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## **Risk in Investment Decision Making and Greenhouse Tomato Production Expansion in Florida**

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### **Abstract**

The outcomes of agricultural investment decisions are affected by the risk in price, cost, and yield outcomes. To examine those risks, net present value models with Monte Carlo simulation are used to analyze the viability of greenhouse tomato investment decisions. The analysis is further extended by utilizing a real options approach. The results indicate that a grower would choose to continue field-grown tomato production due to high option values and risk aversion. Moreover, some policies or market conditions which increase credit availability, decrease energy prices, reduce tomato price fluctuation and/or facilitate effective risk management strategies would make the greenhouse production preferable.

**Keywords:** risk in investment, greenhouse tomato, real option approach, stochastic dominance and efficiency

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## Introduction

The severity of international competition, new trade agreements, change in government policies, weather conditions, and fluctuations in yield and price have significant impacts on the agricultural entities (Harwood et al. 1999). All these factors are combined in the notions of risk and uncertainty. Decision making under risk is a critical component in agricultural management. Growers make decisions by selecting one among many alternatives to diminish the negative economic effects of risky conditions. Additional information about uncertain factors and effective risk management strategies helps producers 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 grower's risk perception, information availability, and the availability and impact of government farm programs.

The risk-based model is widely used by academics and business consultants to explore investment decisions made by growers. Studies in this topic generally focus on (a) decision-making under risk and uncertainty, (b) application of stochastic dominance, and (c) the real option approach for investing in a new technology.

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, Dillon, and Hardaker (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 a single-index model using two separate approaches in portfolio analysis for agricultural firms. In addition, Williams, Llewelyn, and Barbany (1990) examined risk-based decisions in the context of stochastic dominance between two systems and for five crop rotations. They provided results focused on the preference of risk-averse managers.

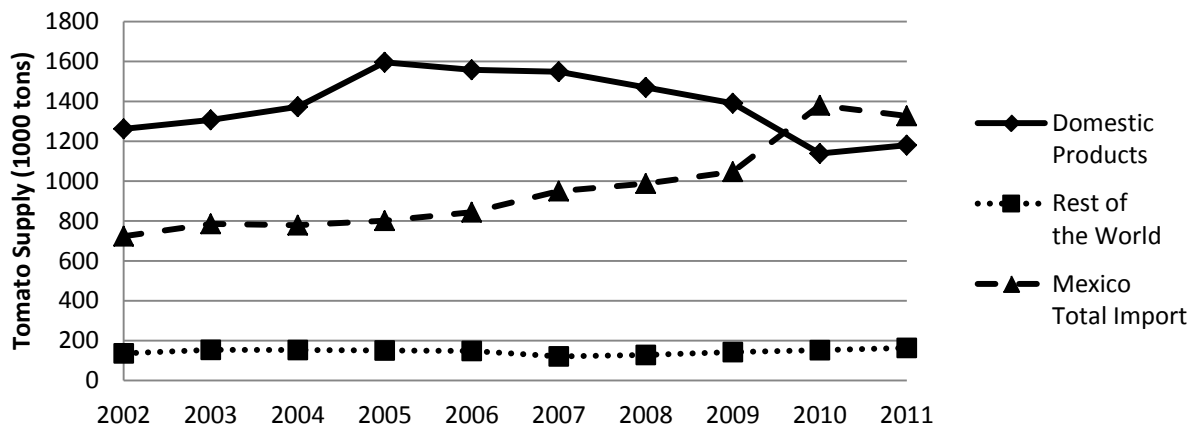
Simulation is a widely covered subject; however, most of the existing studies are not written for agricultural economists and do not relate to agricultural firm-level models. The earliest simulation as a tool for analyzing risky decisions was suggested by an agricultural economist goes back to the 1970s (Richardson and Mapp 1976, Anderson, Dillon, and Hardaker 1977). These studies used various types of equations and identities to construct the Farm Level Income and Policy Simulation Model (Richardson and Nixon 1982). Recently, Richardson, Klose, and Gray (2000) developed a procedure for estimating and simulating probability distributions in farm-level risk assessment and clearly described the procedure on how to analyze risk by this method. This methodology is used widely in the literature (Richardson, Lemmer, and Outlaw 2007; Palma et al. 2011). One of the rare studies on greenhouse production by Uva et al. (2000) investigates risk for adopting any of four commonly used zero runoff sub-irrigation systems in greenhouse operations described in different crop categories with a Monte Carlo simulation approach. Last, Iwai and Emerson (2008) combined risk analysis with a Monte Carlo simulation by calculating NPV and the real options approach to assess sugarcane mechanization investment in Florida.

In lieu of previous studies, the goal and the strength of this paper is to examine possible tomato production alternatives for Florida producers by using different risk analysis tools and incorporating various risks into the decision making analysis. Thus, this study develops a comprehensive investment decision model that implements Monte Carlo simulation and the real option approach to look at the decision to invest in greenhouse production systems. 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 as an increase in credit availability, decreased energy prices, reduced tomato price fluctuation, and/or facilitating effective risk management strategies would make greenhouse production preferable for Florida producers.

## **Overview of the Fresh Tomato Market in the United States**

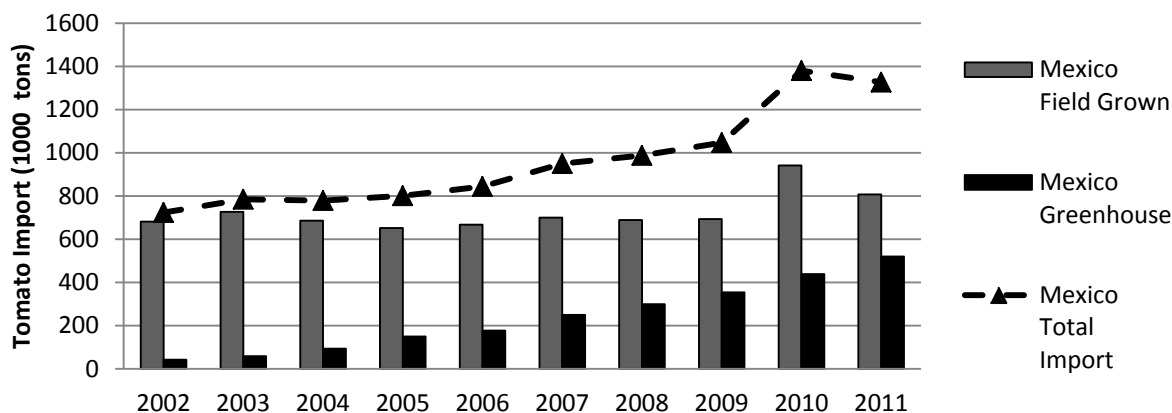
Among all the vegetable crops in the United States, the total value of production is the highest for tomato production (USDA-ERS 2013a). Tomato demand in the U.S. is high during all 12 months of the year (USDA-ERS 2013b). Fresh tomatoes are harvested in California during all seasons except winter. In Florida, tomatoes are harvested from October to June, with peak production from November to January. Most of Florida's tomato production is shipped to the eastern United States while Mexico provides fresh tomatoes for the western United States (VanSickle, Evans, and Emerson 2003). Overall, almost one-third of the fresh tomatoes consumed in the United States is imported from Mexico and Canada during the off-season period. Around 40% of the Mexican and the large majority of Canadian tomatoes imported to the United States are produced in greenhouses (USDA-FAS 2013). Other countries like the Netherlands and Spain also export greenhouse tomatoes to the United States, but in smaller quantities.

Florida field-grown production supplies tomatoes largely for the winter market in the eastern US markets while northern and western US field-grown production supplies the summer markets. California supplies its tomatoes mostly west of the Mississippi River in spring and summer. Florida producers get higher prices for their product because they produce when lower winter supplies result in higher prices (USDA-ERS 2012b). Tomato production in Florida fell from 22,250 hectares (55,000 acres) in 1990 to 12,140 hectares (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 1 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 ten years, from 2002 to 2011, surpassing US domestic tomatoes after 2010.



**Figure 1.** Fresh tomato supply in the U.S. market

Most U.S. states, except Florida, and Mexico and Canada produce tomatoes during the summer season so supplies are generally high and prices are relatively low. However, the dynamics are different during the winter season when the main tomato suppliers are the state of Florida and Mexico. Florida produces mainly field-grown tomatoes. Every year, Mexico is shipping more and more greenhouse/screen-house tomatoes to the United States. Figure 2 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.

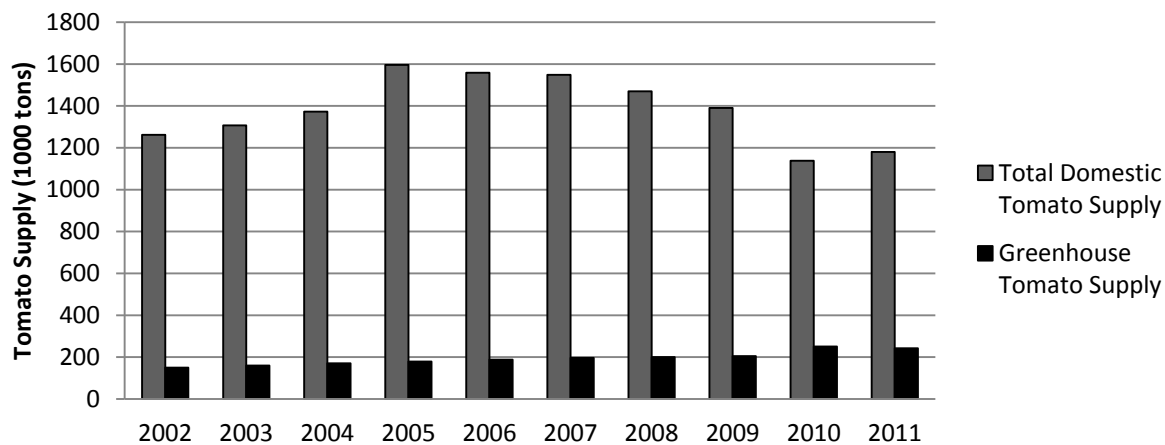


**Figure 2.** Tomato imports from Mexico by technology

The increase in Mexican tomato imports has coincided with a trade conflict between imported and U.S. domestic fresh winter tomatoes. International competition has been an issue in the industry since the early 1970s (Bredahl, Schmitz, and Hillman 1987; VanSickle, Evans, and Emerson 2003). 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 have increased their shares with lower prices, domestic producers have attempted to keep their share in the tomato market without any costly investment in production practices. However, due to the demand for high quality tomatoes by U.S. consumers and the minimum reference price applied

to Mexican tomato imports (USDOC 2013), Mexican producers have increasingly shipped larger quantities of greenhouse tomatoes with higher quality to compete with Florida field-grown winter tomatoes. Mexico greenhouse production acreage increased to 12,000 hectares in 2012, and 70% of this acreage was devoted to tomato production (SAGARPA 2013). Competition with Mexican greenhouse tomato producers pushed winter tomato producers (particularly in Florida) to consider new investment opportunities like greenhouse tomato production.

Since 2000, U.S. greenhouse tomato production increased two-fold (from 122 thousand tons in 2000 to 244 thousand tons in 2011), although its share in the total fresh tomato market is still relatively low at approximately 15% (Figure 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 to this niche market during the winter season when the tomato price is at the peak level. Moreover, recent studies also show that greenhouse tomato production in the U.S. market is in the boom phase and will continue to grow.



**Figure 3.** Domestic fresh tomato market in the United States

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 between three- and twenty-fold more yield (on per-square meter basis) than Florida field-grown production. Although greenhouse production cost is high, its competitiveness in revenue and quality can be better than that of field-grown tomatoes. Hence, imported greenhouse tomatoes have opportunities to increase their market share in the United States (Cantliffe and VanSickle 2003). Overall, the increased interest in greenhouse tomato production in the southwestern U.S. states, as well as increasing competition from imported Mexican greenhouse tomatoes have subsequently decreased winter tomato prices, and hence the profits of Florida producers.

There are advantages and disadvantages to greenhouse production. The controlled environment of greenhouse production gives high and stable yields. It also enables growers to perfect crop timing and to supply winter markets when fresh market prices are at a premium. In contrast, the disadvantages are high initial investment costs, high operating costs, and energy-intensive production practices. Aforementioned, 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 factors for tomato production can be identified as yield, price, and cost risks (Table 1).

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

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

**Source.** Compiled by author based on the literature (Harwood et al. 1999; Roberts, Osteen, and Soule 2004).

Controlled atmosphere almost eliminates much of the yield risk in greenhouse production whereas yield risk is high for field grown production. An industry survey indicates that tomato yields vary from 9 to 14.5 kg (20–32 lbs) per plant per year in a regular greenhouse while yield can range from 21 to 23 kg (46–50 lbs) per plant under the best greenhouse technology (Pena 2005). Furthermore, a field-grown trial showed that per plant tomato yield generally ranges from 3 to 7 kg (6–15 lbs) per plant in Florida (Santos et al. 2013).

The source of price risk lies in the supply and demand relationship. Stabilized greenhouse production (i.e., the ability to target harvesting time to the periods when 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 like 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 greater yields, higher quality products, and a more stable market demand and/or prices than current field-grown production technologies.

This paper incorporates risk into the net present value and real option analysis to investigate the potential benefits of Florida tomato producers investing in greenhouse production methods. The feasibility of the greenhouse investment opportunity is evaluated given the 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 allows Florida producers to increase their per unit revenue or reduce their production costs to keep their market share.

## **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 the high technology greenhouse tomato production system (Greenhouse-HT) which has higher costs and 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. 2009). This budget was updated to 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 (Smith and VanSickle 2009). The first two sets use different greenhouse sizes (the patriot model is based on 120,000 square meters [29.7 acres] greenhouse area and the Florida greenhouse budget is based on 335 square meters). According to the agricultural census, the average tomato farm size is 28 hectares taken as a base to construct a budget for field-grown tomatoes in Florida (Agcensus 2012). For this analysis, all the budget sets are adjusted to a 4047 square meters basis (one acre) to make relevant comparisons between field-grown and greenhouse production systems. Therefore, we assume that the producer will decide based on comparing the technologies at the same scale and allocate land according to the chosen technology. Since the budgets are chosen at the average investment size for these technologies, the producer would invest in the feasible size when the decision is made.

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 \$8.65/square meter (\$35,000.00/acre) for greenhouse production. This value is calculated from the financial model as a minimum requirement to ensure that the cash balance never falls below zero at the mean for a rational investment decision.

Working capital loans are provided for 90% of the annual variable production cost 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% based on previous literature (Richardson and Mapp 1976), which is used as a discount rate for the Net Present Value (NPV) analysis (Table 2).

**Table 2.** Key assumptions used in greenhouse tomato financial model\*

Variable	Unit	Value
Operating Loan Length	Years	1
Operating Loan Interest Rate	Percent	5.0
Long-term Loan Length	Years	7
Long-term Loan Interest Rate	Percent	8.0
Interest on Equity Invested	Percent	10.0
Corporate Tax Rate	Percent	25.0
Inflation Rate	Percent	2.0
Increase in Energy Prices	Percent	7.0

**Note.**\*The assumptions are constructed based on the data collected from IRS (2012), US-EIA (2013), and USDA-FSA (2014).

Greenhouse production requires approximately from 15 to 30 times more start-up cash than does field-grown production (Table 3). The largest expense for greenhouse production is the growing



cost since the high yield requires higher cost seedlings and chemical expenses (Table 4). 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 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.** Initial investment budget for three production technologies (in dollars per acre\*)

	Field-grown	Greenhouse – FL	Greenhouse - HT
Initial Equity	\$—	\$35,000.00	\$35,000.00
Total Liability	\$13,150.00	\$620,919.07	\$1,299,292.49
Start-up Cash	\$13,150.00	\$196,322.35	\$389,055.81
Construction Cost & Durables	\$—	\$459,596.72	\$945,236.68

**Note.** \*1 acre is equal to 4,046.86 square meters.

**Source.** Based financial model built on three budget sets

**Table 4.** Annual operational cost for three production technologies (in dollars per acre\*)

	Field-grown	Greenhouse – FL	Greenhouse – HT	Shares of Production Cost		
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%

**Note.** \*1 acre is equal to 4,046.86 square meters.

**Source.** Based on three budget sets (see Appendix for details).

The simulated net income statements (NIs) of all three tomato production technologies are computed at the expected level for 2014 (Table 5). The simulation result shows that the break-even production points are 26 kg per square meter (22 lbs per plant and 10,650 plants per acre) and 52 kg per square meter (38 lbs per plant and 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:

**Table 5.** Net income statements for alternative tomato production technologies, 2014 (\$/acre)\*

	Field-grown	Greenhouse – FL	Greenhouse– HT
Expected Production	18,370 kg	111,107 kg	214,775 kg
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)

**Note.\*** 1 acre is equal to 4,046.86 square meters.

The net present value (NPV) framework is commonly used to evaluate agricultural investment. In this analysis, free cash flow (FCF) and 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.

$$(1) \quad NPV_0 = -(\text{Start-up Equity Value}) + \sum_{t=1}^T \frac{FCF_t}{(1+r)^t} + \frac{\text{Terminal Value}}{(1+r)^T}$$

where start-up equity value is added manually to prevent firms from running out of cash during the financial year,  $FCF$  is the free cash flow 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*

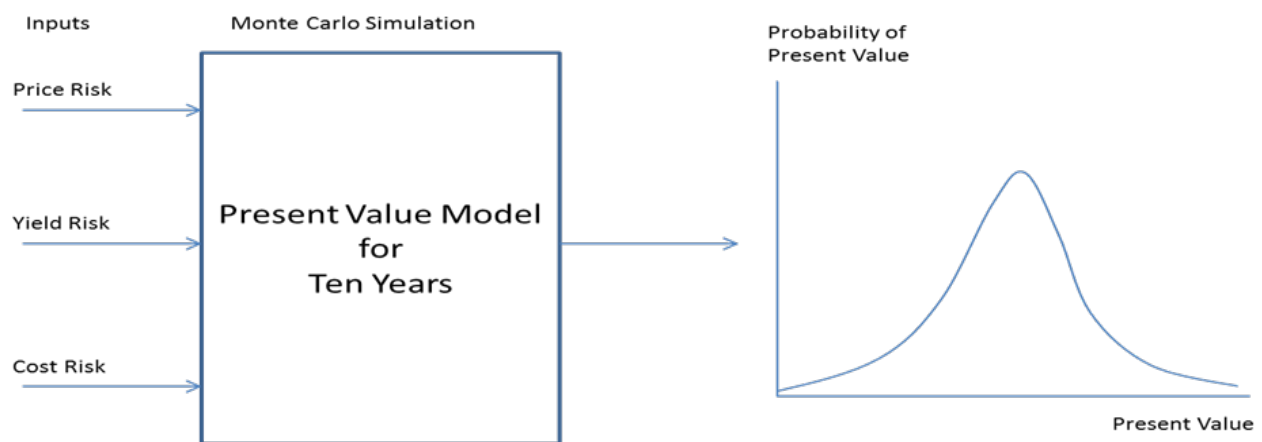
This study aims to incorporate yield, price and cost risks into the NPV analysis. This objective is achieved by simulating the risk parameters for 10 years. Since the average depreciation of all infrastructure and durables for greenhouses is about 10 years, this time frame is selected for the analysis. 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 (2013b) annual field-grown price and yield data from 1990 to 2012 for Florida, and from USDA-AMS (2013) monthly terminal point greenhouse prices in the eastern U.S. 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 are then applied to all financial analyses. 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 energy cost. The risk associated with this cost is accounted for in the model by using the fuel/liquid petroleum gas and electricity price relationship. The gas and electricity price data are collected from 1990 to 2012

(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.

**Table 6.** Summary statistics for stochastic variables, 1990-2012

Variable	Unit	Mean	Standard Deviation	Minimum	Maximum
Tomato Yield	kg/sq m	3.86	0.32	3.25	4.54
Sale Prices	\$/kg	0.83	0.25	0.57	1.60
Electricity Price	\$/KW	5.32	0.87	4.43	6.83
Gas/LPG Price	\$/liter	0.36	0.19	0.18	0.80

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 presented in Figure 4.



**Figure 4.** Risk modeling in the net present value analysis

**Source.** Adapted from Copeland and Antikarov (2003).

The stochastic variables are selected as the tomato yield, sale price, 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. MVE distribution ensures that the simulated variables have the same correlation as they were correlated in the past. Each variable is estimated with trend variable to obtain detrended residuals with which we can calculate fractions of trend ( $S_i$ ) and cumulative probabilities ( $F(S_i)$ ). The stochastic variables, summarized in Table 7, are inserted into financial models for the iteration of NPV to evaluate the economic risk associated with the tomato investment decision. For each variable,  $CUSD_i$  represents the correlated uniform standard deviates calculated to correlate variables appropriately (Richardson, Klose, and Gray 2000).

**Table 7.** Stochastic variables used in financial model of tomato production investment decision

Variable	Unit	Value
Tomato Yield (Field-Grown)	kg/sq m	Mean Yield <sup>k</sup> * [1 + MVE (S <sub>i</sub> , F(S <sub>i</sub> ), CUSD <sub>1</sub> )]
Sale Prices	\$/kg	Mean Price <sup>k</sup> * [1 + MVE (S <sub>i</sub> , F(S <sub>i</sub> ), CUSD <sub>2</sub> )]
Electricity Price	\$/KW	Mean Price <sup>k</sup> * [1 + MVE (S <sub>j</sub> , F(S <sub>j</sub> ), CUSD <sub>3</sub> )]
Gas/Liquid Petroleum Gas Price	\$/liter	Mean Price <sup>k</sup> * [1 + MVE (S <sub>j</sub> , F(S <sub>j</sub> ), CUSD <sub>4</sub> )]

The NPV distributions are ranked using Simetar© software. 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) are applied to rank the risky alternatives (Hardaker et al. 2004). Stochastic dominance with respect to a function (SDRF) and stochastic efficiency with respect to a function (SERF) allow us to incorporate risk aversion in our analysis (Richardson and Outlaw 2008).

### *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 be insufficient to explain why U.S. growers still do not switch to the greenhouse tomato production. The next step in this research is to use the real options approach (ROA) to evaluate the viability of greenhouse tomato production in Florida. ROA has several advantages. First, ROA allows including the future value of agricultural investment into the current investment decision analysis. Second, ROA controls for the irreversibility of investment in the analysis. Third, ROA allows modeling a 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:

$$(2) \text{ NPV : } \text{MAX}(\text{at } t=0)[0, E_0(V_t - X)]$$

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

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 assigns 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 described by Copeland and Antikarov (2003) and used by Iwai and Emerson (2008). The details of the calculations 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 8 presents cash balances and net incomes for field-grown and greenhouse tomato production for ten-year periods. We use equation (1) to separately calculate NPVs for each technology.

**Table 8.** Cash balances (CB) and net incomes for field-grown and greenhouse tomato productions (\$/acre)\*

Years	Field-grown		Greenhouse - FL		Greenhouse - HT	
	CB	Net Incomes	CB	Net Incomes	CB	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

**Note.** \*1 acre is equal to 4,046.86 square meters.

Table 9 suggests that high-tech greenhouse production is the most feasible investment opportunity at the mean. Florida greenhouse technology is the second best investment (given the assumptions made). The [deterministic] NPV results presented in Table 9 are insufficient to explain the greenhouse investment decision made by Florida tomato producers. Therefore, to explain the producers' choices, deterministic NPV values are simulated using Monte Carlo method applied to the financial model in Simetar© add-in to Excel.

**Table 9.** Deterministic net present values per an acre field grown and greenhouse tomato productions\*

	Present Value	Initial Equity	Net Present Value
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

**Note.** \* 1 acre is equal to 4,046.86 square meters.

NPV 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 10. "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.

**Table 10.** Summary statistics of Monte Carlo simulation for NPVs of alternative technologies

	Units*	Greenhouse-HT	Greenhouse-FL	Field-grown
Mean	\$/acre	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	\$/acre	(122,421.19)	(85,587.57)	(14,079.44)
Maximum	\$/acre	222,902.09	126,208.66	10,434.16

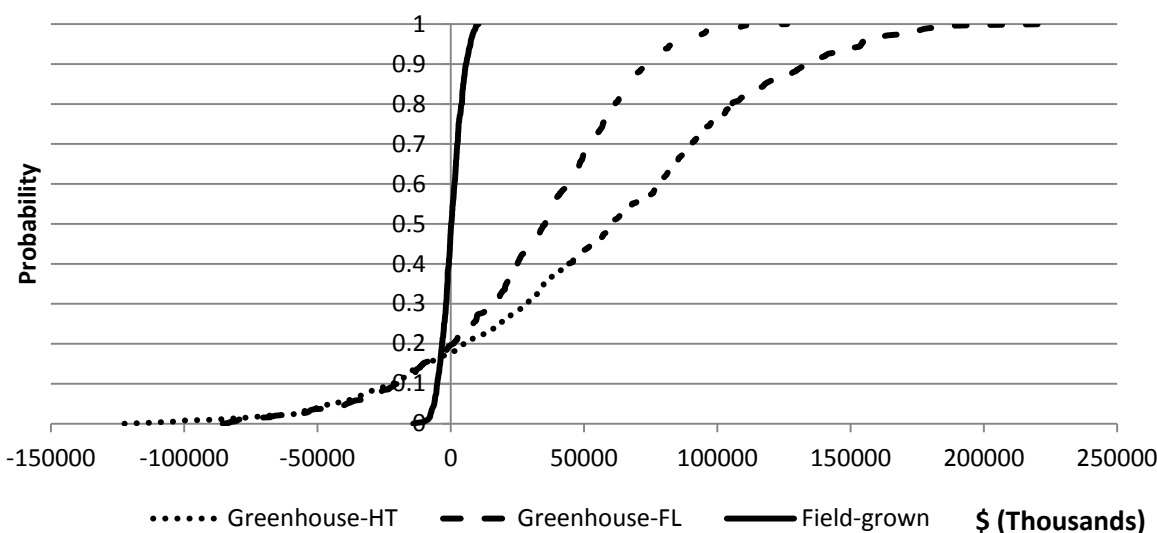
Notes. \* 1 acre is equal to 4,046.86 square meters.

The cumulative distribution function (CDF) of NPV values for alternative production technologies are illustrated in Figure 5. CDFs cross each other and, hence, the technologies cannot be ranked using the first order stochastic dominance criterion (Table 11 and Figure 5).

In turn, the second-order stochastic dominance criterion suggests that “Greenhouse-HT” dominates both “Greenhouse-FL” and “Field-grown”. Furthermore, “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.

**Table 11.** First and second order stochastic dominance rankings for alternative technologies

	Greenhouse-HT	Greenhouse-FL	Field-grown	Approx. 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



**Figure 5.** CDFs of simulated NPVs for alternative technologies

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 (Richardson and Outlaw 2008). The first preferred set based on SDRF at the lower risk aversion coefficient (ARAC=0) shows the ranking for a risk neutral producer (Table 12). The ranking for risk neutral producer suggests that “Greenhouse-HT” is the first preferred alternative, 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 (ARAC=0.00004). Thus, extremely risk-averse decision makers prefer field-grown tomato production over both greenhouse technologies.

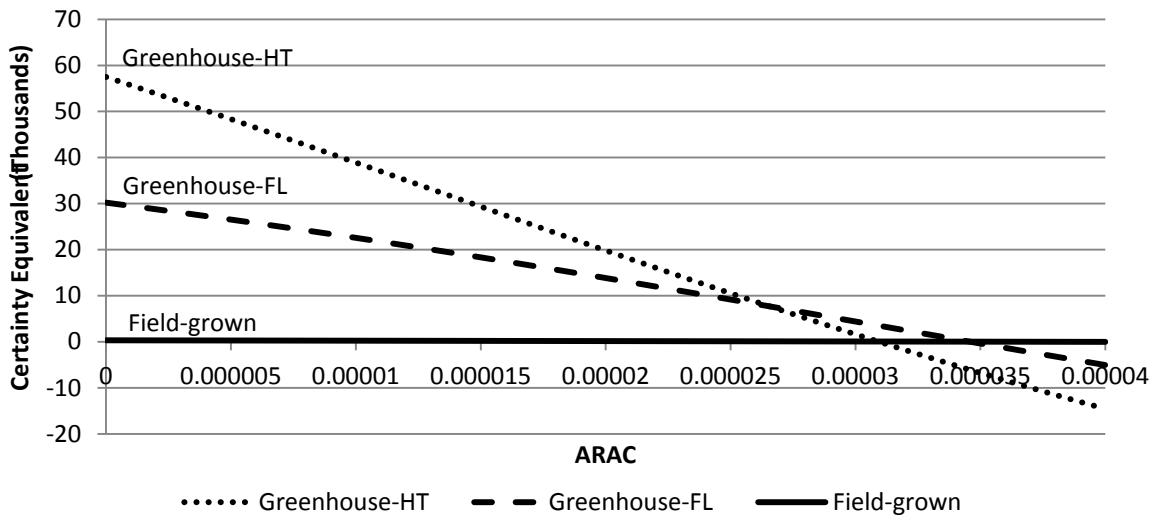
**Table 12.** Stochastic dominance with respect to a function results

Ranking	Name	Level of Preference
Risk-neutral producer		
1	Greenhouse-HT	Most Preferred
2	Greenhouse-FL	2nd Most Preferred
3	Field-grown	3rd Most Preferred
Extremely risk-averse producer		
1	Field-grown	Most Preferred
2	Greenhouse-FL	2nd Most Preferred
3	Greenhouse-HT	3rd Most Preferred

The SDRF results also show that “Greenhouse-FL” dominates “Greenhouse-HT” when the decision maker is extremely risk-averse (Table 12). 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 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 ARAC values from 0 to 0.000026, and “Greenhouse-FL” dominates from 0.000026 to 0.000035 and “Field-grown” dominates for ARACs greater than 0.000035. 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.

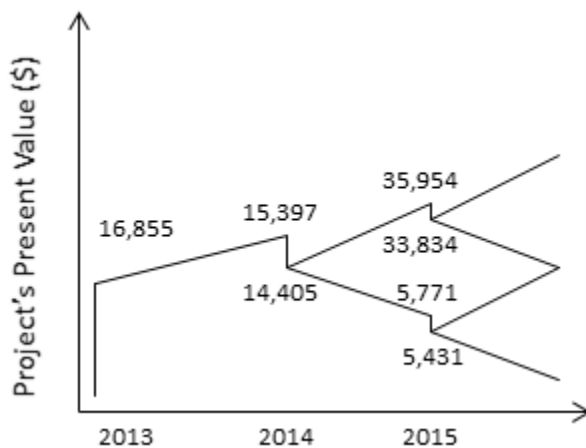
Real option approach is implemented by constructing the binomial decision tree. Field-grown tomato production is taken as a base production technique for Florida, and the investment option for greenhouse tomato is investigated. The procedure described by Copeland and Antikarov (2003) is followed for 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 present value of field grown production and net income, respectively, for the 2014 season, and  $PV_0$  is the fixed present value at \$16,855.19 for the 2013 season. The mean ( $\mu_z$ ) and the standard deviation ( $\sigma_z$ ) 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 incentivize growers to postpone the new investment (Dixit and Pindyck 1994).



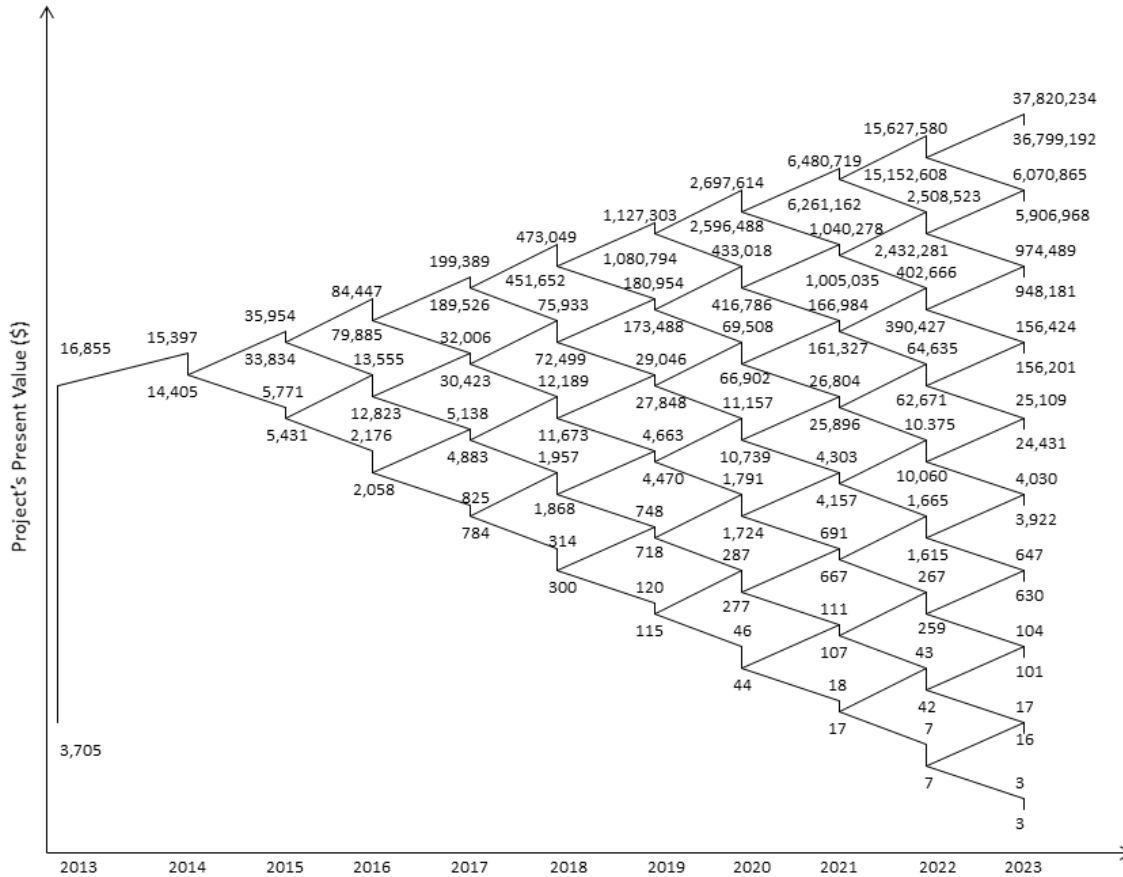
**Figure 6.** Stochastic efficiency with respect to a function under a negative exponential utility function

The present value for the 2014 season (\$14,405) is the cash balance for the field-grown technology (Table 8), 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  $dt=1$  (Figure 7). 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 (Figure 8).



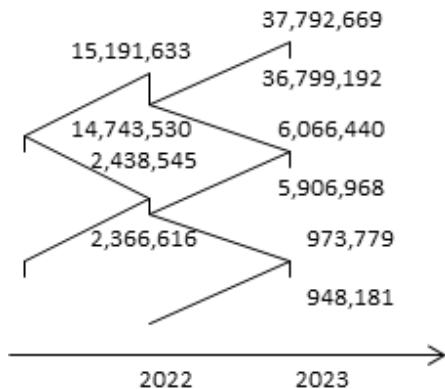
**Figure 7.** Present value binomial tree for the first three years





**Figure 8.** Present value binomial tree for field-grown tomato production

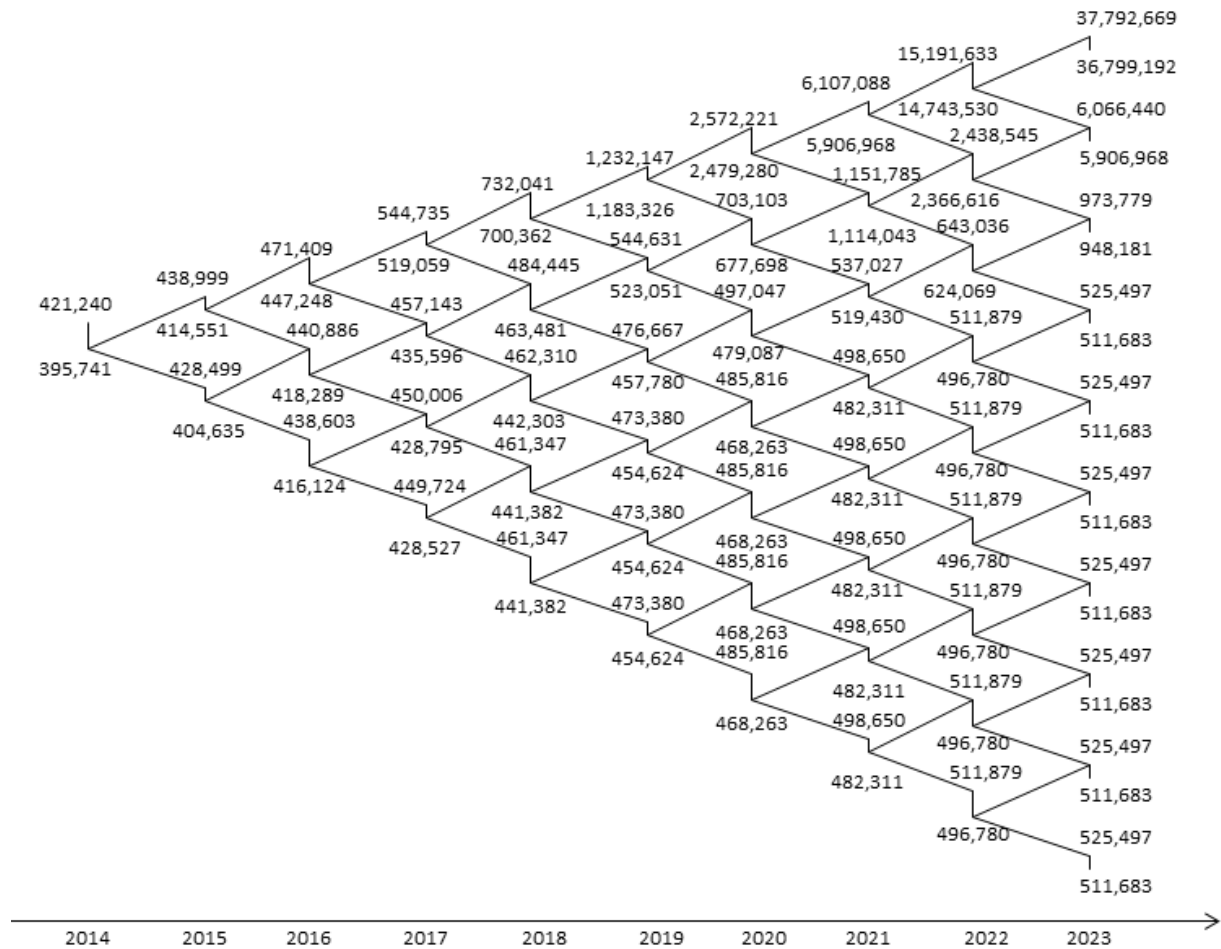
As described in Copeland and Antikarov (2003), we analyze the optimal execution of real options starting at the end of the tree when the option expires. We analyze two different investment options for the field-grown producer: (1) investment in Florida greenhouses and (2) investment in high-tech greenhouses. The final nodes of the option calculation are chosen as the maximum of the three values demonstrated as  $MAX(PV_{2023}^{fg}, PV_{2023}^{fl} - IE_{2023}^{fl}, PV_{2023}^{ht} - IE_{2023}^{ht})$ . The values are the present value of the final year ( $PV_{2023}^{fg}$ ) in Figure 8, present value of high-tech



**Figure 9.** Real option calculation for top nodes of last two years

greenhouse in 2023 minus discounted initial equity for 2023 ( $PV_{2023}^{fl} - IE_{2023}^{fl}$ ) in Table 8, and the present value of the Florida greenhouse in 2023 minus the discounted initial equity for 2023 ( $PV_{2023}^{ht} - IE_{2023}^{ht}$ ) in Table 8. For instance, the top node of the end of three is the maximum value comparing the present value \$36,799,192 from the binomial tree, the value given from the Florida greenhouse as  $\$308,825 - \$35,000 / (1 + 0.3)^{10}$ , and the value given from the Florida greenhouse as  $\$558,720 - \$35,000 / (1 + 0.3)^{10}$ , shown in Figure 9.

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  $q = ((1 + r_f) - e^{-\sigma_c}) / (e^{\sigma_c} - e^{-\sigma_c})$ , 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  $MAX(C_t, PV_t^f - IE_t^f, PV_t^h - IE_t^h)$  and repeat the procedure for the all the remaining nodes. Finally, we compute NPV with option value as \$421,240 (Figure 10). 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 grower loses when the investment option is exercised.



**Figure 10.** Real option calculation for greenhouse tomato investment

Table 13 summarizes the NPV results for each tomato production technology with the option value. The results suggest that a grower in field-grown production still has a high option value to invest in greenhouse technology given the assumed production information. The results explain why we may not have seen greenhouse investment in Florida.

**Table 13.** Net present values with option value for field grown and greenhouse tomato production (\$/acre)\*

	<b>Present Value</b>	<b>Initial Equity</b>	<b>Net Present Value</b>	<b>Option Value</b>
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

**Note.** \* 1 acre is equal to 4,046.86 square meters.

## Conclusions

Florida tomato growers have lost market share in the last decade to 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 continued 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 in competing with imported greenhouse tomatoes, but the lower-cost imported field-grown tomatoes will still be a threat for the market share of the domestic growers. In addition, a greenhouse tomato receives premium prices compared to a field-grown mature green tomato at retail since consumers in the United States perceive a greenhouse tomato as high quality and flavorful.

This study examines the investment potential of Florida producers in greenhouse tomato production. Greenhouse production technology is considered as a strategy to mitigate the impact of the increasing Mexican greenhouse tomato imports on the profitability of Florida's tomato producers. The NPV analysis suggests 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 change 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 the 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. Policies or market conditions that decrease these risks (by affecting credit availability, interest rates, insurance, energy prices, tomato prices, effective risk management strategies, technological advancement in greenhouse production, etc.) would decrease the option value. Thus, with these policies or market conditions, greenhouse tomato production becomes preferable for Florida producers. Otherwise, greenhouse production in Florida will most likely come from outside of Florida exactly as it has done in Arizona (EuroFresh Farms), Texas (Village farms), California (numerous producers), Maine (Backyard farms), and Canada (mainly

immigration from Holland) because Florida tomato producers are least likely to convert to greenhouse production due to their extremely high costs of investments in their field operations and packing houses.

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## Appendix

**Table A-1.** High technology greenhouse production expenses (\$/acre)\*

Items	Unit	Quantity	Total Cost
<b>Materials</b>			
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
<b>Energy</b>			
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
<b>Labor</b>			
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
<b>Sales, General &amp; Administrative</b>			
<b>General &amp; Administrative</b>			
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
<b>Sales &amp; Marketing</b>			
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
<b>Total Annual Production Costs</b>			<b>\$509,283.54</b>

**Note.** \*1 acre is equal to 4,046.86 square meters.



**Table A-2.** Regular Florida greenhouse production expenses (\$/acre)\*

<b>Items</b>	<b>Unit</b>	<b>Quantity</b>	<b>Price (\$ per Unit)</b>	<b>Total Cost</b>
<b>Materials</b>				
A mix 8-12-32	kg	1,918.62	3.62	6,945.40
CaNO <sub>3</sub>	kg	1,645.60	1.50	2,468.40
Sulfuric acid	liter	230.50	6.30	1,452.00
Soap	liter	23.00	9.70	223.12
Neem	liter	11.50	100.50	1,155.55
DiPel	kg	5.50	13.09	72.00
Liquid sulfur	liter	11.52	8.35	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	liter	91.92	13.15	1,208.79
Mousetraps	pair	36.30	7.95	288.59
Total Materials				\$27,043.08
<b>Energy</b>				
Electricity	kwh	158,510.00	0.11	17,436.10
LP Gas	liter	99,035.50	0.41	40,604.58
Total Energy				\$58,040.68
<b>Labor</b>				
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
<b>Sales, General &amp; Administrative</b>				
<b>General &amp; Administrative</b>				
Analytical services& repairs	units	12.10	150.00	1,815.00
Travel	km	4,704.00	0.35	1,646.40
Overhead	%	131,011.97	10.00%	13,101.20
Taxes & Insurance **	%	459,596.72	1.37%	6,289.63
Total G&A				\$22,852.22
<b>Sales &amp; Marketing</b>				
Delivery costs	km	9,600.00	0.35	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
<b>Total Annual Production Costs</b>				<b>\$234,084.31</b>

**Notes.**\*1 acre is equal to 4,046.86 square meters.

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

**Table A-3.** Field-grown tomato production expenses (\$/acre)\*

Items	Unit	Quantity	Price	Total Cost
<b>Materials</b>				
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
<b>Energy</b>				
Total Energy				\$—
<b>Labor</b>				
General Farm Labor	acre	1.00	140.63	140.63
Tractor Driver Labor	acre	1.00	214.29	214.29
Total Labor				\$354.92
<b>Sales, General &amp; Administrative</b>				
<b>General &amp; Administrative</b>				
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
<b>Sales &amp; Marketing</b>				
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
<b>Total Annual Production Costs</b>				<b>\$17,521.66</b>

**Note.\*** 1 acre is equal to 4,046.86 square meters.

