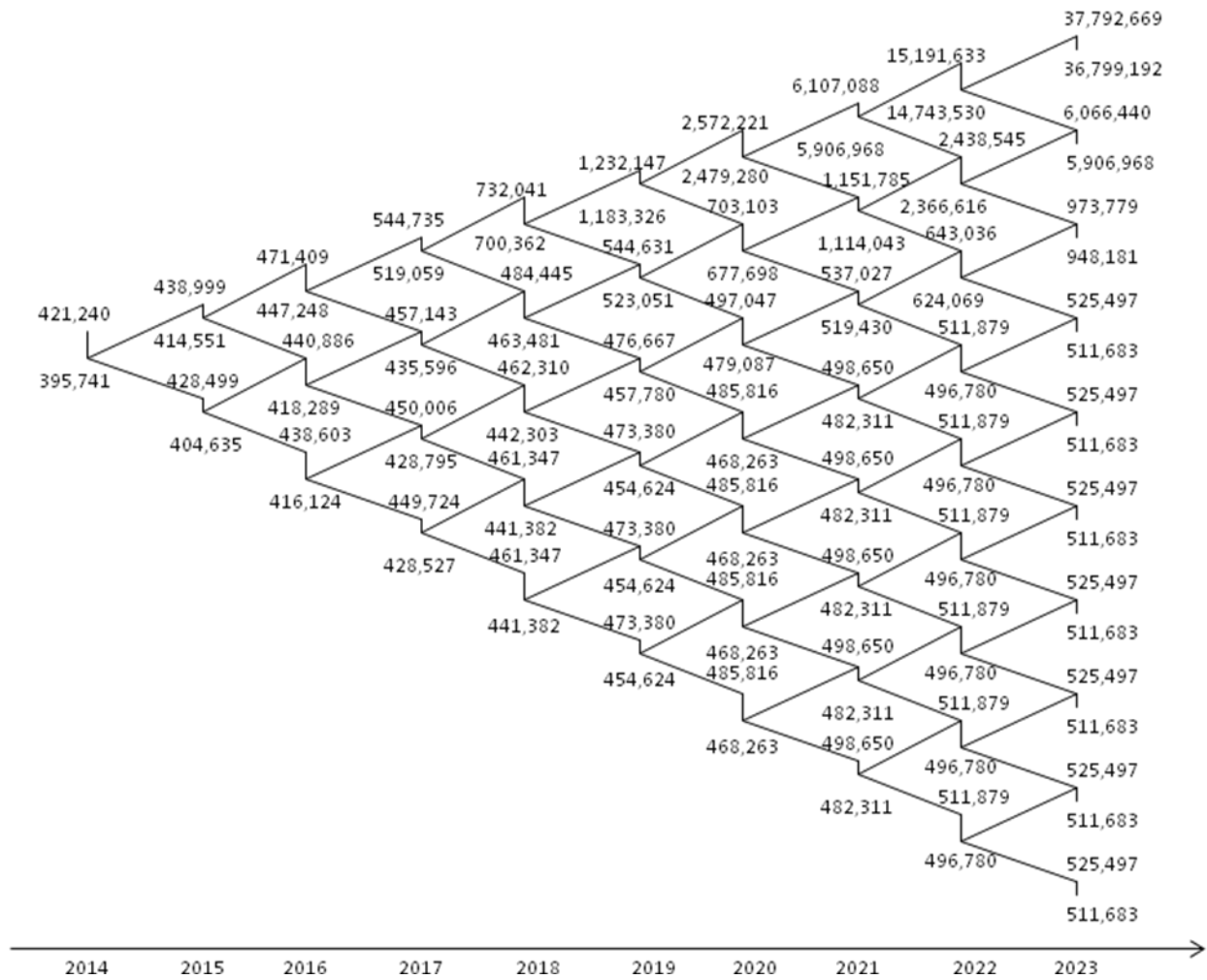


Figure 3-8. Real option calculation for greenhouse tomato investment

CHAPTER 4

RISKS AND FARMERS' FERTILIZER USE DECISIONS: AN ECONOMIC APPROACH TO DEVELOP FERTILIZER BEST MANAGEMENT PRACTICE

Introductory Remarks

Nutrient management is a key decision for an agricultural producer. The amount of nitrogen fertilizer and its placement, type, and timing can have a direct impact on the crop yield and hence, profitability of a farm. Nutrient management also has important implications for water quality in local streams and rivers, helping to reduce fertilizer runoff from agricultural fields. The decision about the optimal fertilizer rate is based on comparison of the marginal fertilizer cost and revenue, which are influenced by imperfectly known future yields. To evaluate the relationship between their fertilizer use and future yields, agricultural producers rely on observations collected through many years of their production experiences. Fertilizer use recommendations developed by the State Cooperative Extension Service, referred to as Best Management Practices (BMPs), are also used by producers. Moreover, given the extent of nutrient water pollution issues nationwide, there have been calls for making the use of fertilizer BMPs mandatory for agricultural producers. In Florida, BMPs are already mandatory for agricultural producers operating in the watersheds with impaired water bodies where watershed management plans (referred to as Total Maximum Daily Load, TMDL, plans) were established. Such mandatory requirement for BMP implementation requires a precise BMP definition, acceptable to all stakeholder groups, and providing for economically viable agricultural production and water quality protection.

Historically, agricultural producers often deviated from fertilizer BMP recommendations, likely due to one of the three reasons: (1) producers' beliefs about the excessively significant effect that additional fertilizer has on their crops' yield and/or

yield variability (Feinerman et al. 1990; Huang 2002); (2) systematic biases in Extension production experiments used to develop recommendations; or (3) the lack of considerations of socio-economic factors in the development of the Extension recommendations, which leads to overly restrictive recommendations. In this study, we focus on the third potential reason. The overall objective of the study is to provide recommendations for BMP definition and development process to better account for the economic factors influencing the producers' fertilizer use decisions.

Existing studies identified a variety of economic and non-economic factors affecting fertilizer use. Antle (2010), Isik (2002), and Pope and Kramer (1979) focus on production risk (defined as the variance of yield) and price risks (defined as the variance of input and output prices). Since the fertilizer use influences yield variability and hence, production risks, the fertilizer application decisions depend on the degree of farmers' risk aversion. Specifically, if the increase in fertilizer use leads to higher yield variability, then farmers who dislike the risks (i.e. more risk-averse) apply less fertilizer, in comparison with those farmers who enjoy risky enterprises (i.e. less risk-averse or risk-loving). Given that nitrogen and phosphorus are found by many studies to increase the variability of yield, more risk-averse farmers should apply less fertilizer. For example, in a study of corn production experiments in Canada, Rajsic et al. (2009) found that it is economically optimal for a risk-neutral farmer to apply 14% more nitrogen than the current Canadian BMP recommendations, while for a very risk-averse farmer it is optimal to apply 37% less nitrogen than the BMP recommendations.

Existing studies states that producers' perceptions of the fertilizer effects on yield variability can differ from the effects observed by researchers. For example, in his study

of twelve Texas grain sorghum producers, SriRamaratnam et al. (1987) found that some of the growers believed that fertilizer reduces yield variability (contrary to conclusions of many production experiment studies). For the producers who believe in reduction in yield variability due to greater fertilizer use, higher risk aversion would increase the fertilizer use.

Published studies have also examined producers' fertilizer use decisions given the uncertainty of future input and output prices. For example, Feinerman et al. (1990) showed that the output price uncertainty lowers the levels of fertilizer use, while the expected increase in future fertilizer prices lead to higher fertilizer application rates. Several studies have also considered the effects of uncertainty of weather and soil fertility on the substitution between nitrogen and land (Babcock and Blackmer 1994), as well as the link between fertilizer use and crop choices (Babcock and Pautsch 1998).

Overall, fertilizer BMP implementation rate depends on the BMP implementation and maintenance costs, perceived benefits of BMP, as well as the farm's financial performance (e.g., farm's debt-to-asset ratio) (Paudel et al. 2008, Prokopy et al. 2008). Farmers' attitudes and perceptions about the process of BMP development and implementation, severity of water quality problems, and the effectiveness of BMPs in reducing potential environmental impacts can also change the likelihood of BMP implementation (FDACS 2011a, Prokopy et al. 2008). Finally, BMP implementation rate can depend on farmers' access to the information from producers' or community organizations (Feather and Amacher 1994).

In this study, the economic factors important for fertilizer BMP definition are explored by considering (a) variability in yield driven by uncertainty in weather and

fertilizer input use; (b) alternative levels of input and output prices; (c) various decision criteria that can be used by producers (i.e. maximizing profits or expected utility); and (d) various levels of producers' risk-aversion. Florida potato industry around Lower St Johns River Basin is used as a case in this study. Contested fertilizer BMP requirement for the potato production, sandy soils that facilitate fertilizer leaching, and potato farms located in close proximity to waterways make this region attractive for this study. The study shows that the fertilizer BMP level depends on the assumptions about the decision criteria, producers' risk aversion, and the market prices. Since the decision criteria and risk aversion varies among producers, and the prices vary from year to year, developing a unique optimal fertilizer rate BMP applicable for all producers and all production and market conditions is impossible. Instead, it should be explicitly recognized that restricting fertilizer rate to a BMP level can result in reductions in profits for some producers and some market conditions. The acceptable tradeoffs between water quality protection and reductions in agricultural profits should be explicitly discussed as a part of BMP development process, and possible funding mechanism to compensate farmers for reductions in profits should be developed (such as water quality credit trading).

This research makes several contributions to the existing literature. First, this study examines an advanced yield response function – quadratic stochastic plateau production function - that has not yet been used in published studies. Secondly, unlike other existing BMP studies that rely on short-term field trials to model yields, this research examines the yield variability using a long-term historic time series to capture a range of weather and market conditions. Thirdly, the combination of production

function estimation and Monte Carlo simulations applied to financial statement allows for a more rigorous modeling of profits and risks than what is found in other agronomic and agribusiness studies. Existing agronomic studies primarily model annual yields using non-stochastic production functions, and rarely analyze profits. In turn, existing agribusiness studies use financial statement to simulate profits, but they do not utilize yield response functions. The combination of stochastic yield response function and financial statement simulation allows for a more comprehensive and rigorous modelling of agricultural profits and risks. And finally, this research is the only study found that utilizes economic methodology to examine the costs associated with the alternative nutrient management BMP definitions. The BMP definition is especially important given the Florida's unique water quality policy that balances water quality improvement goal with the goal of economic growth associated with population increase and protection of the economically important agricultural industry. BMP implementation is mandatory in many watersheds in Florida in contrast to the voluntary approach used in other states. This mandatory policy requirement has resulted in the heated stakeholder discussions about what should constitute a BMP and how BMP development process should be structured. In many respect, Florida is in the forefront of water quality policy development, serving as testing ground for the policies that are to be adopted to address similar issues in other states.

Water Quality Policies to Address Agricultural Water Pollution Issues

Agricultural BMPs are the cornerstone of water quality policy to address agricultural water quality issues nationwide (USDA Nonpoint Source Water Quality Policy, 1986). Given that the 1972 Clean Water Act does not give the federal government the authority to regulate runoff from nonpoint sources (including most of the

agriculture), federal and state agencies rely on cost-share programs to encourage voluntary BMP implementation (USDA, 2006). Agricultural BMPs are developed to improve the efficiency and environmental sustainability of agricultural production.

Florida provides an interesting study area for BMP research because of its unique regulatory environment. Florida is at the forefront of the water quality policy development to address the challenge of accommodating raising population, supporting agricultural industry, and protecting natural resources. As the population in Southern US continues to grow (US Census, 2013), other states will likely revise their agricultural water quality policies, possibly following Florida's example and adopting similar innovative programs.

In Florida, the implementation of BMP is mandatory for agricultural producers operating in the watersheds with impaired water bodies, for which Total Maximum Daily Load (TMDL) plans and their implementation components (referred to as Basin Management Action Plans, or BMAPs) are developed and adopted. To formally participate in the BMP program, agricultural producers should use the Florida Department of Agriculture and Consumer Services (FDACS)-adopted BMP manual(s) appropriate to their operations and geographical regions, identify the applicable BMPs on a notice of intent (NOI) to implement the BMPs, and submit the NOI to FDACS. Agricultural producers also must maintain records, such as fertilizer use, and allow FDACS staff to inspect the BMPs (Migliaccio and Boman 2008). Farmers who submit an NOI and implement and maintain FDACS-adopted BMPs have a presumption of compliance with state's water quality regulations. If farmers choose not to file NOIs, then they are required to monitor their pollution runoff to prove that they are not causing

water quality impairments. Given that the BMPs are mandatory for implementation and that they guarantee the presumption of compliance with water quality standards, BMP development and implementation process attracts increased attention of agricultural producers and environmental groups. State agencies and the Cooperative Extension service work to address concerns and facilitate the dialogue among various stakeholder groups related to BMP development and implementation.

Similar to the definitions used in federal regulations and the definition adopted by other states, FDACS defines BMPs as “practical, cost-effective actions ... designed to benefit water quality and water conservation while maintaining or even enhancing agricultural production” (FDACS 2011a). Although economic performance is the key in BMP definition, BMP development largely rely on agronomic research and stakeholder discussions, while a comprehensive economic analysis is rarely conducted. As a result, there is a room for debate among producers, researchers, and the state agencies about whether specific BMP recommendations are “practical” and is “enhancing agricultural production”.

Moreover, BMP manuals are adopted by rule by FDACS, and are largely based on recommendations established by the Florida Cooperative Extension. Extension faculty face the challenge of conducting production experiments to serve the informational needs of the agricultural producers, while at the same time providing technical support to the state agencies developing water quality programs. While improving the efficiency of agricultural operations can often lead to the dual benefits of increased environmental sustainability and economic viability, situations can arise when there are tradeoffs between the profitability and environmental sustainability objectives.

As a result, the dual role of cooperative extension as benefactor of both agricultural producers and the state agencies can result in distrust in BMP recommendations of one or both stakeholder groups.

This research develops an economic model that can be used in fertilizer BMP development process. Costs associated with alternative fertilizer BMP definitions are explicitly examined. The economic model is developed and applied for a particular study area – Tri-County Agricultural Area – where BMP development process has been especially widely discussed and disagreed about (Borisova et al., 2010).

Study Area

The majority of Florida's assessed streams and lakes are classified as impaired, and 26 BMAPs have already been developed (FDEP, 2013). The BMAP for the Lower St Johns River Basin was the third BMAP developed in Florida, and it has been one of the most detailed and still one of the most contested BMAPs developed in Florida (US-EPA, 2009). The importance of the region and the increased attention to the region of the stakeholders in the state make it an interesting case study.

The main stem of the Lower St. Johns River is classified as impaired with respect to the narrative biologic water quality standard¹ and the numeric DO standard (FDEP, 2013). The main causes of impairment are the discharges from wastewater treatment facilities, and nonpoint source pollution from septic tanks, marinas, silviculture, dairies, storm water from urban development and tributaries, and row crop agriculture (FDEP, 2013). The effect of agricultural runoff is especially significant in the up-stream, southern portion of the Basin, which is largely rural. TMDL and BMAP were adopted for

¹ Although FL will be using numeric as opposed to narrative standards to identify nutrient impairment, existing TMDLs will be used as Site-Specific Alternative Criteria under the new rule.

the main stem of the Lower St. Johns River Basin in October of 2008, and implementation of BMPs is currently mandatory for agricultural producers in the Basin.

Florida is the leading supplier of potatoes in the nation during the spring harvesting season (National Potato Council, 2012), and most of the potatoes are grown in the Northeast portion of the state, in TCAA, most of which is located in the Lower St. Johns River Basin (TCAA, Figure 4-1). Agriculture is an important economic sector for TCAA, and along with potato, farmers grow sod, cabbage, and other vegetables. The total value of agricultural production in the region was \$126.1 M in 2007 (USDA, 2007).

The rate of agricultural BMP implementation, as well as signing the Notices of Intent (NOIs) to implement BMPs, varies among Florida's regions and agricultural crop types. For example, only 37% of agricultural producers in Suwannee River Water Management District signed NOIs (Katz, 2013). For a long time, the rates of signing NOIs and implementing fertilizer BMP were also relatively low in TCAA. This study uses the situation in TCAA as a case study to explore the BMP development and implementation process. Specifically, potato producers in TCAA argued that fertilizer BMP proposed in 2010 – 2012 did not account for the economics of their production, and hence, was not economically feasible and could not therefore be called a BMP. Indeed, large discrepancies between BMP recommendations and actual fertilizer use were observed, with the BMPs being 200 lb/acre, while growers were using up to 300 lb N/acre. Recently, FDACS set a BMP for potato growers in this area that allows growers to use up to 250 lb of N /acre (FDACS, 2011b). This new rule gives growers some flexibility to respond to the changing market and weather conditions; however, it is set without conducting an economic analysis of costs and benefits associated with this or

other possible BMP levels. Such a discrepancy between past and current BMP and the actual producers' practice, and the multiple stakeholder conflicts surrounding TMDL and BMAP development in the Basin make TCAA an interesting case study for this research.²

Below, the data related to the potato production in TCAA are presented. The discussion of the data is followed by the methodology used to examine the fertilizer use decisions and the costs associated with alternative fertilizer BMP definition.

Data

The land area, per acre yield and prices specifically for Hastings potato production in each of TCAA counties were obtained from potato statistics published by USDA – NASS for 1949 to 2006. Data for additional years (2007-2010) were obtained from USDA potato annual summary reports. Finally, NOAA' National Climatic Data Center was used to collect temperature and precipitation data for the study region. Information for Hastings area climatic station (COOP: 081978) was available only for the period of 1952 to 2010. Thus, this analysis focuses on this time period (Table 4-1).

County level fertilizer sale data for the three counties in TCAA were obtained from US Geological Survey (USGS, 2012), National Oceanic and Atmospheric Administration (NOAA, 2012), and Florida Department of Agriculture and Consumer Services (FDACS, 2012). Specifically, NOAA data cover the period from 1945 to 1991, USGS data span the period from 1987 to 2001, and FDACS reports the data for 1997 - 2010. Since the three sources are used for the fertilizer sales, the overlapping years are

² Note that similar issues related to the definition of fertilizer BMP are being widely discussed in other regions (see, for example, discussions of fertilizer rate for tomato production in southwest Florida in Hendriks and Shukla, 2011).

used to adjust time series data after the unit conversion was made. Time series data for the changes in acreage of different agricultural operations was not available, and hence, the total fertilizer use could not be adjusted to account for the use in specific crops. Potato production was considered to be the primary agricultural land use type in TCAA that requires fertilizer use, and hence, all county-level agricultural fertilizer sales were attributed to potato production. It is important to acknowledge that this assumption is an over-simplification. For example, the most recent Agricultural Census showed that in 2007, 24,026 acres were devoted to vegetable production in TCAA, and potato was grown on 67.5% of this area (i.e., 16,224 acres; USDA, 2007).³ The percentage of agricultural area devoted to potato production varies over time, and it would be important to account for this variation in estimating fertilizer use. However, as stated above, the time series data on the proportion of potato production in the total vegetable production area was not available. Moreover, the average fertilizer use estimated in this study ranges from approximately 50 to 250 lb N / acre, which is close to the levels historically observed in potato production in the area.

The analysis of descriptive statistics shows that fertilizer sales increase over time, corresponding to the rise in potato yield in TCAA. The biggest rate of increase in estimated fertilizer sales and yield are seen in the late 70's and the early 80's, and this increase coincides with the green revolution period associated with a series of research and technological improvements in 1970s that increased agriculture production in US and around the globe (Figure 4-2). It is also important to mention that planted potato land does not fluctuate much in the study period (Figure 4-3), and hence the increase in

³ In addition to vegetable production, other types of agriculture included woodland, pasture, and other uses, along with a relatively small percentage of sod and floriculture crops (USDA, 2007).

total potato production is primarily attributed to increases in yield, especially after 1980. This increase in yield can be linked, for example, to the introduction of more productive potato varieties.

The precipitation data indicates the distribution of the number of rains over 1 inch during production season of TCAA (this precipitation level is based on the definition of the “leaching rain” event used in the fertilizer BMP definition).⁴

Methodology

To examine the effect of economic factors on fertilizer use decisions, this study develops a comprehensive model that integrates various production and risk analysis methods. First, potato production function is estimated. Production function (also referred to as a yield response function) represents the relationship between nitrogen fertilizer use, weather conditions, and per acre potato yield. In this study, linear and quadratic stochastic plateau production functions are derived, and then estimated using data for the study area and maximum likelihood technique. Next, financial analysis model is developed to assess profits for a typical potato farm in the study area. The financial model and the estimated potato production function are then combined to simulate ten-year net present value of profits using Monte Carlo technique. The simulations are conducted given alternative weather conditions, nitrogen fertilizer and potato sale prices, and nitrogen fertilizer application rates. The nitrogen fertilizer rates are evaluated using two criteria of ranking risky alternatives: (1) expected profit maximization; and (2) stochastic dominance. The results are used to rank alternative

⁴ Note that temperature records for TCAA was also examined, but the correlation between temperature and potato yield was relatively small, and hence, temperature was excluded from further analysis.

fertilizer rates and to calculate costs associated with alternative nitrogen fertilizer rates, as well as to develop recommendations for BMP development process.

Production Functions

Most agronomic fertilizer BMP studies focus on estimating a production function to find the optimum level of fertilizer that maximizes yield. Only a few studies also estimate the optimum level that maximizes the profit (Hochmuth et al. 2011). Note that in both cases, production and price risks are ignored.

The deterministic quadratic-plateau production function is commonly used in agronomic BMP research and some economic studies (Anderson, 1973; Cerrato and Blackmer, 1982; Bullock and Bullock, 1994). The assumption is that increase in nutrient level after a certain level does not influence the yield (i.e., the plateau level). The plateau level in such function is selected as the maximum point of the quadratic function (estimated with the production experiment data), disregarding the potential stochastic nature of the plateau, as well as the quadratic or linear components of the function.

To account for the stochastic variations in yield, switching regression methodology was introduced by Maddala and Nelson (1974). In addition to agricultural production research, the methodology is commonly used in labor economics, the modeling of housing demand, and the modeling of markets in disequilibrium to evaluate endogenous switching between two or more regions (Lokshin and Sajaia 2004). The methodology allows estimation of data from regions or time periods even though these regions / periods can be characterized by different functional forms for the dependent variable.

Tembo et al. (2008) developed an alternative methodology referred to as response model with a stochastic plateau. This methodology gives better results when

applied to complex functional forms with error terms as compared with the switching regression. Tembo et al. (2008) applied the methodology to the data from wheat production experiments, and the methodology allowed the researchers to account for year random effect in modeling plateau level that is linked to weather effects.

Comparison of the stochastic plateau method with switching regression showed that stochastic plateau methodology better explained the variation in the production experiment data.

Moreover, Brorsen (2013) presented an alternative to this estimation technique by introducing Bayesian estimation with random effects using Markov Chain Monte Carlo method. This technique is appropriate for small data samples (since it does not require asymptotic or plug-in approaches for standard error to determine optimal levels of input use). The other advantage is the evasion from convergence problem of nonlinear estimation methods used in prior methodologies.

In this study we compare the production functions estimated with alternative methods using the time series data. This approach is drastically different from the approach used in the previous studies that relied on the field experiments and panel data. Panel data refer to the data that span several years (i.e., time series component) and include observation for several plots (i.e., cross-section component). Inclusion of both time series and cross-section reduces omitted data variable bias (heterogeneity) and allows researchers to include dynamic relationship (Hausman and Wise, 1979). However, panel data are also extremely costly to collect. Due to the complexity and the costs of field experiments, they are usually conducted for a few years only. In contrast, the time series data aggregated to a county level are collected by USDA and state

agencies on an annual basis, and historic data are available for more than 50 years that span the periods with vastly different weather and market conditions. The data are also widely available for the researchers. Finally, time series data can perform well for the regions where soils are fairly homogeneous, and spatial differences are not significant. In this study, we examine the feasibility of using time series data to substitute for the field experiments results in the analysis of fertilizer use decisions in TCAA.

To summarize, the study makes the following contributions to the literature. First, it relies on time series data (as opposed to the panel data). Second, in contrast to traditional BMP research that relies on deterministic production functions, the study explicitly incorporates weather effects into the stochastic production function. Third, in contrast to existing economic studies that use linear stochastic plateau, the study estimates and tests quadratic stochastic plateau production function (which is more complex than the linear stochastic plateau function and hence, it does not allow for the explicit analytical solution for optimum nitrogen level). Fourth, numerical optimization routine is used to account for price variability and risks.

The following two sub-sections describe the two stochastic production functions analyzed in this study – linear and quadratic stochastic plateau functions.

Linear stochastic plateau production function

Dillon (1961) stated that the majority of production functions have a plateau where yield does not increase in response to additional input use. Following Tembo et al. (2008), assuming single input model, the plateau response function in general form is expressed as follows

$$y = \min(g(N), y_p) + \varepsilon \quad (4-1)$$

where y is the yield, N is the level of nitrogen, $g(N)$ is the production function and y_p is the plateau level and ε is the random error term. This function comes from a mathematical model called the plateau principle in which input contribution to the yield eliminated by time (Spillman 1933). Tembo et al. (2008) described a univariate linear response function and the optimum level of nitrogen as follows:

$$y_t = \min(\alpha_0 + \alpha_1 N_t, \mu_p + \nu_t) + \varepsilon_t \quad (4-2)$$

where N refers to nitrogen use at the time t , μ is a plateau level, ε and ν are random variables. The random shift of the plateau is represented by weather variance for which $\nu_t \sim N(0, \sigma_\nu^2)$. The stochastic variable for weather and random error term for the whole function are assumed to be independent and the production function and ν_t are not linearly dependent (Figure 4-4).

As stated above, assuming a risk-neutral producer that faces only the weather risk, the producer aims at maximizing the expected profit:

$$E(\pi_t | N_t) = p \cdot E(y_t) - w_N \cdot N_t \quad (4-3)$$

where p is the output price and the w_N is the input price. If we use non-stochastic plateau model, the optimum input level is obtained from the first order condition as

$$N_t = \begin{cases} N_p, & \text{if } p \cdot \alpha_1 > w_N \\ 0, & \text{otherwise} \end{cases} \quad (4-4)$$

where N_p represents the nitrogen level at the plateau. We add distribution function to this solution to determine input level for stochastic plateau. The censored normal distribution theorem developed for Tobit models can be used to find the optimum input level for stochastic plateau model (Greene 2000). The optimum level can be on the plateau or to the left of the plateau, then the expected yield becomes

$$E(y_t) = (1 - \Phi) \cdot a + \Phi \cdot (\mu_p - \sigma_v \cdot \phi / \Phi) \quad (4-5)$$

where a represents the function $a = \alpha_0 + \alpha_1 N_t$, and Φ represents the probability of being on the function while $(1 - \Phi)$ gives the probability of being on the plateau. Therefore, the terms Φ and ϕ indicate the cumulative distribution function

$(\Phi = \Phi((a - \mu_p) / \sigma_v) = \text{prob}(y_p \leq a))$ and standard normal density function

$(\phi = \phi((a - \mu_p) / \sigma_v))$.

Substituting equation (4-5) into (4-3) yields

$$E(\pi_t | N_t) = p[(1 - \Phi)(\alpha_0 + \alpha_1 N_t) + \Phi(\mu_p - \sigma_v \cdot \phi / \Phi)] - w_N N_t. \quad (4-6)$$

The first order condition of the profit function is

$$\frac{\partial E(\pi_t | N_t)}{\partial N_t} = p \frac{\partial[(1 - \Phi)(\alpha_0 + \alpha_1 N_t)]}{\partial N_t} + p \frac{\partial[\Phi(\mu_p - \sigma_v \cdot \phi / \Phi)]}{\partial N_t} - w_N = 0. \quad (4-7)$$

Note that $\frac{\partial \Phi}{\partial N_t} = \frac{\partial[\Phi((a - \mu_p) / \sigma_v)]}{\partial N_t} = \frac{\partial[\Phi((\alpha_0 + \alpha_1 N_t - \mu_p) / \sigma_v)]}{\partial N_t} = \phi \frac{\alpha_1}{\sigma_v},$

$$\begin{aligned} \frac{\partial \phi}{\partial N_t} &= \frac{\partial[\phi((a - \mu_p) / \sigma_v)]}{\partial N_t} = \frac{\partial[\phi((\alpha_0 + \alpha_1 N_t - \mu_p) / \sigma_v)]}{\partial N_t} \\ &= -((\alpha_0 + \alpha_1 N_t - \mu_p) / \sigma_v) \phi \frac{\alpha_1}{\sigma_v} \end{aligned} \quad (\text{McDonald and Moffitt 1980}).$$

Application of the chain rule results in the following equation

$$\begin{aligned} \frac{\partial E(\pi_t | N_t)}{\partial N_t} &= p \frac{\partial[(1 - \Phi)(\alpha_0 + \alpha_1 N_t)]}{\partial N_t} + p \frac{\partial[\Phi(\mu_p - \sigma_v \cdot \phi / \Phi)]}{\partial N_t} - w_N \\ &= p \left[\alpha_1 - \phi \frac{\alpha_1}{\sigma_v} (\alpha_0 + \alpha_1 N_t) - \Phi \alpha_1 + \phi \frac{\alpha_1}{\sigma_v} \mu_p + \sigma_v ((\alpha_0 + \alpha_1 N_t - \mu_p) / \sigma_v) \phi \frac{\alpha_1}{\sigma_v} \right] - w_N \\ &= p \left[\alpha_1 - \Phi \alpha_1 - \phi \frac{\alpha_1}{\sigma_v} (\alpha_0 + \alpha_1 N_t) + \phi \frac{\alpha_1}{\sigma_v} \mu_p + \phi \frac{\alpha_1}{\sigma_v} (\alpha_0 + \alpha_1 N_t - \mu_p) \right] - w_N = 0 \end{aligned}$$

The cancellation of the terms allow us to reduce the equation (4-7) into

$$\frac{\partial E(\pi_t | N_t)}{\partial N_t} = p\alpha_1[1 - \Phi] - w_N = 0 \quad (4-8)$$

Since $\Phi = \Phi(a - \mu_p / \sigma_v)$, rearranging the terms to find the optimum level of nitrogen value yields

$$\begin{aligned} \frac{\partial E(\pi_t | N_t)}{\partial N_t} &= p\alpha_1[1 - \Phi((\alpha_0 + \alpha_1 N_t) - \mu_p / \sigma_v)] - w_N = 0 \\ [1 - \Phi((\alpha_0 + \alpha_1 N_t) - \mu_p / \sigma_v)] &= \frac{w_N}{p\alpha_1} \\ \Phi((\alpha_0 + \alpha_1 N_t) - \mu_p / \sigma_v) &= 1 - \frac{w_N}{p\alpha_1} \\ \Phi^{-1}\Phi((\alpha_0 + \alpha_1 N_t) - \mu_p / \sigma_v) &= \Phi^{-1}\left[1 - \frac{w_N}{p\alpha_1}\right] \\ \alpha_0 + \alpha_1 N_t - \mu_p / \sigma_v &= \Phi^{-1}\left[1 - \frac{w_N}{p\alpha_1}\right] \\ N_t^* &= \frac{1}{\alpha_1} \left[\Phi^{-1}\left[1 - \frac{w_N}{p\alpha_1}\right] \cdot \sigma_v + \mu_p - \alpha_0 \right] \end{aligned} \quad (4-9)$$

where Φ^{-1} shows the inverse standard normal cumulative distribution function.

Quadratic stochastic plateau production function

Tembo et al. (2008) described the estimation procedure for linear stochastic plateau production function and the expected profit function. In this study, this methodology is extended for the case of quadratic stochastic plateau function.

Assuming a univariate quadratic function of the form $g(N) = \alpha_0 + \alpha_1 N + \alpha_2 N^2$, the

following stochastic plateau function can be developed:

$$y_t = \min(\alpha_0 + \alpha_1 N_t + \alpha_2 N_t^2, \mu_p + v_t) + \varepsilon_t \quad (4-10)$$

where t subscript is the years and α_i for $i=0,1,2$ are the parameters estimated. Yield at plateau level and further is showed as $\mu_p = \alpha_0 + \alpha_1 N_p + \alpha_2 N_p^2$ and N_p is the minimum level of the nitrogen input needed to reach the plateau with the same assumptions applied for stochastic variables.

A risk-neutral producer facing only weather risk aims to maximize the expected profit:

$$E(\pi_t | N_t) = p \cdot E(y_t) - w_N \cdot N_t \quad (4-11)$$

where p is the output price and the w_N is the input price. If one uses non-stochastic plateau model, the optimum input level is obtained from the first order condition as

$$N_t = \begin{cases} N_p & \text{if } N \geq (w_N - p \cdot \alpha_1) / 2p \cdot \alpha_2 \\ 0 & \text{otherwise} \end{cases} \quad (4-12)$$

The censored normal distribution theorem developed for Tobit models can be used to find the optimum input level for stochastic plateau model (Greene 2000). The optimum level can be on the plateau or to the left of the plateau. The expected yield becomes

$$E(y_t) = (1 - \Phi) \cdot a + \Phi \cdot (\mu_p - \sigma_v \cdot \phi / \Phi) \quad (4-13)$$

where $a = \alpha_0 + \alpha_1 N_t + \alpha_2 N_t^2$, $\Phi = \Phi(a - \mu_p / \sigma_v) = \text{prob}(y_p \leq a)$ and $\phi = \phi(a - \mu_p / \sigma_v)$.

The first order condition of the profit function when we substitute equation (4-13) into (4-11) yields

$$\frac{\partial E(\pi_t | N_t)}{\partial N_t} = p \frac{\partial [(1 - \Phi)(\alpha_0 + \alpha_1 N_t + \alpha_2 N_t^2)]}{\partial N_t} + p \frac{\partial [\Phi(\mu_p - \sigma_v \cdot \phi / \Phi)]}{\partial N_t} - w_N = 0 \quad (4-14)$$

The chain rule allows us to reduce the equation into

$$\frac{\partial E(\pi_t | N_t)}{\partial N_t} = p(\alpha_1 + \alpha_2 N_t)[1 - \Phi] - w_N = 0 \quad (4-15)$$

Since $\Phi = \Phi(a - \mu_p / \sigma_v)$, rearranging the terms to find the optimum level of nitrogen value yields

$$\alpha_1 N_t + \alpha_2 N_t^2 = \Phi^{-1} \left[1 - \frac{w_N}{p(\alpha_1 + \alpha_2 N_t)} \right] \cdot \sigma_v + \mu_p - \alpha_0 \quad (4-16)$$

where Φ^{-1} shows the inverse standard normal cumulative distribution function. Using quadratic function⁵ solution, two possible solutions are obtained as

$$N_t^* = \left(\frac{-\alpha_1 \pm \sqrt{\alpha_1^2 + 4\alpha_2 \left(\Phi^{-1} \left[1 - \frac{w_N}{p(\alpha_1 + \alpha_2 N_t^*)} \right] \cdot \sigma_v + \mu_p - \alpha_0 \right)}}{2\alpha_2} \right). \quad (4-17)$$

Since both sides of the equation have the nitrogen value, we find the optimum level of nitrogen numerically.

Maximum likelihood estimation of linear and quadratic plateau production functions

Let $f(.)$ be the probability density function and A be the vector of estimated parameters for quadratic or linear production functions, $A = (N_t, \alpha_0, \alpha_1, \alpha_2, \nu_t, \sigma_\varepsilon^2)$, where α_2 is equal to zero for linear function. Then the joint conditional probability density function is obtained as

$$f_y(y_t, \nu_t | N_t, A) = f_y(y_t | N_t, \alpha_0, \alpha_1, \alpha_2, \nu_t, \sigma_\varepsilon^2) \cdot f_\nu(\nu_t | \sigma_\nu^2) \quad (4-18)$$

⁵ Quadratic formula for $ax^2 + bx + c = 0$ is given as $x = (-b \pm \sqrt{b^2 - 4ac}) / 2a$.

The maximum likelihood function can be found by integrating the y_t with respect to v_t and taking the product over time as follows:

$$l(A|N, y) = \prod_{t=1}^T \int_a^b f_y(y_t | N_t, \alpha_0, \alpha_1, \alpha_2, v_t, \sigma_\varepsilon^2, v_t) \cdot f_v(v_t | \sigma_v^2) dv_t \quad (4-19)$$

where a and b are the limits of integration for the distribution of v_t . Although maximum likelihood estimation (MLE) maximizes the logarithmic transformation of this function, v_t prevents this function from having an open form solution. Therefore, numerical approximation is used for the estimation of the value of coefficients through nonlinear optimization. SAS NLMIXED procedure facilitates this process. The procedure includes Gaussian quadrature methods, the common method used to approximate complex integral similar to the integral in equation (19) (SAS Institute Inc 2004). Various combinations of starting values, optimization algorithms, and integral approximation with quadrature method were applied to get the convergence of the equation and the global maximum. The same MLE technique is also applied to estimate the coefficients of the linear response stochastic plateau production function (described in the previous section).

Maximization of Expected Profit

Assuming a risk-neutral producer that faces only the weather risk, the producer aims at maximizing the expected profit:

$$E(\pi_t | N_t) = p \cdot E(y_t) - w_N \cdot N_t \quad (4-20)$$

where p is the output price, w_N is the input price, y_t is yield, and t is the year index. The optimum level of nitrogen fertilizer, N_t , is obtained from the first order condition as:

$$\frac{\partial E(\pi_t | N_t)}{\partial N_t} = p \frac{\partial E(y_t)}{\partial N_t} - w_N = 0 \quad (4-21)$$

The specific level of nitrogen fertilizer use will depend on the relationship between N and y , which is described by the production function (see the section above). It is important to note that the assumption about the functional form of the production function will influence the optimal fertilizer use level, and hence, the assumption can have important implications for the fertilizer use decision and BMP recommendations.

Financial Analysis Model

The analysis described above employs expected profit maximization criterion to find the optimal fertilizer rate. While this analysis accounts for the production risks associated with variability in yield, it ignores the market risk, i.e., the risk associated with the variability in sale prices. Furthermore, this analysis is based on the assumption that the producer is risk-neutral, and is primarily concerned with the expected profits as opposed to the profit variability.

To account for the effects on fertilizer use decisions of both production and market risks, financial analysis model is developed, as described in the next subsection. The financial analysis model is then integrated with the estimated linear plateau production function, and Monte Carlo simulations are conducted to estimate the effects of production and sale price variability on ten-year net present value of a typical potato producer. A variety of producers risk preferences are then examined.

Financial sheet model

Financial sheet model consist of financial statement, cash flow statement, and balance sheet. The model is based on the model by Barker (2013) that has been used

in evaluation of market risks associate with alternative investment portfolios. The financial model is constructed in MS Excel.

The model allows calculating total costs, revenues, and the annual present values (PV) of a business enterprise (see Appendix E for more details). For this study, ten-year net present value is computed as follows:

$$NPV = -(\text{Start – up Equity Value}) + \sum_{t=1}^{10} \frac{PV_t}{(1+r)^t} + \frac{\text{Terminal Value}}{(1+r)^{10}} \quad (4-22)$$

The NPV for a typical potato producer in TCAA is estimated based on discussions with industry experts and the latest financial and business literature (Richardson et al. 2007a; Richardson et al. 2007b; Palma et al. 2011). The firm is chosen to be a 100% financed by the equity holder; in other words, it is totally owned by the producer. The start-up equity value (beginning wealth) for potato production is approximately \$325.00/ acre. This amount is chosen as the minimum amount to insure that the farmer does not run out of cash over 10-year period. Farmers use operating loans which account for 90% of total variable cost at a 5% interest rate annually; in addition, 80% of the fixed costs are financed at an 8% interest rate over a 7 year period. These levels of operating loans for variable and durable expenses, the annual interest rates, and the loan periods are based on literature and discussions with experts. Farmers are also assumed to receive 10% interest for their equity investment at the end of each year. The interest on equity investment refers to farmers' annual return from the positive net income, and 10% level is assumed as the minimum level typically used in existing studies.

To reflect production and price risks faced by the potato producers in the region, yield level and sale prices used in NPV estimation for each year are assumed to be

stochastic. NPV levels are then estimated for a variety of fertilizer and sale prices, and fertilizer use levels, as described in the next sub-section.

Simulations

The model uses a Monte Carlo simulation method and financial statements to analyze the returns for alternative nitrogen fertilizer rates. Monte Carlo simulation is a method that utilizes repeated random sampling to calculate probabilities of events, and it is well suited to approximate probability distributions of stochastic variables (Palma et al. 2011). This method is applied to simulate stochastic components in the financial model. A sample of values for all stochastic variables is selected simultaneously, and the process is repeated 500 times to estimate the probability density functions (PDF) and cumulative distribution functions (CDF) for the stochastic outcomes. The approach is used to obtain the distribution of yield, revenue, cost and net present value (NPV) for ten year period. The simulations are conducted using Simetar© add-in for MS Excel (Richardson, Schumann and Feldman, 2008).

The following stochastic variables are used to model production and price risks: yield (simulated using linear stochastic production functions described in the section above), output price (assumed to be correlated with historical yield), and fertilizer price.

Potato yield is simulated by using estimated linear stochastic plateau production function coefficients and the stochastic terms ($\nu_t \sim N(0, \sigma_\nu^2)$ and $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$) shown in the Table 4-4. Stochastic terms are assumed to be normally distributed in the estimation process and predicted yields are used as a mean yield for the simulation purposes.

Sale prices are simulated jointly with the yields, since historical price and yield data show negative correlation. A multivariate empirical (MVE) probability distribution is

used for the joint simulation of stochastic output prices and yields (Richardson, Klose and Gray 2000). First, the non-random components are found for historic prices and yields as a function of linear time trend.

$$\hat{X}_{it} = \hat{a} + \hat{b} \cdot Trend_t \quad (4-23)$$

where X represents the historical data for each component i (where $i=1$ refers to yield, and $i=2$ refers to price), while t indexes the year. Then the random components are calculated as the difference between actual and predicted values of historic prices and yields ($\hat{X}_{it}$):

$$\hat{e}_{it} = X_{it} - \hat{X}_{it} \quad (4-24)$$

Relative variability of the observations is then measured as a fraction of random components to the predicted values:

$$D_{it} = \frac{\hat{e}_{it}}{\hat{X}_{it}} \quad (4-25)$$

The relative variability, D_{it} , is calculated for each observation X_{it} , and then relative variability values are sorted from small to large to find their distributions. The correlation matrix is calculated using the fraction values calculated in equation (4-25). Given the historic values (Table 4-1), the correlation matrix for potato price and yield variables is as follows:

$$\rho = \begin{bmatrix} 1 & -0.14 \\ -0.14 & 1 \end{bmatrix} \quad (4-26)$$

Following Richardson, Klose and Gray (2000), one can calculate independent standard normal deviates (R_{ik}) taking square root of the correlation matrix. One can also calculate correlated standard normal deviates ($CSND_{ik}$) by multiplying R_{ik} by

independent standard normal deviates ('Norm()'' comment in Simetar©). $CSND_{ik}$ is generated for a ten-year simulation time span (the simulated years indexed by k). Multivariate Empirical distribution (MVE) for the price and yield variables can be calculated using correlated uniform deviates (CUD) that are generated from correlated standard normal deviates $CSND_{ik}$ and the distribution of the fraction values D_{it} . For a large sample, the correlated uniform deviates CUD approach the correlated fractional deviates (CFD) that incorporate fractional relationship among the simulated variables. Correlated fractional deviates are called MVE distribution:

$$CUD_{ik} = normdist(R_{ik} \cdot CSND_{ik}) \rightarrow CFD_{ik} \quad (4-27)$$

At last, stochastic simulation ($\tilde{X}_{ik}$) is found by the multiplying the predicted values calculated from trend function at equation (4-23) and MVE distribution, i.e.,

$$\tilde{X}_{ik} = \hat{X}_{ik} \cdot (1 + CFD_{ik}) \quad (4-28)$$

where X is the yield inserted from the production function and the future values of prices, obtained from historical distribution ($i=1$ refers to yield from production function, and $i=2$ refers to forecasted prices), while k indexes the simulated years.

Unlike yield and sale prices, historic data for nitrogen are not easily accessible. Farmers in TCAA are using a variety of fertilizer types with various nitrogen content, which complicates the selection of the historic price data to accurately represent the time series of nitrogen fertilizer prices. In agribusiness studies, the variables that lack historical data are frequently simulated as a GRKS distribution (named after Gray, Richardson, Klose and Schuman; Richardson et al. 2007a). Following this approach, nitrogen input price is simulated with the GRKS distribution. This distribution uses mean, maximum and minimum value information to generate a distribution that can also

account for rare events outside the minimum and maximum values. Specifically, the GRKS distribution provides an advantage of accounting for the unforeseen risk which represents approximately 2.5% of quantiles from both ends, the probability of the unforeseen event (Richardson et al. 2007a). Such unpredicted upside and downside risky events are referred in the literature as Black Swans.

The stochastic variables and the financial assumptions are provided in Table 4-2 while the detailed potato production budget for one acre of land is given in Appendix C. The potato yield is simulated using the stochastic production function and various levels of fertilizer use (as described in Simulation Scenarios section). Output price is the other stochastic variable which is assumed to be fluctuating around the mean of \$14/cwt. At last, the nitrogen prices is simulated by using GRKS distribution having mean, maximum and minimum levels at 0.60, 0.65 and 0.55, respectively. The assumptions for the financial terms are explained in the previous section and production cost values (variable, marketing and durable costs) are found at the potato budget by Smith and VanSickle (2009).

Simulation scenarios

Two set of simulation scenarios are developed in this study to evaluate the sensitivity of potato production returns to changes in nitrogen application rate and potato sale prices. In the first set of scenarios (scenarios 1 – 3, Table 4-3), the distribution of potato sale prices is assumed to shift from the distribution with the mean of \$12/cwt, to the one with the mean of \$14/cwt, and then the mean of \$16/cwt. Note that the fertilizer rate is fixed on the level which is estimated to be optimal from the

expected profit maximization (as described in the section above).⁶ These scenarios allow one to explore the profit loss associated with different price expectation for determining optimum nitrogen level.

In the second set of scenarios (scenarios 4 – 6, Table 4-3), the fertilizer application rate is assumed to vary between 150 lb N/acre to 207 lb N/acre, and then to 250 lb N/acre. For these scenarios, potato sale prices are assume to be fluctuating around \$14/cwt. Note that for all scenarios NPV is calculated on per acre basis. These scenarios help to evaluate preferred level of fertilizer application depends on the risk aversion level of the producer.

Decision criteria used in scenario ranking

The key outputs of the scenarios 1 – 3 and 4 – 6 are ranked using the mean variance method, first and second degree stochastic dominance, and stochastic dominance with respect to a function (SDRF) to incorporate producers' risk aversion. These tools help one to determine which risky alternative (i.e., fertilizer rate) is more feasible and how the fertilizer use decision changes with different risk behavior. All these risk ranking tools are available in the Simetar© add-in.

Mean variance method simply looks for the least variance and the highest mean to rank the risky alternatives. In turn, the first degree stochastic dominance compares CDFs of the outcomes for the risky alternatives. If we represent the CDFs of two alternatives with $F(x)$ and $G(x)$, and $F(x)$ dominates $G(x)$, then it should be true that $\sum F(x) \leq \sum G(x)$ for all x . The first-degree stochastic dominance also implies that the CDFs of the two alternatives should not cross (Richardson and Outlaw 2008). If they

⁶ As described below, this level is 207 lb N/acre, see table 5. The optimum is based on the assumption of \$14/cwt potato sale price and \$0.6/lb N input price

cross, the first degree stochastic dominance criteria are not applicable, and the second degree stochastic dominance should be used to rank the risky alternatives. If $F(x)$ dominates $G(x)$ when one obtains $\sum F(x) - \sum G(x) \leq 0$ for all x .

At last, SDRF is used to incorporate risk aversion into ranking of the risky alternatives. SDRF can be defined as follows:

$$\sum U(x, r_i(x))F(x) \leq \sum U(x, r_i(x))G(x) \quad (4-29)$$

where $F(x)$ is preferred to $G(x)$ under given risk aversion coefficient ($r_i(x)$) of the decision maker (Richardson and Outlaw 2008), where i refers to the upper and lower limits of risk aversion coefficients, respectively, represented as ($r_U(x)$) and ($r_L(x)$). The negative exponential utility function is used since it allows increasing relative risk aversion proportional to wealth increase.

Results

This section starts with the estimation results for the linear and quadratic stochastic plateau production functions. For such production function specification, random factors either influence the maximum yield (reflecting plateau effects, such as heavy rains that influence the additional yield potential from nitrogen application), or they are captured in the residual error term. In comparison with the existing agronomic studies (e.g. Hochmuth et al. 2011), this approach allows for a more accurate representation of changing relationship between yield and fertilizer use given various weather conditions. The optimal fertilizer use is then defined as the level maximizing profit, which is also more realistic representation of producers' decision criterion, in comparison to yield maximization used in agronomic studies (Anderson, 1973; Cerrato and Blackmer, 1982; Bullock and Bullock, 1994).

Next, multivariate empirical probability distributions (Richardson et al. 2000) are used to simulate output prices based on the historic correlation between yields and prices. Lastly, the distribution of ten year net present values (NPV) is estimated given stochastic yield, output prices, and fertilizer prices, and the negative exponential utility function is used to interpret the input decision of risk-averse producer.

Production Functions

The estimation results for linear response stochastic plateau and quadratic response stochastic plateau, as well as quadratic response non-stochastic plateau functions (for comparison purposes), are reported in the Table 4-4. All parameter and estimated variance components are significant at the 1% level. Standard errors for the coefficients are given under the coefficient values in the parenthesis.

Figure 4-5 demonstrates that estimated yield is reasonably close to the actual yields based on historic weather and nitrogen use levels. Yield is higher for the drier seasons (with smaller number of rain events), and it is lower for the rainy seasons.

The results of the analysis are summarized below:

- The hypotheses that the production function as quadratic response stochastic plateau or non-stochastic plateau functions are rejected at the 5% level (by log likelihood ratio test) by taking linear response stochastic plateau function as a base function.
- Standard errors of the optimum nitrogen level for non-stochastic functions are not computed because the convergence is not satisfied for these estimations.
- The expected plateau estimated in linear response stochastic function is higher than the estimated plateau level in the quadratic and non-stochastic plateau functions.
- The estimated linear terms in the alternative specifications of the production function show that the estimated marginal productivity of nitrogen (α_1) is higher in quadratic response stochastic plateau function.

- The optimum level of nitrogen is found as 207.26 lb N/acre in the linear model, and 201.42 lb N/acre in quadratic stochastic plateau functions when potato price is assumed to be \$14/cwt and the price of nitrogen is \$0.6/lb.

Sensitivity Analysis

Optimum fertilizer level given stochastic response functions is calculated by using the equation (4-7) and equation (4-15), respectively, for linear and quadratic response stochastic plateau functions. These equations are derived from the profit maximization function for specific nitrogen input price and output price. Therefore, we include sensitivity analysis to determine the different optimum nitrogen levels given both production functions. Table 4-5 indicates that optimum fertilizer level in the linear function increases when the output price increases and the nitrogen price decreases. The optimal ranges from 203.71 lb N / acre to 210.46 lb N / acre.

Table 4-6 illustrates the sensitivity analysis of optimum nitrogen level for the quadratic function. Similar to the results above, the optimum fertilizer level increases when the output price increases and the nitrogen price decreases. The optimal ranges from 193.97 lb N / acre to 207.13 lb N / acre.

As shown in the sensitivity analysis above, high output price results in high optimal fertilizer levels for a profit maximizing producer. Therefore, different price expectation of growers leads to various fertilizer rates among the growers. Similarly, a policy maker can have low price expectations, and in this case, BMP fertilizer level recommended by the regulators will be lower than the optimal.

Financial Analysis Results

The estimated coefficients of the stochastic plateau functions can be used to simulate (or forecast) yields and use the simulated values in the financial analysis. Stochastic terms allow fluctuation to be included in the forecasted yield values. Figure

4-6 illustrates the forecasted yield for quadratic and linear stochastic plateau production functions for 2010 – 2020. Lower and upper confidence intervals for forecasted yield levels at the 95% are illustrated in the figure for each production function. The upper and lower limits include the error term of the estimation and variance of error which represents the weather effect on the plateau function. Therefore, yield is close to the upper limit for the drier seasons (with smaller number of rain events) and it is close to the lower limit for the rainy seasons.

In contrast to the expected profit maximization described in the previous section, this analysis presents a more comprehensive model of the farmers' behavior by explicitly considering the output and input price variability in the financial analysis. Specifically, instead of finding the optimal fertilizer level for each pair of output and input prices, the simulations allows one to compare the distribution of NPV given a range of input and output prices, and then consider the changes in NPV distributions for different fertilizer levels. Moreover, risk-aversion behavior of the farmers is accounted for in the model, making the analysis even more comprehensive.

Scenario Analysis: Alternative Fertilizer Application Rates

First, NPVs are compared for three different fertilizer levels: 150, 207, and 250 lb N/acre (Table 4-7). Recall that 207 lb N/acre was found to be the optimal fertilizer use level given the expected profit maximization criterion (see the previous section and fixed output and nitrogen prices). Note that this level is approximately equal to the fertilizer BMP level used in 2008 - 2012. The high nitrogen use scenario is selected to represent the current BMP level that allows producers to add extra fertilizer if required (FDACS, 2011b). The low nitrogen use scenario is selected hypothetically to represent exceptionally low fertilizer use requirement. The summary statistics for the three

fertilizer use scenarios is summarized in Table 4-7. The mean variance technique does not reveal the clear dominance of one fertilizer level, since the levels with higher mean NPV (i.e. 250 lb N / acre) is also associated with higher variability of the NPV (with the standard deviation equal to 1,054.13).

As a second step in ranking scenarios, PDFs and CDFs of the 10-year NPV are drawn for alternative fertilizer use levels (Figure 4-7). The figure indicates that fertilizer application at 207 and 250 lb N/acre level robustly dominates fertilizer application at 150 lb N/acre level given the first degree stochastic dominance criterion. However, the comparison of NPV distributions for 207 lb N /acre and 250 lb N / acre is not so straightforward. The CDFs of 'Fertilizer Applied-207' and 'Fertilizer Applied-250' cross each other, and the first degree stochastic dominance does not allow selecting the preferred fertilizer use level. Nevertheless, an alternative criterion - the second degree stochastic dominance - shows that 'Fertilizer Applied-250' dominates 'Fertilizer Applied-207' since the result shows that higher NPV is expected when more fertilizer applied (Table 4-8).

Note the difference between the preferred levels of fertilizer use given the two decision models considered – expected profit maximization given fixed prices, and the second degree stochastic dominance given stochastic prices. For the expected profit maximization, the optimal fertilizer level ranged from 203.71 lb N / acre to 210.46 lb N / acre (see the sensitivity analysis above). For the second degree stochastic dominance, it is shown that fertilizer level of 250 lb N / acre dominates the lower levels of the fertilizer use. This difference in the results can be explained by the effect of price variability that is not accounted for in profit maximization.

In the last section of the analysis, the role of farmers' risk aversion on the fertilizer use decision is examined. SDRF is applied to incorporate various degrees of risk aversion into the ranking of alternative fertilizer use rates. The absolute risk aversion coefficients ranged from 0 to 0.00131 in the analysis. The absolute risk aversion coefficients, a , are based on the relative risk aversion, r , and are calculated as $a(w)=r(w)/w$ where w is the level of wealth, which is taken as the mean NPV value in this analysis. The relative risk aversion coefficients considered in this study are 0.0, and 2.0, which, respectively, indicating risk-neutral and moderately risk-averse producers (Richardson and Outlaw 2008). For example, for a moderately risk-averse producer, $a(w) = 2.0/1,524=0.00131$ where \$1,524 is the expected worth (i.e. 10-year NPV).

Table 4-9 presents the results of the SDRF ranking. The results show that the preferred level of fertilizer application depends on the risk aversion level of the producer. Specifically, Risk-neutral producers would prefer the scenario with fertilizer rate of 250 lb N / acre ('Fertilizer Applied-250'). In contrast, a producer who is moderately risk-averse prefers 'Fertilizer Applied-207' and avoid the downward risk caused by the high fertilizer expense and low yields.

Scenario Analysis: Shifts in the Output Price Distributions

As shown in the sensitivity analysis above, high output price results in high optimal fertilizer level for profit maximizing producer when the fertilizer price is constant. Therefore, different price expectation leads to various optimal fertilizer rates selected by the growers. In the second set of scenarios, different output price expectations are compared (Table 4-10). Note that the prices are kept stochastic, and hence, the difference in the price expectations is captured in the shifts in the price distributions.

The reduction in NPV profits is then estimated for the case when the recommended fertilizer BMP level is set below the optimal level for a given output and fertilizer prices. Specifically, a policy maker can have low price expectations, and in this case, BMP fertilizer level recommended by the regulators will be lower than the optimal.

Figure 4-8 shows the PDF approximations of simulated NPVs of optimum nitrogen levels at various output prices. The graphs illustrate the mean values and the distribution around the mean. As illustrated in the figure, the mean value increases when the output prices are high; however, high output prices decreases the risk. For instance, 'Mean Output Price-\$16' has the highest mean and the lowest risk.

Table 4-11 shows NPV for two levels of N application, given different mean sale prices. The first N application level is fixed at 204.94 lb N/acre (i.e. the optimal N rate if the sale price is \$12/cwt, input price is \$0.60/lb, and the producer is maximizing expected profits). The second level is fixed at 209.22 lb N/acre (i.e. the optimal level for the output price of \$16/cwt and the fertilizer price of \$0.60/lb). Note that for both fertilizer levels, NPV is simulated given sale prices of \$16/cwt and fertilizer prices of \$0.60/lb.

There is a slight difference between NPV simulation when the fertilizer level determined at 'Mean Output Price-\$16' (optimum fertilizer level is 209.22 lb N/acre from Table 4-5), while the actual output price is \$12/cwt. However the loss to producers at the mean is \$16.56/acre and the loss could increase up to \$137.54/acre when weather and production conditions are favorable for a grower (the difference of the NPV values at the Table 4-11).

Summary and Discussion

This study aims at exploring the socio-economic factors that should be considered in the development of the fertilizer best management practices (BMPs).

Specifically, the study examined various decision criteria used by producers, alternative specifications of crop production function, alternative levels of input and output prices and various levels of producers' risk-aversion. The analysis focuses on TCAA region in northeast Florida.

It is shown that the selection of the production function specification plays an important role in predicting the growers input use decision. The optimum level of nitrogen is found as 207.26 lb N/acre in linear, and 201.42 lb N/acre in quadratic stochastic plateau functions (given potato price of \$14/cwt and nitrogen prices of \$0.6/lb). For a 400-acre farm (which is typical for the TCAA), the difference translates into 2,336 lb N. This result also implies that the fertilizer BMP definition will depend on the assumption about the production function. And it is possible that the assumptions about the yield-response relationship captured in the production function may differ for the farmers, policy-makers, and researchers.

The study also shows that the optimum nitrogen rate varies significantly depending on input and output prices. Specifically, the optimal rate varied from 193.97 lb N / acre (for quadratic stochastic plateau production function, low potato sale prices, and high nitrogen fertilizer prices) to 210.46 lb N / acre (for linear stochastic plateau production function, high potato sale prices, and low nitrogen fertilizer prices). Again, for a 400-acre farm, the difference is 6596 lb N. This result shows that the fertilizer BMP recommendation should account for the range of input and output prices.

The study also examined the effect of risk preferences of the farmers on the choice of preferred fertilizer rate. Given the stochastic input and output prices, as well as stochastic yields, fertilizer rate of 250 lb/acre is more preferred for a risk neutral

producer, but the rate of 207 lb/acre is more preferred by a risk-averse producer. This result is consistent with other existing studies that shows that risk-averse growers prefer to apply less fertilizer than risk-neutral growers.

Finally, the profit loss is estimated for a producer when the fertilizer BMP is selected for one level of output prices, but the growers expect to receive a higher level of prices. Given a BMP developed for only four-dollar lower expectation of output prices (i.e., \$12/cwt instead of \$16/cwt), the average cost of the fertilizer BMP is \$16.56/acre (or \$6,624 for a 400-acre farm). However, the costs can reach \$137.54/acre (or \$55,016 for a 400-acre farm) at the favorable weather conditions.

The latest BMP regulation developed for TCAA allows farmers to adjust fertilizer application if necessary; therefore, it gives the farmers the flexibility to avoid reductions in profits associated with too restrictive BMP recommendations. Overall, this is consistent with the conclusion derived from this study that no single fertilizer BMP can be recommended for all growers and all market conditions. This study shows that as a part of the BMP development process, state agencies and extension agents should attempt to elicit producers' opinions about the relationship between crop yield and fertilizer rates. Specifically, producers' perceptions about the likelihood of 'risky' events when high fertilizer use can be critical for high profits should be examined. Production function estimation results that are used in BMP development should also be discussed with producers, along with profit variability analysis. Based on the assessed costs and associated water quality improvements, cost-effectiveness of alternative fertilizer recommendation should be evaluated, and the most cost-effective recommendation should be identified as the BMP. The effect on optimal fertilizer use decisions of the

market conditions and producers' risk preferences should be explicitly recognized. In addition to fertilizer BMP, cost-effectiveness should be examined for alternative pollution reduction strategies (such as improved irrigation technologies, or regional storm-water treatment facilities). The effect of potato varieties on optimal fertilizer use should also be examined. Next, water quality policies should be developed to encourage the implementation of the most cost-effective pollution reduction strategies. In addition to traditional cost-share payments, such policies can include an insurance to compensate for yield losses attributed to fertilizer BMP use. Labeling of sustainably-produced agricultural products (e.g., Czarnecki, 2011), performance-based payments (Shortle et al. 1998; Winsten, 2009), and payments for environmental services (PEPA, 2011) are the strategies that can increase the rate of BMP implementation without affecting agricultural profits. Overall, Sheriff (2005) stated that there is no one policy appropriate for all crops and locations, and a policy mechanism should be designed based on specific characteristics of a particular region.

Table 4-1. Descriptive statistics summary for TCAA potato production, 1952-2010

Variables	Average	Standard Deviation	Minimum	Maximum
Potato Yield (cwt/acre)	209.9	55.1	110.0	330.0
Planted Potato Area (acre)	22.9	4.1	15.5	30.5
Fertilizer Sale (lb N /acre)	117.0	57.0	34.4	235.1
Precipitation (Number of rain events over 1 inch per potato production season)	5.3	2.6	1.0	12.0
Total Potato Production (1000 cwt)	4,605.8	1,223.6	2,376.0	6,930.0
Potato Price (\$/cwt)	6.9	4.1	1.9	18.0

Table 4-2. Stochastic variables and financial model assumptions

Variable	Unit	Value
Potato Yield	cwt/acre	$y_k = \min(\alpha_0 + \alpha_1 N^{opt}, \mu_p + \sqrt{\sigma_v}) + \sqrt{\sigma_\varepsilon}$
Output Prices	\$/cwt	Mean Price ^k (~\$14) * [1 + MVE (S ⁱ , F(S ⁱ), 1)]
The Nitrogen Input Prices	\$/ lb	GRKS(0.55,0.60,0.65)
Production financed	%	100% equity
Start-up equity	\$/acre	325.00
Operating Loan Length	Years	1
Operating Loan Interest Rate	%	5.0
Durables Loan Length	Years	7
Durables Loan Interest Rate	%	8.0
Interest on equity invested	%	10.0
Total Variable Cost (excl. Nitrogen fertilizer expense and marketing)	\$/acre	2,409.36
Marketing Cost	\$/acre	\$1/cwt * Yield
Nitrogen Fertilizer Expense	\$/acre	GRKS(0.55,0.60,0.65) * N^{opt}
Durable Cost	\$/acre	185.00

Note: Cost items are inserted from Smith and VanSickle (2009) and the others are constructed by author.

Table 4-3. Sets of scenarios

Scenario	Name	Set	Key Stochastic Variables
1	Mean Output price-\$14	1	Mean Price _k (~\$14) * [1 + MVE (Si, F(Si), 1)]
2	Mean Output price-\$12	1	Mean Price _k (~\$12) * [1 + MVE (Si, F(Si), 1)]
3	Mean Output price-\$16	1	Mean Price _k (~\$16) * [1 + MVE (Si, F(Si), 1)]
4	Fertilizer Applied-Opt	2	$y_k = \min(\alpha_0 + \alpha_1 N^{opt}, \mu_p + \sqrt{\sigma_v}) + \sqrt{\sigma_\varepsilon}$ where N=207
5	Fertilizer Applied-150	2	$y_k = \min(\alpha_0 + \alpha_1 N, \mu_p + \sqrt{\sigma_v}) + \sqrt{\sigma_\varepsilon}$ where N=150
6	Fertilizer Applied-250	2	$y_k = \min(\alpha_0 + \alpha_1 N, \mu_p + \sqrt{\sigma_v}) + \sqrt{\sigma_\varepsilon}$ where N=250

Table 4-4. Production functions and the optimum nitrogen levels

Estimated Parameters		Linear Response Stochastic Plateau	Linear Response Non-Stochastic Plateau	Quadratic Response Stochastic Plateau	Quadratic Response Non- Stochastic Plateau
α_0	Intercept	103.79 (10.96)	113.38 (10.55)	46.77 (3.63)	63.02 (3.95)
α_1	Linear term	1.03 (0.09)	0.88 (0.07)	2.71 (0.29)	2.03 (0.19)
α_2	Quadratic term	N/A	N/A	-0.0074 (0.0015)	-0.0057 (0.0008)
μ_p	Plateau level	260.54 (7.69)	257.80	227.67 (7.83)	239.25 (0.82)
σ_v^2	Variance of year random	1061 (34)	N/A	2342 (669)	N/A
σ_ε^2	Variance of error term	1034 (214)	1240 (218)	653 (204)	1382 (238)
N^*	Optimum Nitrogen Level	207.26 (2.79)	163.36	201.42 (4.96)	206.39
-2 Log Likelihood		588.50	590.70	599.60	597.80

Note: The expected price of nitrogen is \$0.6/lb, the price of potato is \$14/cwt.

Table 4-5. Sensitivity analysis of optimum nitrogen level for linear function (in pounds of nitrogen per acre)

Sale Prices - \$/cwt	Nitrogen Prices - \$ / lb		
	\$ 0.55	\$ 0.60	\$ 0.65
\$ 12	206.26	204.94	203.71
\$ 14	208.54	207.26	206.07
\$ 16	210.46	209.22	208.05

Note: Nitrogen levels are provided in lb N/acre.

Table 4-6. Sensitivity analysis of optimum nitrogen level for quadratic function (in pounds of nitrogen per acre)

Sale Prices - \$/cwt	Nitrogen Prices - \$ / lb		
	\$ 0.55	\$ 0.60	\$ 0.65
\$ 12	202.07	199.64	193.97
\$ 14	205.55	201.42	197.27
\$ 16	207.13	204.69	199.13

Note: Nitrogen levels are provided in lb N/acre.

Table 4-7. Summary statistics for 10-year NPV simulations for various fertilizer rates

Linear Stochastic production Function, Output price = \$14, various N fertilizer rates

	Fertilizer Applied-207	Fertilizer Applied-150	Fertilizer Applied-250
Mean	1,524.00	706.62	1,608.32
Standard Deviation	997.96	968.25	1,054.13
Coefficient Var.	65.48	137.03	65.54
Minimum	(1,516.84)	(2,083.70)	(1,912.51)
Maximum	5,128.98	3,708.96	4,325.47

Table 4-8. First and second order stochastic dominance results for alternative fertilizer uses

	Fertilizer Applied-207	Fertilizer Applied-150	Fertilizer Applied-250	Approximate Area
First Degree Dominance				
Fertilizer Applied-207 FDD	-	Dominates	-	
Fertilizer Applied-150 FDD	-	-	-	
Fertilizer Applied-250 FDD	-	Dominates	-	
Second Degree Dominance				
Fertilizer Applied-207 SDD	-	Dominates	-	3641.46
Fertilizer Applied-150 SDD	-	-	-	4459.33
Fertilizer Applied-250 SDD	Dominates	Dominates	-	3557.23

Table 4-9. Analysis of Stochastic Dominance with Respect to a Function (SDRF)

Rank	Name	Level of Preference
Lower Risk Aversion Coefficient: 0 (Risk-neutral)		
1	Fertilizer Applied-250	Most Preferred
2	Fertilizer Applied-207	2nd Most Preferred
3	Fertilizer Applied-150	3rd Most Preferred
Upper Risk Aversion Coefficient: 0.00131 (Moderately Risk-averse)		
1	Fertilizer Applied-207	Most Preferred
2	Fertilizer Applied-250	2nd Most Preferred
3	Fertilizer Applied-150	3rd Most Preferred

Table 4-10. Summary statistics for 10-year NPV simulations for various output prices

Linear Stochastic production Function, optimum N fertilizer rates, various output prices			
	Mean Output Price-\$14	Mean Output Price-\$12	Mean Output Price-\$16
Mean	1,508.97	(345.67)	2,893.31
Standard Deviation	1,004.01	1,079.03	996.38
Coefficient Var.	66.54	(312.16)	34.44
Minimum	(1,516.84)	(3,596.91)	(361.44)
Maximum	5,128.98	2,505.62	5,991.60

Table 4-11. Simulated NPV of a strict fertilizer level determined at the \$12/cwt sale price

Linear Stochastic production Function, optimum N fertilizer rates, various output prices		
	Fertilizer Level=204.94 lb N / acre	Mean Output price-\$16
Mean	2,868.02	2,884.58
Standard Deviation	976.77	969.67
Coefficient Var.	34.06	33.62
Minimum	(199.51)	(192.27)
Maximum	6,111.92	6,249.46

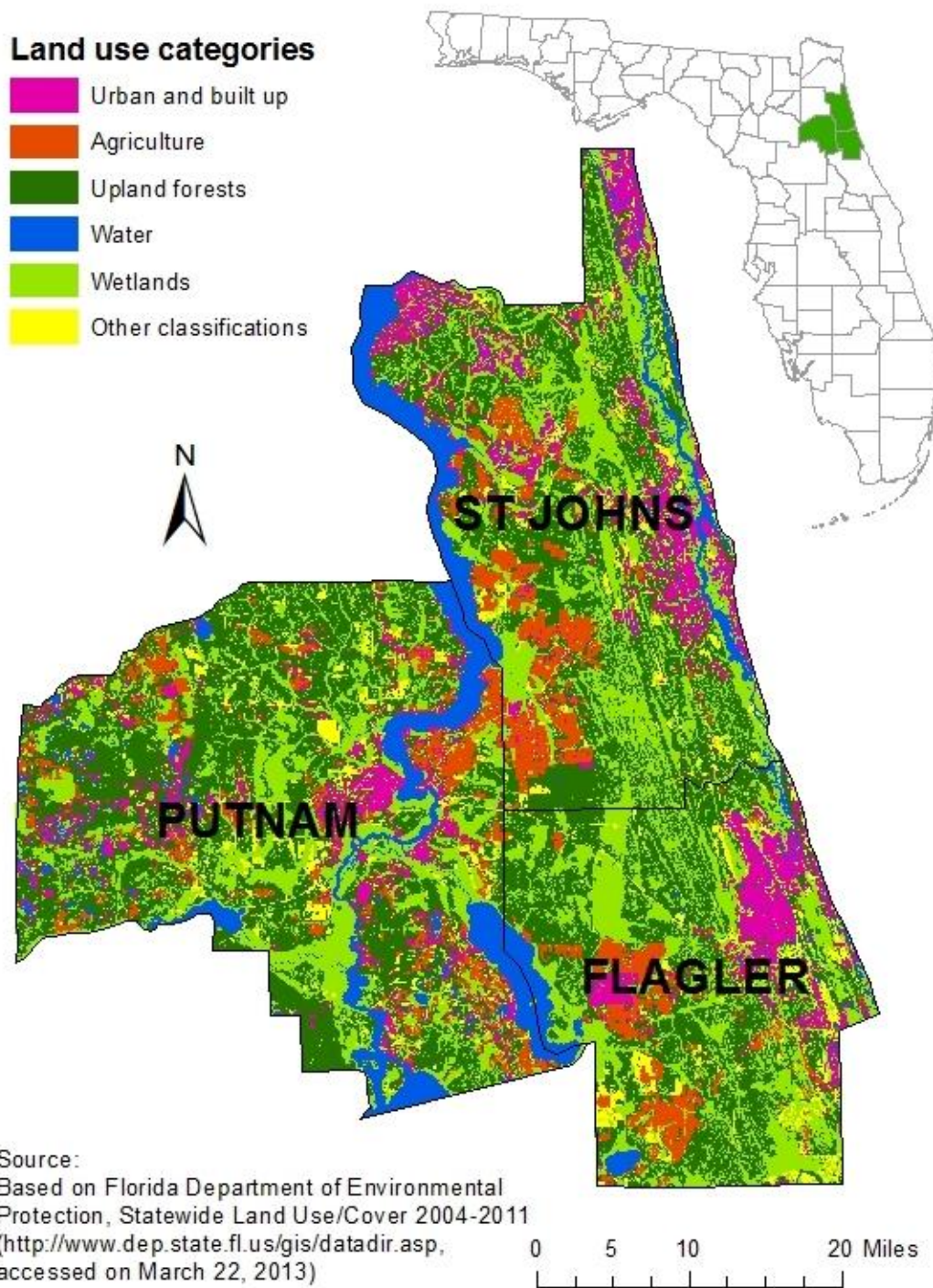


Figure 4-1. The counties of Tri-County Agricultural Area and agricultural areas

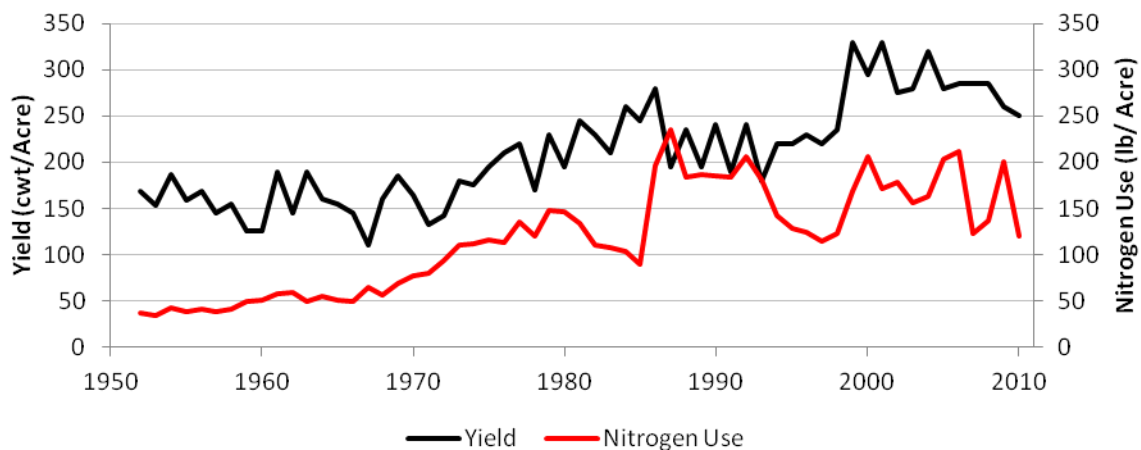


Figure 4-2. Potato yield and nitrogen use data (per acre) for Tri-County Agricultural Area

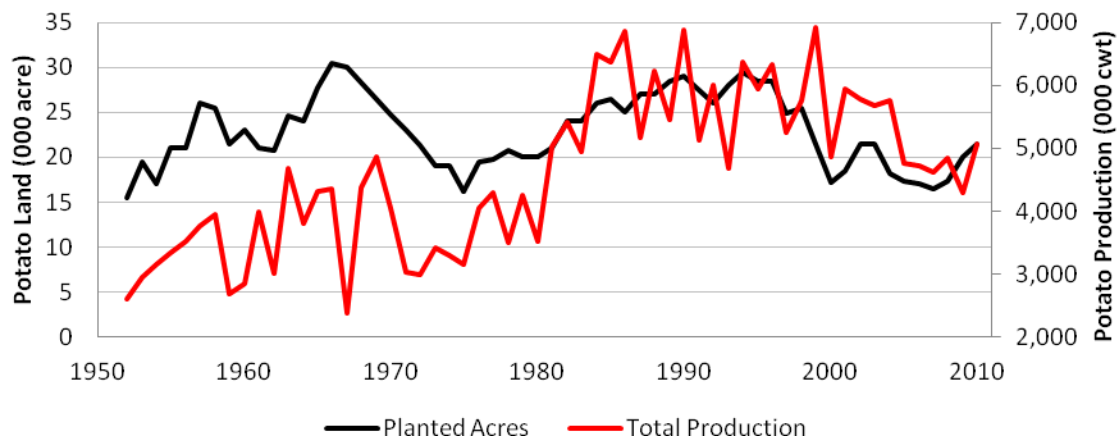
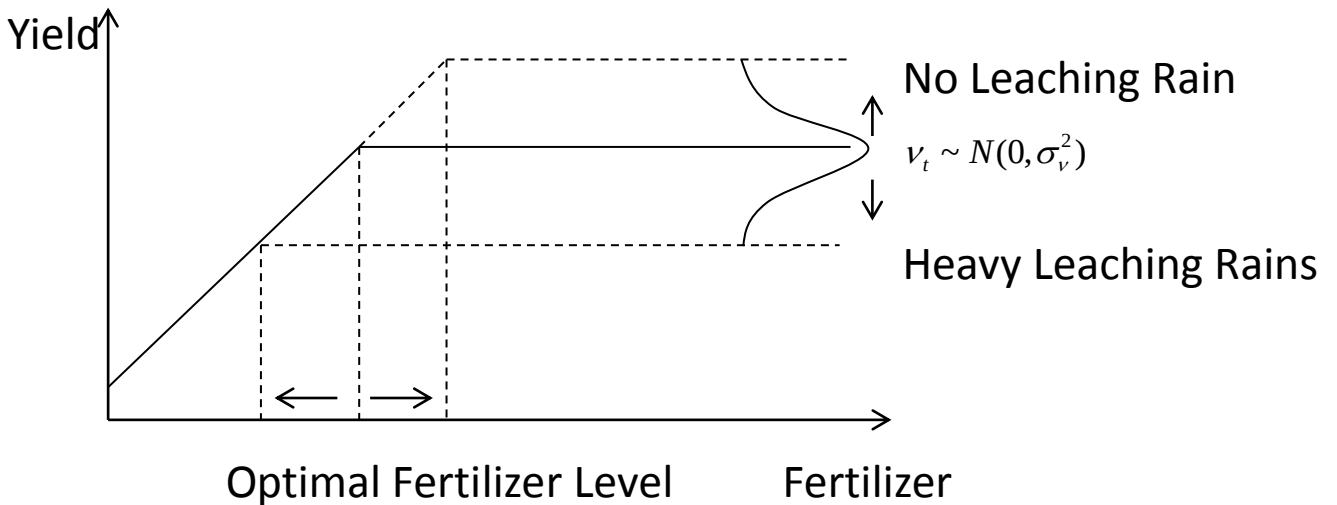


Figure 4-3. Potato acreage and total production in Tri-County Agricultural Area



Notes: Based on Tembo et al. (2008).

Figure 4-4. Plateau shift for the stochastic function due to weather effect

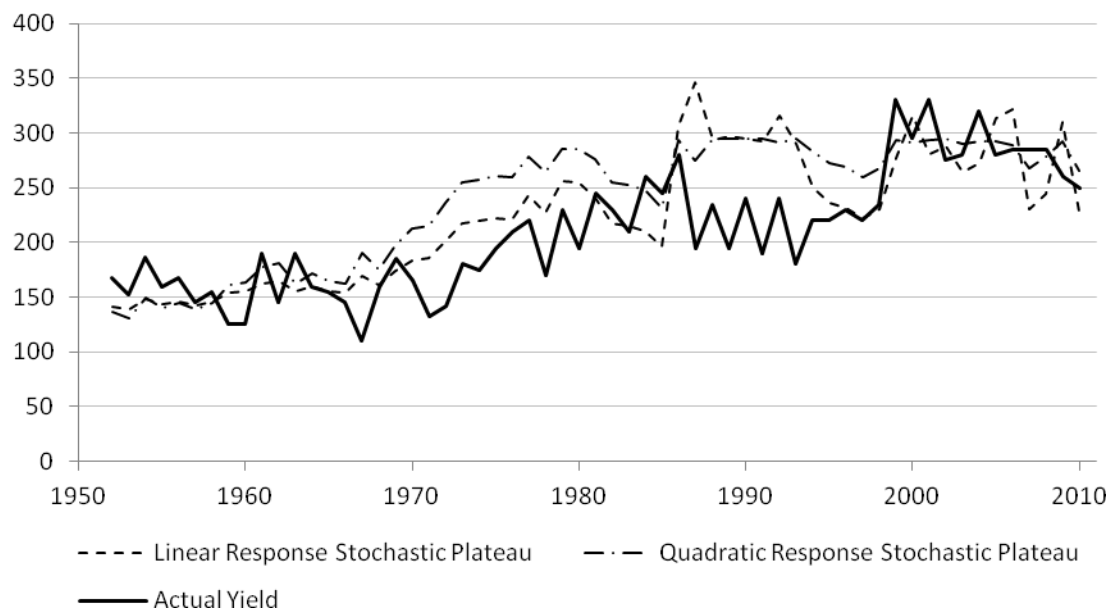


Figure 4-5. Predicted and actual yields given historic weather conditions and fertilizer use

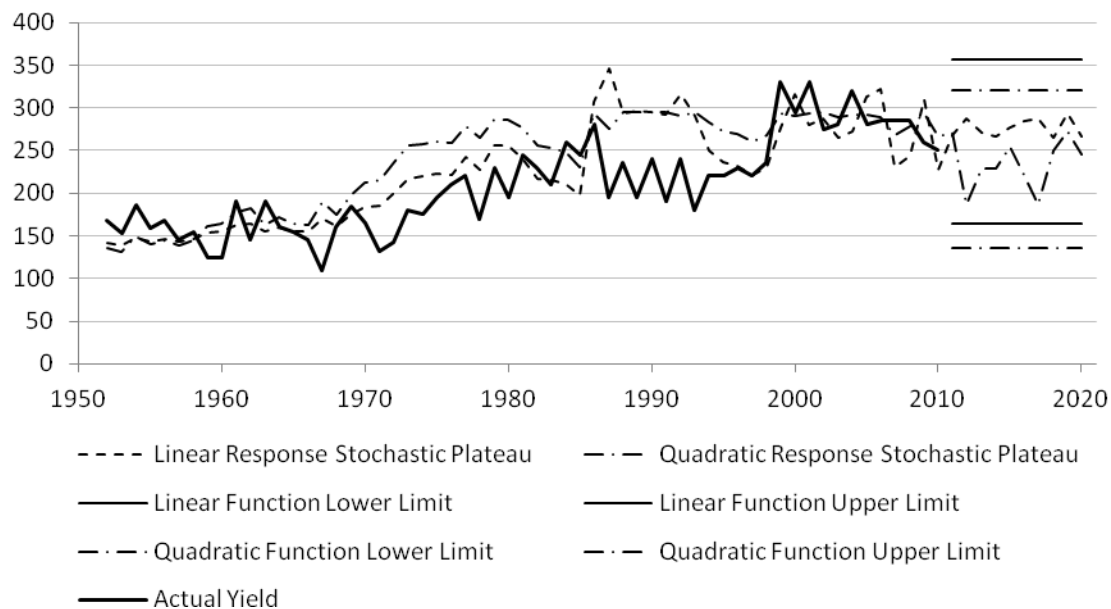


Figure 4-6. Predicted, actual and forecasted yields

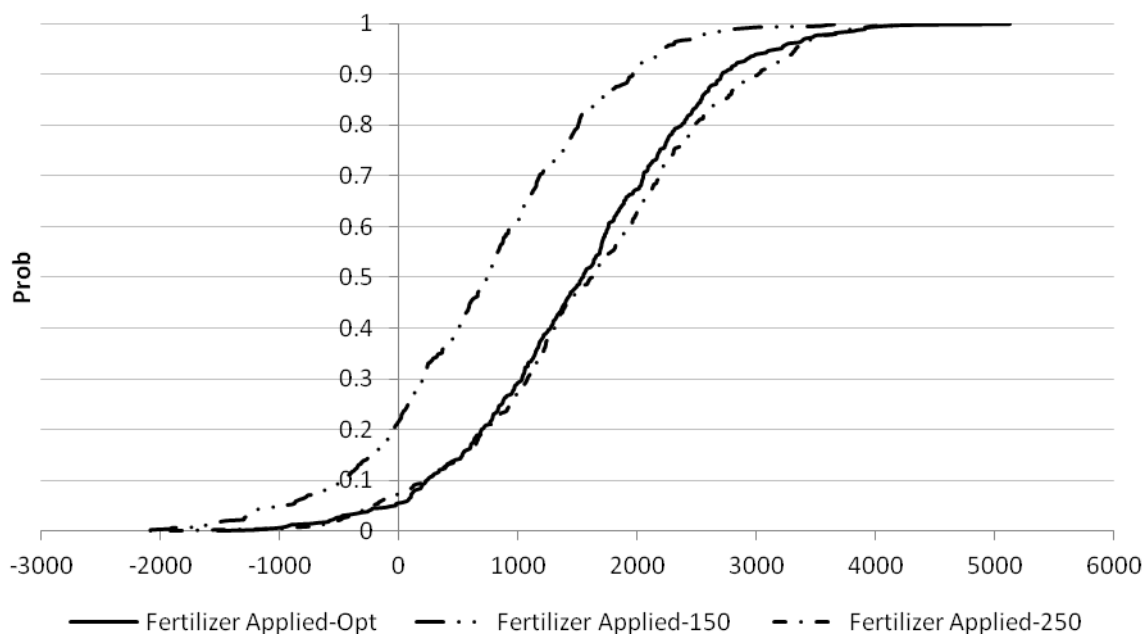


Figure 4-7. CDFs of simulated net present values for various fertilizer use decisions

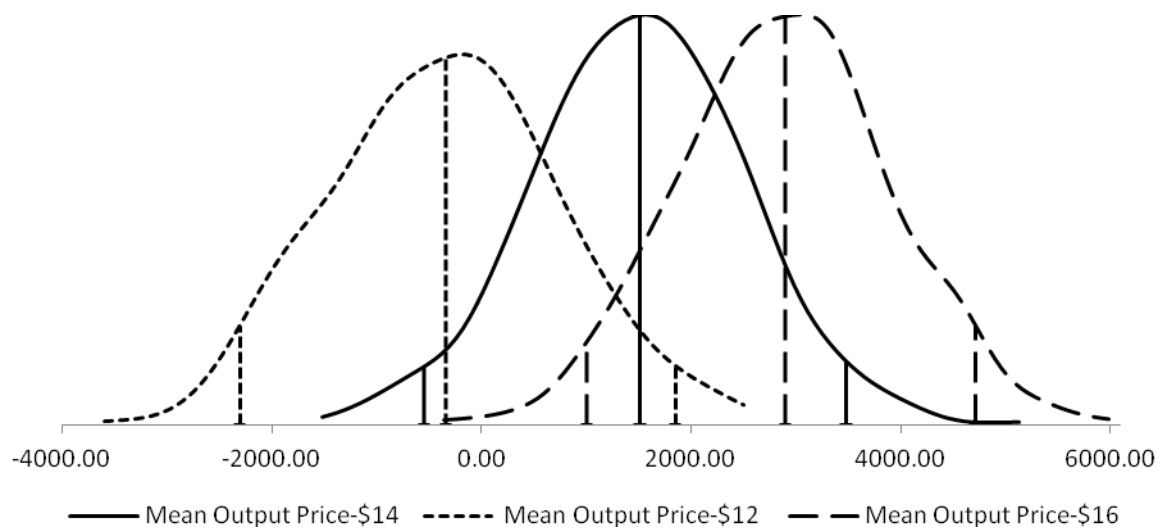


Figure 4-8. PDF approximations of simulated net present values of optimum nitrogen levels at various output prices

CHAPTER 5 CONCLUSION

The three essays in this dissertation explore a few of the many issues related to the management of risk and uncertainty in agricultural production. The particular emphasis is on global competition, trade negotiations, and environmental policies. In the first essay, the trade conflict between the U.S. and Mexico tomato producers in the winter tomato market is examined. The renegotiated suspension agreement for the antidumping investigation raises the reference prices of Mexican tomatoes by 50% - 300% as compared with the previous agreement depending on tomato category (US-DC, 2013). This agreement distinctively covers four different tomato categories including open area (i.e., field-grown), controlled environment (i.e., greenhouse production), specialty loose, and specialty packed tomatoes. Although this study confirms the importance of categorizing tomatoes, it also emphasizes the significant substitution and complementary effects between these categories. For instance, an increase in total consumer expenditure for field-grown tomatoes would increase the demand for U.S. tomatoes more than the demand for imported tomatoes (see the result of the aggregate analysis, Chapter 2). However, the disaggregated analysis shows that the demand for Mexican greenhouse tomatoes responds similarly to the expenditure change that of U.S. field-grown tomatoes. Therefore, a policy that increases consumers' tomato expenditure would increase the demand for both U.S. field-grown tomatoes and Mexican greenhouse tomatoes. Since the beginning of the 21st century, we have witnessed a large increase in the production and marketing of greenhouse tomatoes, taking market share away from field-grown tomato producers. Mexican greenhouse tomatoes are competing with and taking market share from U.S. field-grown tomatoes

but have led to a growth in production of U.S. greenhouse tomatoes. When a sector is in a boom phase of growth (as has been the greenhouse tomato market), it appears that competitive products are complimentary in the market as we see a synergistic relationship between imported and domestically grown greenhouse tomatoes in this analysis. This phase will continue until the market matures and it moves into the bust side of the boom-bust business cycle in sector analysis (Schmitz 1995). When the market matures, we hypothesize that U.S. and imported greenhouse tomatoes will shift from being complementary products to being substitutes in the market. Until then, the investment in greenhouse tomato production will continue to grow in the U.S., while the demand for field-grown tomatoes continues to shrink.

In the second essay, the investment in Florida greenhouse tomato production is examined. This production technology is considered as a strategy to mitigate the impact of the increasing Mexican greenhouse tomato imports on profitability of Florida's tomato producers. The NPV analysis results suggest that investment in the high technology greenhouse is preferred over regular greenhouse and field-grown production (if the crop yield for each technology is fixed at the break-even point). However, the investment decision preferences changes with an increase in a producer's risk aversion coefficient. Stochastic efficiency ranking of the investment decision shows that the high technology greenhouse is preferred by risk neutral and normally risk-averse decision makers. However, moderately risk-averse decision makers would prefer to invest in a regular Florida greenhouse technology, while extremely risk-averse growers would continue to produce field-grown tomatoes. These results are consistent with what has been witnessed in tomato production in Florida. The increase in greenhouse investment

shows that some growers are beginning to take more risk because they find greenhouse investment as a way to compete better in the market. However, at this point in time, the producers continue to choose to have option open instead of committing to investment in greenhouse technology because of high option values in Florida. This explains why there are few greenhouse operations in Florida. The risk of the new tomato production technology is related to the price, production and financial risks. Therefore, policies or market conditions that decrease these risks (credit availability, interest rates, insurance, energy prices, high tomato prices, technological advance in greenhouse production etc.) would decrease the option value.

In the third essay, an economic model is developed to assist in the development of the fertilizer best management practices. Specifically, the model allows to account for various decision criteria used by producers, alternative specifications of crop production function, alternative levels of input and output prices, and various levels of producers' risk-aversion. The model is applied to examine fertilizer use decisions in potato producing Tri-County Agricultural Area (TCAA) in Florida. Overall, the conclusion is that no single fertilizer BMP can be recommended for all growers and all market conditions. The latest BMP regulation developed for TCAA allows farmers to adjust fertilizer application if necessary; therefore, it gives the farmers the flexibility to avoid reductions in profits associated with restrictive BMP recommendations. This regulation is consistent with the conclusion derived from this study. It is shown that as a part of the BMP development process, state agencies and extension agents should attempt to elicit producers' opinions about the relationship between crop yield and fertilizer rates. Specifically, producers' perceptions about the likelihood of 'risky' events when high

fertilizer use can be critical for high profits should be examined. Production function estimation results that are used in BMP development should also be discussed with producers, along with profit variability analysis. Based on the assessed costs and associated water quality improvements, cost-effectiveness of alternative fertilizer recommendation should be evaluated, and the most cost-effective recommendation should be identified as the BMP. Overall, the three essays contribute to the economic literature on agricultural risk management, and generate information to assist agricultural producers and policy makers.

APPENDIX A DERIVATION OF CONSUMPTION MODEL

Consumption theory starts with maximization of utility in general form

$U = U(q_1, \dots, q_n)$. Utility function is assumed to be twice differentiable so that

$$\frac{\partial U}{\partial q_i} > 0 \quad i = 1, \dots, n \quad (\text{A-1})$$

There is generalized diminishing marginal utility, so the Hessian matrix of the utility function is negative definite and it is also symmetric.

$$U = \frac{\partial^2 U}{\partial q_i \partial q_j} \quad (\text{A-2})$$

We can derive demand equation by maximizing the utility function subject to the consumer's budget constraint,

$$\sum_i p_i q_i = M \quad (\text{A-3})$$

where p_i is the price of tomato, q_i is exported quantity and M is the total budget:

$$\sum_i p_i \frac{\partial q_i}{\partial p_j} = -q_j \quad \text{and} \quad \sum_i p_i \frac{\partial q_i}{\partial M} = 1 \quad (\text{A-4})$$

Next differentiating proportionality (resulting from differentiating

$U(q) - \mu(p'q - M)$ with respect to ' q ', that is $\frac{\partial \mu}{\partial q} = \mu p$ and with respect to p_j and M

yields:

$$\sum_{k=1}^n \frac{\partial^2 U}{\partial q_i \partial q_k} \frac{\partial q_i}{\partial p_j} = \mu \delta_{ij} + p_i \frac{\partial q_i}{\partial p_j} \quad \text{where } \delta_{ij} \text{ is kronecker delta and}$$

$$\sum_{k=1}^n \frac{\partial^2 U}{\partial q_i \partial q_k} \frac{\partial q_k}{\partial M} = p_i \frac{\partial \mu}{\partial M} \quad (\text{A-5}).$$

Combining results leads to get Barten's Fundamental matrix:

$$\begin{bmatrix} U & p \\ p' & 0 \end{bmatrix} \begin{bmatrix} dq/dM & dq/dM \\ -d\mu/dp' & -d\mu/dp' \end{bmatrix} = \begin{bmatrix} 0 & \mu I \\ 1 & -q' \end{bmatrix} \quad (\text{A-6})$$

Solving the matrix, gives the following result:

$$\frac{dq}{dp'} = \mu U^{-1} - \phi M \frac{dq}{dM} \frac{dq'}{dM} - \frac{dq}{dM} q' \quad (\text{A-7})$$

Where $\frac{1}{\phi} = \frac{d\mu}{dM} \frac{M}{\mu}$. That yields the following differential demand equation.

$$w_i d(\ln q_i) = \theta_i d(\ln Q) + \phi \sum_{j=1}^n \theta_{ij} d\left(\ln \frac{p_j}{p^*}\right) \quad (\text{A-8})$$

Note that the budget component, $w_i d(\ln q_i)$ is the contribution of good i to the Divisia volume index and also the dependent variable in the equation.

The general system in simple parameterization gives us Rotterdam model and can be written as

$$w_i d(\ln q_i) = \theta_i d(\ln Q) + \sum_{j=1}^n \pi_{ij} d(\ln p_j) \quad (\text{A-9})$$

The following conditions are satisfied for the Equation 11;

Adding-up $\sum_i \theta_i = 1, \sum_i \pi_{ij} = 0$

Homogeneity $\sum_j \pi_{ij} = 0$

Slutsky Symmetry $\pi_{ij} = \pi_{ji}$.

The income share elasticities of the import demand (η_i) and the slutsky price elasticity (η_{ij}) are calculated by using Barten (1993), in addition, cournot price elasticity (c_{ij}) is also shown below;

$$\eta_i = \frac{\theta_i}{w_i} \quad (\text{A-10})$$

$$\eta_{ij} = \frac{\pi_{ij}}{w_i} \quad (\text{A-11})$$

$$c_{ij} = \frac{\pi_{ij} - \theta_i w_j}{w_i} \quad (\text{A-12})$$

Replacing $\theta_i = w_i + \beta_i$ gives us CBS equation;

$$w_i d(\ln q_i - d(\ln Q)) = \beta_i d(\ln Q) + \sum_{j=1}^n \pi_{ij} d(\ln p_j). \quad (\text{A-13})$$

The income share elasticity of CBS changes as;

$$\eta_i = 1 + \frac{\beta_i}{w_i} \quad (\text{A-14})$$

AIDS model is obtained by substituting π_{ij} by $\gamma_{ij} = \pi_{ij} + w_i \delta_{ij} - w_i w_j$;

$$d(w_i) = \beta_i d(\ln Q) + \sum_{j=1}^n \gamma_{ij} d(\ln p_j) \quad (\text{A-15})$$

by satisfying the conditions ;

$$\text{Adding-up} \quad \sum_i \beta_i = 0, \sum_i \gamma_{ij} = 0$$

$$\text{Homogeneity} \quad \sum_j \gamma_{ij} = 0$$

$$\text{Slutsky Symmetry} \quad \gamma_{ij} = \gamma_{ji}.$$

Elasticities are found as the following formulas;

$$\eta_i = 1 + \frac{\beta_i}{w_i} \quad (\text{A-16})$$

$$\eta_{ij} = \frac{\gamma_{ij}}{w_i} - \delta_{ij} + w_j \quad (\text{A-17})$$

$$c_{ij} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} - \beta_i \frac{w_j}{w_i} \quad (\text{A-18})$$

At last, we could get the NBR model by replacing $\beta_i = \theta_i - w_i$ in AIDS model.

$$d(w_i) + w_i d(\ln Q) = \theta_i d(\ln Q) + \sum_{j=1}^n \gamma_{ij} d(\ln p_j) \quad (\text{A-19})$$

One can write following equation from budget share components

$$d(w_i) = w_i d(\ln q_i) + w_i d(\ln p_i) - w_i d(\ln M) \quad (\text{A-20})$$

which gives us a relationship between $w_i d(\ln q_i)$ and $d(w_i)$. When we insert equation (A-15) into equation (A-20), yields

$$d(w_i) = (\theta_i - w_i) d(\ln Q) + \sum_j (\pi_{ij} + w_i \delta_{ij} - w_i w_j) d(\ln p_j). \quad (\text{A-21})$$

Thus, those four models could be mentioned in a general model

$$w_i d(\ln q_i) = (d_i + \delta_1 w_i) d(\ln Q) + \sum_{j=1}^n e_{ij} d(\ln p_j) + \delta_1 w_i d(\ln Q) - \delta_2 w_i (d \ln p_i - d \ln P) \quad (\text{A-22})$$

The parameters could be used by restricting δ_1 and δ_2 as shown below and even test the demand to find out which model suits well to the given data;

Rotterdam $\delta_1 = 0$ and $\delta_2 = 0$

CBS $\delta_1 = 1$ and $\delta_2 = 0$

AIDS $\delta_1 = 1$ and $\delta_2 = 1$

NBR $\delta_1 = 0$ and $\delta_2 = 1$

APPENDIX B
BUDGET TABLES FOR ALTERNATIVE TOMATO PRODUCTION TECHNOLOGIES

Table B-1. High technology greenhouse production expenses

Cost of Goods Sold	Unit	Quantity	Total Cost
Materials			
Plant Material (January / August)	Acre	1.00	38,400.00
Substrate	Acre	1.00	15,680.00
Fertilization	Acre	1.00	99,000.00
Plantprotection chemical	Acre	1.00	2,946.53
Plantprotection biological	Acre	1.00	1,180.67
Small/other materials	Acre	1.00	4,800.00
Work by third parties	Acre	1.00	800.00
Transport/waste plants	Acre	1.00	700.00
Plant insurance	Acre	1.00	6,000.00
Other cultivation costs	Acre	1.00	640.00
Total Materials			\$ 170,147.20
Energy			
Gas Boiler	Acre	1.00	36,666.67
Electricity	Acre	1.00	49,666.67
CO2	Acre	1.00	6,963.84
Total Energy			\$ 93,297.17
Labor			
Corporate Labor	Acre	1.00	30,113.89
Maintenance and Other	Acre	1.00	2,021.07
Harvesting Team	Acre	1.00	33,347.60
Cultivating Team	Acre	1.00	57,600.40
Packing Team	Acre	1.00	8,084.27
Total Labor			\$ 131,167.23
Sales, General & Administrative			
General & Administrative			
Maintenance company	Acre	1.00	16,576.00
Other costs	Acre	1.00	10,000.00
Growing advice	Acre	1.00	919.80
Insurance	Acre	1.00	2,242.98
General costs	Acre	1.00	3,204.32
Real Property Tax (Est.)	Acre	1.00	384.53
Unforeseen Expenses (Contingency)	Acre	1.00	824.00
Total G&A			\$ 34,151.64
Sales & Marketing			
Packing/cask	Acre	1.00	19,685.72
Transport (Est.)	Acre	1.00	-
Sales costs	Acre	1.00	60,000.00
Sales Commissions	Acre	1.00	834.58
			\$ 80,520.31
Total Annual Production Costs			\$ 509,283.54

Table B-2. Regular Florida greenhouse production expenses

Cost of Goods Sold	Unit	Quantity	Price	Total Cost
Materials				
A mix 8-12-32	lbs	4,235.00	1.64	6,945.40
CaNO ₃	lbs	3,630.00	0.68	2,468.40
Sulfuric acid	gal	60.50	24.00	1,452.00
Soap	gal	6.05	36.88	223.12
Neem	qt	12.10	95.50	1,155.55
DiPel	lb	12.10	5.95	72.00
Liquid sulfur	qt	12.10	7.95	96.20
Layflat bags	each	3,549.29	2.29	8,127.88
Trust (seeds)	each	10,648.00	0.44	4,685.12
Speedling flats 128	each	84.70	1.55	131.29
Fafard Germ Mix	bag	12.10	15.60	188.76
Greenshield	gal	24.20	49.95	1,208.79
Mousetraps	pair	36.30	7.95	288.59
IPM	box	24.20	-	-
Pollentation	box	36.30	-	-
Total Materials				\$ 27,043.08
Energy				
Electricity	kwh	158,510.00	0.11	17,436.10
LP Gas	gal	26,196.50	1.55	40,604.58
Total Energy				\$ 58,040.68
Labor				
Pre-harvest	hrs	5,662.80	7.79	44,113.21
Harvest	hrs	3,484.80	7.79	27,146.59
Cleanout	hrs	435.60	7.79	3,393.32
Total Labor				\$ 74,653.13
Sales, General & Administrative				
General & Administrative				
Analytical services& repairs	units	12.10	150.00	1,815.00
Travel	milage	2,940.00	0.56	1,646.40
Overhead	%	131,011.97	10.00%	13,101.20
Taxes & Insurance *	%	459,096.72	1.37%	6,289.63
Total G&A				\$ 22,852.22
Sales & Marketing				
Delivery costs	milage	6,000.00	0.56	3,360.00
Packing labor	hrs	1,913.63	7.79	14,907.20
Boxes, foams & labels	box	21,300.00	0.76	16,188.00
Marketing & miscellaneous	box	21,300.00	0.80	17,040.00
				\$ 51,495.20
Total Annual Production Costs				\$ 234,084.31

* The taxes and insurance are taken as the 1.37% of the total structure cost.

Table B-3. Field-grown tomato production expenses

Cost of Goods Sold	Unit	Quantity	Price	Total Cost
Materials				
Seeds/Transplants	Acre	1.00	624.00	624.00
Fertilizer, mixed and Lime	Acre	1.00	1,449.25	1,449.25
Fumigant	Acre	1.00	736.00	736.00
Tractors and Equipment	Acre	1.00	1,882.29	1,882.29
Tractors and Machinery	Acre	1.00	241.65	241.65
Herbicide	Acre	1.00	21.40	21.40
Insecticide and Nematicide	Acre	1.00	448.85	448.85
Fungicide	Acre	1.00	392.21	392.21
Stakes + others	Acre	1.00	771.17	771.17
Plastic String	Acre	1.00	28.75	28.75
String and Stake Disposal	Acre	1.00	123.42	123.42
Pull and Bundle Mulch	Acre	1.00	181.50	181.50
Cross Ditch	Acre	1.00	27.20	27.20
Tie Plants	Acre	1.00	145.20	145.20
Trickle Tube	Acre	1.00	145.20	145.20
Total Materials				\$ 7,218.09
Energy				
Total Energy				\$ -
Labor				
General Farm Labor	Acre	1.00	140.63	140.63
Tractor Driver Labor	Acre	1.00	214.29	214.29
Total Labor				\$ 354.92
Sales, General & Administrative				
General & Administrative				
Land Rent	Acre	1.00	500.00	500.00
Overhead and Management	Acre	1.00	3,632.85	3,632.85
Taxes & Insurance *	%	-	1.37%	-
Total G&A				\$ 4,132.85
Sales & Marketing				
Pick, Pack and Haul	Box	1,620.00	2.60	4,212.00
Sell	Box	1,620.00	0.15	243.00
Containers	Box	1,620.00	0.75	1,215.00
Organization Fees	Box	1,620.00	0.09	145.80
				\$ 5,815.80
Total Annual Production Costs				\$ 17,521.66

Table B-4. High technology greenhouse construction cost

	Cost	Life
Greenhouse		
Groundwork	40,937.33	20.0
Infrastructure - Utility	30,382.79	20.0
Infrastructure - Greenhouse European	275,260.57	15.0
Infrastructure - Greenhouse US Purchased	83,719.71	15.0
Packing and Warehouse	71,759.40	10.0
Office Area	5,833.33	7.0
Corporate IT and Other Set Up items	8,333.33	3.0
Canteen	1,800.00	20.0
HVAC Installation - Heating & CO2	81,382.92	15.0
HVAC Installation - Cooling	134,790.66	10.0
Screen Installation	28,695.68	7.0
Electrical Installation	55,542.67	12.0
Water Technical Installation	41,123.47	10.0
Growing gutters	25,555.47	7.0
Logistics automation greenhouse	26,541.83	10.0
Logistics automation working area	6,673.33	7.0
Other Installations	5,600.00	7.0
Unforeseen Investments	21,304.17	12.0
Total Greenhouse Investment	\$ 945,236.68	

Table B-5. Regular Florida greenhouse construction cost

	Cost	Life
Greenhouse		
Ground cover	6,776.00	7.0
Irrigation/fertigation system	20,570.00	7.0
Environmental control	11,047.30	7.0
Warehouse (10'x10')	15,125.00	10.0
Site preparation + inflation kit	50,299.70	10.0
LP gas heating system	26,402.20	10.0
Plant support system	9,075.00	10.0
Backup generator + electrical	17,545.00	10.0
Labor (const. + equip. install.) *	84,700.00	10.0
Greenhouse frame (30x120)	105,270.00	20.0
Total Construction Costs	\$ 346,810.20	
Durables		
Shade system 30%	6,969.60	3.0
Cooling pads	9,105.25	3.0
Spray mask	798.60	3.0
Emitter & tubing	3,726.80	3.0
Convection tube	3,630.00	3.0
Blower fan	2,795.10	3.0
Thermometer	762.30	3.0
Timer	4,840.00	3.0
Clips	955.90	3.0
String	14,907.20	3.0
Scale	605.00	3.0
pH/EC meter	1,210.00	3.0
Tools	1,028.50	3.0
Poly cover	13,140.60	4.0
Cooling pump	2,148.36	5.0
Cooling fans	19,093.80	5.0
Sprayer	8,820.90	5.0
HAF fans	7,260.00	5.0
Speedling 128 flats	461.62	5.0
Tapener	907.50	5.0
Light meter	1,210.00	5.0
Harvest bins	5,082.00	5.0
Harvest aids	907.50	5.0
Pad curtain	2,420.00	5.0
Total Durables Costs	\$ 112,786.52	
Total Greenhouse Investment + Durables	\$ 459,596.72	

APPENDIX C

POTATO PRODUCTION EXPENSES FOR AN ACRE

Table C-1. Potato production expenses in TCAA (\$/acre)

Cost of Goods Sold	Unit	Quantity	Price	Total Cost
Materials				
Seed/Transplants	Units	26.00	11.87	308.62
Fertilizer, mixed and Lime	Units	1.00	426.24	426.24
Nitrogen	lb N/acre	207.26	GRKS(0.60)	124.67
Crop Insurance	Units	1.00	35.00	35.00
Cover Crop Seed	Units	1.00	20.00	20.00
Herbicide	Units	1.00	22.48	22.48
Insecticide and Nematicide	Units	1.00	146.92	146.92
Fungicide	Units	1.00	131.55	131.55
Tractors and Equipment	Units	1.00	413.98	413.98
Farm Trucks (driver cost included in overhead expense)	Units	88.67	0.51	45.22
Aerial Spray	Units	1.00	19.50	19.50
Total Energy				\$ 1,694.48
Labor				
General Farm Labor	Hrs	15.92	7.79	124.00
Tractor Driver Labor	Hrs	20.54	7.79	160.00
Total Labor				\$ 284.00
Sales, General & Administrative				
General & Administrative				
Analytical services& repairs	Units	1.00	100.12	100.12
Land Rent	Units	1.00	150.00	150.00
Overhead and Management	Units	1.00	445.69	445.69
Taxes & Insurance *	%	185.00	1.37%	2.53
Total G&A				\$ 698.34
Sales & Marketing				
Dig and Haul	Box	268.53	0.70	187.97
Grading	Box	268.53	0.30	80.56
				\$ 268.53
Total Annual Production Costs				\$ 2,945.36

* The taxes and insurance are taken as the 1.37% of the total durable cost.

Source: Enterprise budget information for potato production is constructed by authors by using experimental plot data and Florida research center and UF/FRED published data (Smith and VanSickle 2009).

APPENDIX D

SAS CODES FOR ESTIMATING PLATEAU FUNCTIONS

```

*** Straight with a random component included;
Data one; *Hastings,FI Potato Production Data;
input n yield rain;
proc nlmixed data=one noad hess qmax= 199 tech=trureg gconv=.00000000001;
PARMS b0=30.8 b2=.5 plateau=30.43 s2u=21.2 s2e=1.2;
**Rescaling;
s2u_actual=s2u*100;
s2e_actual=s2e*100;
mean = min(b0 + b2*n, plateau + U);
model yield~normal(mean,s2e_actual);
random U ~normal(0,s2u_actual) subject=rain;
/*optimal N equation */;
estimate 'optimal N' (1/b2)*(Plateau - b0+sqrt(s2u_actual)*probit(1-.6/(14*b2)));
estimate 's2u_actual' s2u*100;
estimate 's2e_actual' s2e*100;
RUN;

*** Quadratic with a random component included;
Data one; *Hastings,FI Potato Production Data;
input n yield rain;
proc nlmixed data=one noad hess qmax= 199 tech=trureg gconv=.00000000001;
PARMS b0=40.8 b1=-.01 b2=-.001 plateau=60.5 s2u=20.25 s2e=.6;
**Rescaling;
s2u_actual=s2u*100;
s2e_actual=s2e*100;
mean = min(b0 + b1*n + b2*n*n , plateau + U);
model yield~normal(mean,s2e_actual);
random U ~normal(0,s2u_actual) subject=rain;
/*optimal N equation */;
estimate 'optimal N' (1/(2*b2))*(-b1-sqrt(b1*b1-4*b2*(b0-Plateau-sqrt(s2u_actual)*probit(1-
.6/(14*(b1+2*b2*201))))));
estimate 's2u_actual' s2u*100;
estimate 's2e_actual' s2e*100;
RUN;

```

APPENDIX E FINANCIAL SHEET FORMULATIONS

Stochastic Variables

$$\text{Grower Price}_t = \text{Mean Price}_t \times [1 + \text{MVE} (S_t F(S_t), C_8)] \quad (\text{E-1})$$

$$\text{Potato Yield}_t = y_k = \min(\alpha_0 + \alpha_1 N^{opt}, \mu_p + \sqrt{\sigma_v}) + \sqrt{\sigma_\varepsilon} \quad (\text{E-2})$$

$$\text{Input Price}_t = \text{GRKS (minimum, middle, maximum)} \quad (\text{E-3})$$

Receipts

$$\text{Potato Production}_t = \text{Potato Yield}_t \times \text{Grower Price}_t \quad (\text{E-4})$$

Expenses

$$\text{Fertilizer Cost}_t = \text{Nitrogen Used}_t \times \text{Fertilizer Price}_t \quad (\text{E-5})$$

$$\text{Marketing Cost}_t = \text{Potato Yield}_t \times \text{Marketing Expense}_t \quad (\text{E-6})$$

$$\text{Total Variable Cost}_t = \text{Potato Production Cost}_t + \text{Fertilizer Cost}_t + \text{Marketing Cost}_t \quad (\text{E-7})$$

Other Costs

$$\text{Debt Interest}_t = \text{Principal Owed}_t \times \text{Fixed Interest Rate}_t \quad (\text{E-8})$$

$$\text{Operating Interest}_t = \text{Total Variable Cost}_t \times \text{OP Interest Rate}_t \times \text{Fraction of year} \quad (\text{E-9})$$

$$\text{Carryover Loan Interest}_t = \text{Cashflow Deficits}_{t-1} \times \text{OP Interest Rate}_t \quad (\text{E-10})$$

$$\text{Total Interest Cost}_t = \text{Debt Interest}_t + \text{Operating Interest}_t + \text{Carryover} \quad (\text{E-11})$$

Loan Interest

$$\text{Total Expenses}_t = \text{Total Variable Cost}_t + \text{Total Interest Cost}_t + \text{Depreciation}_t \quad (\text{E-12})$$

$$\text{Net Returns}_t = \text{Total Receipts}_t - \text{Total Expenses}_t \quad (\text{E-13})$$

$$\text{Net Cash Income}_t = \text{Total Receipts}_t - \text{Total Variable Costs}_t - \text{Total Interest Cost}_t \quad (\text{E-14})$$

Cashflow

$$\text{Cash Inflows}_t = \text{Net Cash Income}_t + \text{Positive Cash Reserves}_{t-1} \quad (\text{E-15})$$

$$\text{Principal Payment}_t = \text{Fixed Annual Payment} - \text{Debt Interest}_t \quad (\text{E-16})$$

$$\text{Federal Income Taxes}_t = \text{Positive Net Returns}_t \times \text{Income Tax Rate} \quad (\text{E-17})$$

$$\text{Cash Outflows}_t = \text{Principal Payment}_t + \text{Repay Cashflow Deficit}_{t-1} + \text{Capital Replacement}_t + \text{Federal Income Taxes}_t \quad (\text{E-18})$$

$$\text{Ending Cash}_t = \text{Cash Inflows}_t - \text{Cash Outflows}_t \quad (\text{E-19})$$

Balance Sheet

$$\text{Assets}_t = \text{Land Value} + \text{Value Firm}_t + \text{Positive Ending Cash}_t \quad (\text{E-20})$$

$$\text{Liabilities}_t = \text{Debt Interest}_{t-1} - \text{Principal Payments}_t + \text{Negative Ending Cash}_t \quad (\text{E-21})$$

$$\text{Net Worth}_t = \text{Assets}_t - \text{Liabilities}_t \quad (\text{E-22})$$

Financial Ratios

$$\text{NPV} = \text{Beginning Net Worth} + (\Delta \text{Net Worth}_t) / (1 + 0.10)^{(\text{years})} \quad (\text{E-23})$$

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BIOGRAPHICAL SKETCH

Serhat Asci received his Ph.D. in Food and Resource Economics from the University of Florida in the fall of 2013. He has extensive experience with all three missions of a Land Grant University: research, teaching, and extension. He acquired international experience from European Union research projects. Serhat holds a Bachelor degree in Food Engineering (2000) and a Master degree in Food Economics and Management (2008).

Serhat's research focuses on three key areas: agricultural decision-making under uncertainty, agricultural demand modeling, and land allocation dynamics. He has applied his analytical and quantitative skills to the projects about water quality policy for agricultural areas; stochastic production function modeling; investment under uncertainty; international trade; differential demand and production systems; and agricultural land allocation.

For the last three years, Serhat served as a teaching assistant for PhD level econometrics, price analysis and macroeconomics, leading laboratory sessions, holding office hours, and evaluating students' performances. Serhat's extension experience stems from his work on multi-disciplinary projects on alternative production methods for Florida vegetable production. Serhat also served as a president of the Graduate Student Organization, and a member of the Academic Committee.

Serhat worked as a researcher in the multinational EU projects focused on traceability, logistics and food quality schemes having primary duties on public survey design, administration, and analysis, public outreach, project management, budget analysis, and development of funding proposals.