CONSUMER BEHAVIOR AND GROWER PREFERENCE ANALYSIS FOR AGRICULTURAL ECONOMICS

By

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Abstract

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This dissertation consists of three independent but related studies that investigate consumer behavior and grower preference for specialty crops. I analyze consumer purchase decisions for flowers considering two different purchase uses, own use and gift use. I also evaluate growers' preference and willingness to pay for improved fruit cultivars, focusing on improvements in increased resistance to diseases and superior fruit quality. These results enable calculation of producer, consumer, and total welfare change under the crop loss due to disease.

The first study applies Heckman two step method to investigate differences and similarities for Washington state consumer cut flower purchase behaviors for own use and gift giving. The results indicate that some factors affecting consumer purchase decisions (purchase likelihood and expenditure amount) for own use are differ from as those affecting purchase decision for gift giving. These findings are useful to target potential consumers.

The second study use a discrete choice experiment method to investigate southeastern states (i.e., Georgia, North Carolina, and South Carolina) peach grower preferences for various attributes of new peach varieties. The mixed logit model results indicate peach growers have heterogeneous preferences for attributes of peach cultivars and are willing to pay higher premiums for peaches with higher resistance to disease but lower premiums for fruit quality attributes. WTP for disease resistance and fruit quality also differ among harvest seasons.

The third study evaluates Florida strawberry growers' preference for disease resistance and fruit quality. Results suggest that larger operations are more likely to grow new cultivars with disease improvement. This study calculates the welfare loss for the Florida strawberry industry after methyl bromide phase-out and crop loss due to disease. These results have important implications to Florida strawberry industry and breeders in the development of new cultivars with disease improvement to reduce the crop loss percentage.

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This dissertation is dedicated to my father, mother, sister, brother in law, and nephews.

CHAPTER ONE

INTRODUCTION

This dissertation consists of three papers that examine different aspects of consumer and grower preferences in the field of agricultural specialty crop economic research. The first paper is a study about consumer purchase decisions for cut flower. The second paper is a discrete choice experiment study on peach growers to elicit their preferences and willingness to pay (WTP) for fruit attributes associated with peach cultivars. The last paper investigates strawberry growers' preferences and WTP for various attributes of new strawberry cultivars and examines the producer surplus and consumer surplus loss after methyl bromide phase out and crop loss due to disease.

In the first paper (Chapter Two), we identify factors influencing Washington state consumers purchase decisions for cut flowers (purchase likelihood and expenditure amount), separating the analyses into purchase purposes for own use and gift use. Results indicate the factors influencing the two purchase purposes are different. And an interesting finding from this study is that both purchase behavior likelihoods are positively impacted by the interest level in information that the cut flowers grown in Washington state. The findings from this study provide useful information in identifying market opportunities and potential consumers for Washington state cut flower growers.

The second paper (Chapter Three) use a discrete choice experiment to understand how peach growers in the southeastern U.S. value fruit quality versus disease resistance. Results indicate that peach growers assign higher values to disease resistance compared to fruit size and external fruit color. Importantly, grower preferences for the same peach attribute varied across peach harvest time (e.g., early, mid, and late season). These results will be useful to breeding programs to more effectively allocate resources to develop breakthrough cultivars that would improve market acceptance and horticultural management.

The third paper (Chapter Four) estimates Florida strawberry growers' WTP for fruit quality and disease resistance attributes using a discrete choice experiment. The results of WTP suggest that strawberry growers place a higher value on fruit quality attributes such as flavor and size compared to attribute of disease resistance improvement. This study calculates welfare loss for the Florida strawberry industry after methyl bromide phase-out and crop losses due to disease. These results are useful for Florida strawberry industry and breeders in the development of new strawberry cultivars with disease improvement.

CHAPTER TWO

FACTORS INFLUENCING WASHINGTON STATE CONSUMER PURCHASE DECISION OF CUT FLOWERS

1. Introduction

In the U.S., the supply of fresh cut flowers come from both domestic growers and foreign growers (Bonarriva, 2003). While domestic production remained relatively stable in value in recent years, cut flower imports have been consistently increasing. In 2015 the wholesale market value of domestically produced cut flowers was $374 million while the market value of imported cut flowers was $645 million and it increased to $790 million in 2018 (GATS, 2018; USDA NASS, 2016b). In 2015 cut flower imports accounted for 72% of the total value of cut flowers sold in the United States and they came from multiple countries (GATS, 2018; USDA NASS, 2016b). About 90% of imported cut flowers came from Colombia, Ecuador, and Netherland and other big importing countries include Mexico, Thailand, and Costa Rica (GATS, 2018). Shipping flowers from these countries to the U.S. results in large transportation, energy, refrigeration, and storage costs, leaving a large carbon footprint (Holt and Watson, 2008). Also, these floral materials may carry chemical pesticides or fungicides residues (Holt and Watson, 2008). Consumers can buy locally grown flowers to reduce such environmental impacts (Holt and Watson, 2008).

Washington state is among the top ten cut flowers producing states in recent years (USDA NASS, 2016b). As competition with international growers has increased, the structure of the Washington state industry has changed resulting in more small-scale growers growing specific flowers that weren't easily imported (Connolly and McCracken, 2016). Popular types of flowers sold by florists are rose, lily, and carnation and able to be shipped long distance and maintain quality, which are mainly imported, other specialty cut flower types (e.g., dahlia, sun flower, and zinnia) are not so resilient and hence cannot be shipped long distances (Connolly and McCracken, 2016). In Washington state small scale cut flowers growers are mostly growing these different types and selling their produce directly to consumers (e.g., farmers market, community supported agriculture, and on-farm sales) (Connolly and McCracken, 2016). In Washington state, cut flowers were sold in 93 farmers markets out of the 127 farmers markets in 2010 (Ostrom and Donovan, 2013) and in 2014 direct sales to consumers accounted for about 20% of the marketing sales value of horticultural crops, followed by retail garden centers and supermarkets (USDA NASS, 2014a).

On the demand side, flowers are purchased for own use (self enjoyment or daily use at own home) and gift use (giving flowers as a gift for someone else). There are some correlations found from the two purchases. For example, an element of quality of life for a consumer was observed from the purchase for own use and gift use (Tzavaras, Tzimitra-Kalogianni, and Bourlakis, 2010). And a study focused on floral purchase frequencies by Huang (2005a) found that consumers usually bought flowers 15 or more times per year either for daily use or gift-giving use. Other behaviors, however, differed between the two types of purchases, Tzavaras, Tzimitra-Kalogianni, and Bourlakis (2010) found that consumers purchased cut flowers for themselves because of improvement of life quality and purchased cut flowers for gift giving because of special or social occasions.

The objective of this study is twofold, first identify factors impacting purchase likelihood and then identify factors impacting expenditure amount if consumers purchased, specifically to identify differences and similarities between consumers' purchase behavior when shopping cut flowers for own use and gift use. Moreover, besides socio-demographic characteristics this study includes flower knowledge, preference for local, price perceptions, and food shopping habits to investigate how they affect the probability and expense for cut flower purchase. Findings in the differences and similarities of factors impacting the two purchase behaviors (own use versus gift use) in two step decision provide a detailed profile of potential consumer for cut flower growers to target when competing in cut flowers markets. Also cut flowers growers in Washington or other states could benefit from better knowledge about cut flower consumers preferences and purchase behavior.

2. Literature Review

Numerous studies have focused on socio-demographic factors influencing cut flower consumers purchase frequency and expenditure and they identified that floral knowledge, attitude, income, age, gender, and household size were usually important factors impacting consumer decision of floral products (Behe and Wolnick, 1991; Huang, 2005a; Yue and Behe, 2008a; Yue and Hall, 2010). Besides socio-demographic factors, Zhao et al. (2016) found that urban and metropolitan residency and housing status also increased consumers purchase likelihood and expenditure amount. Previous studies also identified flower attributes associated with consumers' preferences when they purchased flowers. Yue and Behe (2010b) found that the color of flower was an important attribute. Rihn et al. (2014) found that information about vase life longevity and the presence of a guarantee about vase life longevity for a cut flower arrangement positively influenced consumers’ likelihood to purchase cut flowers.

Besides sensory and quality attributes, credence attributes (e.g., locally grown, eco-label, and environment sustainable) were also found to be associated with consumers' preferences for horticultural products. Yue et al. (2011) indicated that consumers were very interested in locally grown plants. Michaud, Llerena, and Joly (2012) evaluated consumers preferences for roses with environmental attributes. They found that consumers who typically purchased organic food products and male consumers were more likely to buy roses with eco-labels and with a low carbon footprint.

Previous studies (Huang and Yeh, 2009; Huang and Lin, 2015; Tzavaras, Tzimitra-Kalogianni, and Bourlakis, 2010) have indicated that different factors were correlated with different uses of cut flowers. Rihn et al. (2011) suggested that short vase longevity, limited trendiness, appropriateness, and uniqueness were usually associated with consumers dissatisfaction when considering whether to buy cut flowers for gifts. They also found that Generation Y consumers (born between 1977 and 1994) perceived that their friends didn't enjoy receiving floral gifts and hence had a lower interest in floral gifts compared to their Generation X counterparts (born between 1965 and 1976). Huang (2007b) identified differences between consumers who purchased cut flowers for own use and gift use. Consumers who purchased flowers for their use focused more on longevity, price, and quality and less on symbolic meaning compared to consumers who purchased flowers for gifts. And when choosing where to buy flowers consumers who purchased flowers for own use were more likely to buy from traditional flower markets while consumers who purchased for gifts focused more on the availability of a home delivery service.

Our study contributed to the literature in accessing factors that impact the two step purchase decision for a non-food agricultural specially crop, differentiated by intended use (own or gift). Our findings would help determine what marketing messages and can inform the industry about appropriate sales strategies, as well as product attributes consumers will respond to most favorably when marketing cut flowers.

3. Empirical Model

There are two separate but linked decisions associated with cut flowers purchases. The first is the decision to purchase cut flowers, which is the likelihood of purchase in the cut flower market, and the second is the decision of how much to spend on cut flowers. The one step decision process implied in a Tobit model, for example, assumes that the decision to purchase and expenditure amount are a single decision (Heckman, 1976a). A two step decision process models the two decisions separately allowing the factors for each decision to differ (Heckman, 1979b). Here it is assumed that consumers first decide whether or not they will purchase cut flowers, and then they decide which flowers to purchase and hence how much they will spend. We further assumed that this decision process differs for flowers for own use and for gift use. Therefore, the model used in this study had two steps. At the first step, a bivariate probit model was used to identify factors impacting cut flowers consumers' likelihood to purchase for own use and for gift use. In the second step, a Heckman approach with an additional variable (i.e., the inverse Mill's ratio) to control for selection bias (Heckman, 1979b) was used to evaluate factors impacting the expenditure spent on cut flowers for own use and for gift use. This model has been applied to general models of food and fresh produce consumption (Dettmann and Dimitri, 2007; Mergenthaler, Weinberger, and Qaim, 2009). Zhao et al. (2016) identified factors influencing consumers' two step purchase decision for fresh flowers and potted plants using the same methodology.

3.1. Purchase likelihood using bivariate probit model

In the first step**,** random utility theory was used to model the consumer purchase likelihood of cut flowers. Let ${U_{ts}}^{\mathrm{D}}$ be the utility for consumer t derived from a decision to purchase cut flowers for use s represented by a random utility model such that:

$$ {U_{ts}}^{\mathrm{D}} = \alpha'_{ts} r_{ts} + \varepsilon_{ts} \qquad s = 1,2 \tag{1} $$

where r_{ts} was a vector including characteristics of consumer *t* and cut flower attributes, α'_{ts} was a vector of parameters to be estimated, ε_{ts} was an iid (independent identical distributed) error term with mean zero. It is assumed that the consumer bought cut flowers for a specific use only if the expected utility from purchasing was greater than the expected utility from not purchasing ($U_{ts}{}^{1} > U_{ts}{}^{0}$). Define $U_{ts}{}^{*}$ is the difference between the expected utility from purchasing and not purchasing. Hence consumer *t* bought cut flower for use *s* when $U_{ts}{}^{*} > 0$. $U_{ts}{}^{*}$ was an unobservable latent variable, but the decision to purchase cut flower was observable and can be represented by the binary variable (Greene 2003),

$$D_{ts} = \begin{cases} 1\ if\ \ U_{ts}{}^{*} > 0 \\ 0\ if\ \ U_{ts}{}^{*} \leq 0 \end{cases} \tag{2}$$

where $D_{ts} = 1$ if consumer *t* decided to buy cut flowers for purpose *s* and $D_{ts} = 0$ otherwise. There are likely similar unobservable variables that influenced cut flower purchases for own use (D_{t1}) and for gift use (D_{t2}) so a bivariate probit model was specified as follows:

$$\begin{gathered} D_{t1} = \mathrm{H}_{t1}\beta_1 + \mathrm{x}_{t1}\tau_1 + e_{t1} \\ D_{t2} = \mathrm{H}_{t2}\beta_2 + \mathrm{x}_{t2}\tau_2 + e_{t2} \\ Corr(e_{t1}, e_{t2}) = \rho \end{gathered} \tag{3}$$

where H_{ts} and x_{ts} were vectors of socio-demographic and cut flower attributes variable, respectively, for cut flower purchase decisions for use *s*.

Assuming a normal distribution of e_{t1} and e_{t2}, the probability that consumer *t* purchases cut flowers for use *s* is:

$$\mathrm{P}(\mathrm{D}_{ts} = 1) = \Phi\big(\mathrm{H}_{ts}\hat{\beta} + \mathrm{x}_{ts}\hat{\tau}\big) \qquad s\ = 1,2 \tag{4}$$

the estimates from equation (4) were used to calculate the inverse of Mills ratio (λ_{ts}) for consumer *t* as follows:

$$\widehat{\lambda_{ts}} = \frac{\phi_t(\mathrm{H}_{ts}\hat{\beta} + + \mathrm{x}_{ts}\hat{\tau})}{\Phi_t(\mathrm{H}_{ts}\hat{\beta} + \mathrm{x}_{ts}\hat{\tau})} \tag{5}$$

then this variable can be used as an instrument in the second step regression to account for censoring.

3.2. Expenditure decision using linear expenditure regression

In the second step, expenditures for own use and gift use regressions by ordinary least square (OLS) were estimated. With product attributes variables ($H^{*}{}_{\mathrm{ts}}$), consumer characteristics variables ($\mathrm{X}^{*}{}_{\mathrm{ts}}$) and inverse Mills ratio included the expenditure regression ($\mathrm{E}^{*}{}_{\mathrm{ts}}$) can be written as:

$$\mathrm{E}^{*}{}_{\mathrm{ts}} = H^{*}{}_{\mathrm{ts}}\theta + \mathrm{X}^{*}{}_{\mathrm{ts}}\alpha + \widehat{\lambda_{\mathrm{ts}}}\gamma + \upsilon_{\mathrm{ts}} \quad (6)$$

4. Data

The data for this study was from a survey panel of consumers in Washington State (general population, over age 18) in 2012. The survey was developed by economists from Washington State University and was managed by the online research company 'Qualtrics.' A total of 594 respondents were collected from the online survey platform in December of 2012. There were four sections in this survey. In the first section, consumers were asked about whether they purchased cut flower for own use or gift use and how much they spent if bought cut flower. The second section asked consumers to rate the importance of cut flower attributes, such as quality, color, and uniqueness, opinions from cut flower consumption experience, the importance ranking of Washington state grown cut flowers, and cut flower knowledge. In the third section, consumers were asked about their food shopping habits and to rate the importance of factors associated with their food purchase behaviors. The fourth section asked respondents about their socio-demographic information, whether owned a garden at home, and did they know the percentage of imported cut flowers in the U.S. market.

A total of 466 observations were available for purchase decision analysis in the first step after eliminating missing and incomplete responses. Definitions and descriptive statistics for variables used in the first step (purchase likelihood) are presented in Table 1. About 49% of the respondents purchased cut flowers for own use in the previous year whereas and 50% of the respondents purchased cut flowers as a gift for others. In the sample, the average age category was between 41-50 years old. The majority of the respondents in the sample were females (74%) and about 47% of the respondents' income level was above $50,000[1]. About 55% of the respondents were married, 34%[2] of the respondents had an education degree above four years of college, and half of the respondents had a garden at home.

For knowledge regarding cut flowers, the self- reported knowledge level (from 0 to 100) about cut flowers on average was about 39. Concerning knowledge about specific procedures for taking care of cut flowers, about 38% of the respondents correctly knew that use of clean water kept flowers fresh. Also, respondents valued color, quality, and uniqueness of cut flowers (4 on a 5 point Likert scale) and agreed that cut flowers were good gifts for many occasions. About 83% of the respondents used direct marketing channels to obtain food products. Respondents also had a high interest level in Washington state grown cut flowers, with an average interest level of 4 (on a 5 point Likert scale). The findings were similar for agreement with shopping at locally owned business. Only 4% of the consumers indicated they knew the exact percentage of imported cut flowers in the U.S. market and most were not aware that imported cut flowers and greens account for 79% of the U.S. supply.

For the cut flowers expenditure analysis in the second step, there were 218 observations available for own use expenditure analysis and 248 observations available for gift use expenditure analysis. The summary statistics for the variables used in the cut flowers expenditure

[1] In 2012, the median household income in Washington was $57,284 (Washington State Census of Bureau, 2015) https://www.ofm.wa.gov/sites/default/files/public/legacy/economy/hhinc/medinc.pdf

[2] From 2012-2016, about 33.6% of 25 older persons have 4 year college degree or higher (U.S. Census of Bureau, 2017). https://www.census.gov/quickfacts/WA

for own use regression and gift use regression were shown in Table 2 and Table 3, respectively. For the sample, the average of the expenditure amount on the most spent on a single purchase of cut flowers for personal use was $24.23 and it was $29.64 for gift use. The average age for both own and gift use expenditure samples was 41-50 years old. The percentage of women consumers purchasing for their own use was about 77% and 70% for gift use. About 66% purchasing flowers for own use were married, 60% purchasing for gifts were married, and about 41% of the respondents who purchased for both uses had least a 4-year college degree.

5. Results and Discussion

5.1. Bivariate probit model estimates

A bivariate probit model was used in the first step to evaluate the influence of factors on Washington state consumer cut flowers purchase likelihoods. In this model variables for both education and interest level about Washington grown variable were included. Many studies (Jekanowski, Williams, and Schiek, 2000; Nganje, Hughner, and Lee, 2011) had indicated that education was correlated with interest in locally grown. To see how education and interest in grown in Washington jointly influence consumer cut flowers purchase decisions we also included an interaction term between these two variables. We used likelihood ratio tests to determine whether we should include education as a separate variable in addition to its presence in the interaction term. The results indicate that education did not need to be included as a separate variable.[3]

The final bivariate probit model estimates were presented in Table 4. The overall model was significant at the 1% level of significance and the estimated coefficient of correlation

[3] The likelihood ratio test result suggests we cannot reject the null hypothesis that the estimate coefficient of education variable is equal to 0 and the p-value=0.143.

between the residuals (ρ) in equation (3) was 0.58 and significantly different than zero. This result supported the hypothesis that error terms in the equation (3) were correlated across two uses and that a bivariate probit model approach was appropriate. This result indicated that there were unobservable variables that affected both purchases for own use and gift use simultaneously. Also, the positive significant ρ estimation indicated that one purchase use was positively related with another purchase use and vice versa, which suggested that the two purchase behaviors were correlated, and consumers purchased cut flowers for both the use for themselves and the purpose for others at the same time. Factors including age, income, and garden ownership had similar impacts on both types of purchase behaviors.

Importance of color of cut flowers and agreement that cut flowers were a good gift for many occasions influenced both purchase likelihoods positively. Likewise, both purchase likelihoods were positively impacted by information that cut flowers were grown in Washington. While grown in Washington had a direct impact on the own use purchase probability (not through education), its impact on gift use occurred only through the education interaction. The positive local preference impact on cut flower purchase likelihood is consistent with the findings from Yue et al., (2011) about plants purchase. And this result suggested that when shopping cut flowers for own, consumers might consider shopping Washington grown cut flowers was supporting the local community or neighborhood, but when shopping cut flowers for gift consumers with higher education level might prefer Washington grown products and hence consider Washington grown was a part of product value. This information suggested some policymakers such as Washington state Department of Agriculture or cut flower commissions might consider designing a “Washington Grown” label to help cut flowers growers in Washington to sell flowers.

Looking at the differences between the two purchase likelihoods, we found consumer knowledge about cut flowers affected the probability of cut flowers purchases for own use but not for gift use. And factors important in the purchase likelihood for gift use only were male, education, and consumers' use of direct marketing channels for food products. All else constant, consumers more likely to buy cut flowers for gift use were male, had an education level four year college and beyond, and valued variety uniqueness in cut flowers. However, consumers more likely to buy cut flowers for themselves were married, with higher floral knowledge, and correctly knew how to keep cut flowers last longer. The findings that married, higher income, and higher educated Washington state consumers were more likely to purchase cut flowers were consistent with the study about United States consumers for fresh flowers and potted plants by Zhao et al. (2016).

5.2. Bivariate probit model marginal effects

Since the two dependent variables were binary the coefficients didn't directly measure the marginal effects. Here we reported the marginal effects for the four different combinations of purchase or not purchase for own use and gift use, calculated at the mean of continuous variables and all dummy variables were set equal to one (Table 5, Row 1). The sample predicted the joint probability for purchase for both own use and gift use was 68.3%; purchase for only gift use was 19.2%; purchase for only own use was 8.3%; and no purchase for either use was 4.2%.

At the individual variable level, ten variables had statistically significant marginal effects on the joint decision to purchase cut flowers for both own use and gift use. Nine out of these ten variables had positive marginal effects as shown in column (1). Age was the only variable negatively influencing this joint purchase decision. In particular, as a consumer's age category increased (by one decade), the likelihood of joint purchase fell by 6% less. When the level of knowledge about cut flowers increased by ten units (on a scale of 0 to 100) the likelihood that consumer purchases cut flowers for both uses increased by 1%. Consumers who had gardens at home were 12% higher more likely to purchase cut flowers for both uses compared to their otherwise similar consumers without a garden. Married consumers were 11% more likely than their unmarried counterparts; consumers who reported more than $50,000 in total household income were 18% more likely than their level income counterparts; and when consumers knew how to use clean water to keep cut flowers longer they were 14% more likely than their less knowledgeable counterparts.

For the joint probability of purchase for own use and no purchase for gift use, gender was the only significant variable (column (2)). A female consumer was 12% more likely than their male counterpart to purchase cut flowers for own but not for gift use. In contrast to the case of joint probability for purchase for both uses, variables like marriage status, income, floral knowledge about taking care of cut flowers, and interest level in Washington grown cut flowers now were negatively significantly influence the joint probability of purchase cut flower for gift use but not for own use (column (3)). A male consumer was 11% more likely to purchase cut flower for gifts but not for own use relative to their female counterparts. Consumers who were not married, with lower income, who didn’t correctly know how to take care of flowers, who didn’t think flowers are good gifts, or had less interest in grown in Washington, were 11%, 10%, 10%, 7%, and 6%, respectively, more likely than their counterparts to buy flowers for gift but didn’t for themselves. Focusing in consumers who didn't purchase cut flowers for own or gift use (column (4)), income was a significant factor, and those had an annual income below $50,000 were 8% more likely than their higher income counterparts to be in this non purchasing group. Likewise, consumers who didn’t have a garden, who didn’t think that flowers were great gifts, or were older, were 7%, 6%, and 3% respectively more likely than their counterparts to not purchased flowers for either own or gift use.

5.3. Expenditure regression estimates

The estimates from bivariate probit model in the first step were used to calculate the inverse Mills Ratios for each consumer reporting positive expenditures for each of the two purchases decisions. We log-normalized the expenses in our estimations (Table 6).

The inverse mills ratios in both expenditure equations were significant. This result supported the assumption that there was sample selection bias in the data (which includes only respondents reporting positive expenditure) and implied the Heckman two step approach was appropriate. The significant inverse mills ratios also suggested that the unobservables in the first step of purchase likelihood also affected the second step of expenditure level for cut flowers. In addition, the inverse mills ratio was positive in the own use expenditure regression, which suggested that after consumers decided to purchase cut flowers for own use they also spent more on cut flowers for own use. While the inverse mills ratio was negative in the gift use expenditure regression, which suggested that after consumers decided to purchase cut flowers for gift use but they spent less on cut flowers for gift use. Similar to the results from purchase likelihood in the first step, some common variables had similar effects on the expenditure of cut flowers for both own and gift use. For example, male consumers spent $1.41 (exp($0.34)) more for own use, and $1.27 (exp($0.24)) more on flowers for gift use than their female counterparts. Consumers who were more concerned about food price in their purchase decision spent less on cut flowers for own use ($1.14) and gift use ($1.27). This finding may suggest that for price cautious households may feel cut flowers were luxury products and weren't deemed affordable when compared to otherwise similar not price cautions households.

Looking at differences in the impact of variables on two cut flowers expenditures, consumers who spent more on cut flowers for own use were younger, married, and had an annual household income above $50,000. And this result that married and higher income consumers spent more on cut flowers was consistent with the findings by Zhao et al. (2016). Other things constant, consumers who enjoyed receiving cut flowers as a gift, who indicated that they value the quality, and had higher knowledge levels about cut flowers spent more on cut flowers for own use. Consumers who reported a stronger opinion about involvement in the community paid about $1.11 (exp($0.1)) more on cut flowers for own use. And consumers who spent more on cut flowers for gift use, tended to have lower education levels (less than a four year college degree), value the visual appearance, and had a higher level interest in the price range of cut flowers.

6. Conclusion

In the market for cut flowers, imported cut flowers have dominated the U.S. cut flower market in recent years. Washington State was among the top ten cut flower producing state. However, it was very challenging for the small-scale cut flower growers to reach the consumers in a market where 70-80% of all cut flowers were imported. This study evaluated the two step purchase decisions for cut flowers, differentiating purchase for own use and purchase for gift use. Specifically, the results suggested the value of providing information about the origin, variety, and quality of cut flowers when marketing cut flowers. In addition, results indicated that when consumers were knowledgeable about how to care for cut flowers they were more likely to purchase and spend more, which was the useful information in identifying market opportunities not only for Washington state growers but also for cut flower growers from other states**.** The information can help small-scale cut flower growers develop profitable cut flower business. In addition, this information can help extension agencies and government to better assist small-scale cut flower growers in market access and resource needs for the production plan, while helping them to stay competitive in the marketing of cut flower.

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Table 1. Summary statistics of variables for cut flower purchase likelihood model (n=466).

Variable	Description	Mean
A. Dependent variables		
Purchaseown	1 if purchase cut flowers for own use, 0 otherwise	0.49
Purchasegift	1 if purchase cut flowers for gift use, 0 otherwise	0.50
B. Independent variables		
Demographic		
Age category	1 if 18-30 years 2 if 31-40 years 3 if 41-50 years 4 if 51-60 years 5 if 61-70 years 6 if 71-80 years 7 if 81 years older	3
Male	1 if male, 0 otherwise	0.26
Marital	1 if married, 0 otherwise	0.55
Education	1 if education level is four year college degree or above, 0 otherwise	0.34
Income	1 if annual household income is above $50,000, 0 otherwise	0.47
Garden	1 if has a garden at home, 0 otherwise	0.50
Floral knowledge		
Knowlevel	self reported knowledge about cut flowers (from 0 to 100: no to perfect)	39.25
Cleanfresh	1 if correctly use clean water to keep flowers fresh, 0 otherwise	0.38
Opinion about cut flowers characteristics		
Color	importance on color, 1 means unimportant and 5 means important	4.42
Quality	importance on quality, 1 means unimportant and 5 means important	4.47
Goodgift	agreement on cut flowers are good gift for many occasions, 1 means strongly disagree and 5 means strongly agree	4.11
Uniqueness	interest in uniqueness of flowers, 1 means not at all interested and 5 means very interested	4.02
Preference for local		
Growwa	interest in Washington grown cut flowers, 1 means not at all interested and 5 means very interested	4.01
Directsale	1 if uses direct sale (farmers market, roadstand, u-pick, and own garden) to obtain food, 0 otherwise	0.83
Shoplocal	agreement on shop locally owned businesses more, 1 means strongly disagree and 5 means strongly agree	3.71
Perceptions about imported cut flower market in U.S.		
Answer_import	1 if consumer indicate they knew the percentage of imported cut flowers in U.S., 0 otherwise	0.04

Table 2. Summary statistics of variables for own use purchase expenditure model (n=218).

Variable	Description	Mean
A. Dependent variables		
Log_expenditureown	log expenditure of cut flowers for own use	3.19
B. Independent variables		
Demographic		
Age category	1 if 18-30 years 2 if 31-40 years 3 if 41-50 years 4 if 51-60 years 5 if 61-70 years 6 if 71-80 years 7 if 81 years older	3
Male	1 if male, 0 otherwise	0.23
Marital	1 if married, 0 otherwise	0.66
Education	1 if education level is four year college degree or above, 0 otherwise	0.41
Income	1 if annual household income is above $50,000, 0 otherwise	0.62
Opinion about food product characteristics		
Foodprice	importance on food product price, 1 means unimportant and 5 means important	4.47
Organicgrow	importance on organically grown food product, 1 means unimportant and 5 means important	3.59
Safegrow	importance on food safety, 1 means unimportant and 5 means important	4.45
Opinion about cut flowers characteristics		
Color	importance on color, 1 means unimportant and 5 means important	4.68
Quality	importance on quality, 1 means unimportant and 5 means important	4.68
Enjoy_receiveflower	agreement on enjoy receiving cut flowers as a gift, 1 means strongly disagree and 5 means strongly agree	4.40
Flowerprice	importance on flower price, 1 means unimportant and 5 means important	4.52
Satisfy_longevity	agreement on bought flower longevity satisfaction, 1 means strongly disagree and 5 means strongly agree	3.89
Knowlevel	Self reported flower knowledge (from 0 to 100: no to perfect)	46.21
Preference for local		
Growwa	interest in purchasing Washington grown cut flowers, 1 means not at all interested and 5 means very interested	4.26
Invocomm	agreement on community involvement, 1 means strongly disagree and 5 means strongly agree	3.15
Perceptions about imported cut flower market in U.S.		
Answer_import	1 if consumer indicate they knew the percentage of imported cut flowers in U.S., 0 otherwise	0.06

Table 3. Summary statistics of variables for gift use purchase expenditure model (n=248).

Variable	Description	Mean
A. Dependent variables		
Log_expendituregift	log expenditure of cut flowers for gift use	3.39
B. Independent variables		
Demographic		
Age category	1 if 18-30 years 2 if 31-40 years 3 if 41-50 years 4 if 51-60 years 5 if 61-70 years 6 if 71-80 years 7 if 81 years older	3
Male	1 if male, 0 otherwise	0.30
Marital	1 if married, 0 otherwise	0.60
Education	1 if education level is 4-year college degree or above, 0 otherwise	0.41
Income	1 if annual household income is above $50,000, 0 otherwise	0.57
Opinion about food product characteristics		
Foodprice	importance on food product price, 1 means unimportant and 5 means important	4.48
Organicgrow	importance on organically grown food product, 1 means unimportant and 5 means important	3.52
Season	importance on food seasonality, 1 means unimportant and 5 means important	4.04
Opinion about cut flowers characteristics		
Color	importance on color, 1 means unimportant and 5 means important	4.68
Visual	importance on visual appearance, 1 means unimportant and 5 means important	4.69
Enjoy_receiveflower	agreement on enjoy receiving cut flowers as a gift, 1 means strongly disagree and 5 means strongly agree	4.25
Flowerprice	importance on cut flower price, 1 means unimportant and 5 means important	4.52
Satisfy_price	agreement on bought flower price satisfaction, 1 means strongly disagree and 5 means strongly agree	3.83
Pricerange	interest in sold cut flowers price range, 1 means not at all interested and 5 means very interested	4.29
Preference for local		
Growwa	interest in Washington grown cut flowers, 1 means not at all interested and 5 means very interested	3.75
Shoplocal	agreement on shop local business more, 1 means strongly disagree and 5 means strongly agree	3.89
Perceptions about imported cut flower market in U.S.		
Answer_import	1 if consumer indicate they knew the percentage of imported cut flowers in U.S., 0 otherwise	0.06

Table 4. Estimated parameters from bivariate probit model for evaluating factors influencing cut flower purchase likelihood (n=466).

Parameters Estimates for Purchase Decision Equations				
Independent Variables	Purchase for Own Use		Purchase for Gift Use	
	Coef.	Std. Err.	Coef.	Std. Err.
Demographic Variables				
Age	-0.14***	0.05	-0.20***	0.05
Male	-0.21	0.16	0.62***	0.16
Marital	0.34**	0.15	0.02	0.15
Education*Growwa	0.04	0.04	0.10***	0.04
Income	0.49***	0.15	0.35**	0.15
Garden	0.29*	0.15	0.35**	0.15
Opinions about Floral Knowledge Variables				
Knowlevel	0.01**	0.01	0.01	0.01
Cleanfresh	0.40***	0.14	0.17	0.14
Opinions about Cut flower characteristics Variables				
Color	0.18**	0.09	0.18**	0.09
Quality	0.06	0.09	0.10	0.09
Goodgift	0.41***	0.09	0.36***	0.09
Uniqueness	0.01	0.09	0.20**	0.09
Preference for local				
Growwa	0.26***	0.08	0.11	0.08
Directsale	0.06	0.20	0.36*	0.20
Shoplocal	0.04	0.08	0.01	0.08
Perceptions about imported Cut Flower in U.S market				
Answer_import	-0.09	0.37	-0.15	0.37
Likelihood Value	-450.22			
Likelihood Ratio	196.85			
Correlation Coefficient	0.58***			

*, **, *** denotes significance at the 10%, 5%, and 1% levels respectively.

Table 5. Marginal effects from bivariate probit model for cut flower purchase likelihood (n=466).

	Purchase for Own and Gift (1)		Purchase for Own only (2)		Purchase for gift only (3)		Don't purchase for own or gift (4)	
Predicted Probability	0.6834		0.0425		0.1915		0.0826	
	Marginal effect	Std. Err	Marginal effect	Std. Err	Marginal effect	Std. Err	Marginal effect	Std. Err
Demographic Variables								
Age	-0.06***	0.02	0.01	0.01	0.02	0.02	0.03*	0.02
Male	0.06	0.08	-0.12*	0.07	0.11*	0.06	-0.05	0.04
Marital	0.11*	0.06	0.02	0.02	-0.11**	0.05	-0.02	0.03
Education	0.02*	0.01	-0.01	0.01	-0.01	0.01	-0.01	0.01
Income	0.18***	0.06	-0.01	0.02	-0.10*	0.06	-0.08*	0.05
Garden	0.12**	0.05	-0.02	0.02	-0.03	0.05	-0.07*	0.04
Opinions about Floral Knowledge Variables								
Knowlevel	0.01**	0.01	-0.01	0.01	-0.01	0.01	-0.01	0.01
Cleanfresh	0.14***	0.05	0.01	0.01	-0.10**	0.05	-0.05	0.03
Opinions about Cut flower characteristics Variables								
Color	0.07**	0.03	-0.01	0.01	-0.03	0.03	-0.03	0.02
Quality	0.03	0.03	-0.01	0.01	-0.01	0.02	-0.01	0.01
Goodgift	0.15***	0.04	-0.01	0.01	-0.07*	0.04	-0.07*	0.03
Uniqueness	0.02	0.03	-0.02	0.02	0.02	0.03	-0.02	0.02
Preference for local								
Growwa	0.08**	0.03	0.01	0.01	-0.06**	0.03	-0.03	0.02
Directsale	0.06	0.07	-0.04	0.04	0.03	0.05	-0.05	0.04
Shoplocal	0.01	0.03	0.01	0.01	-0.01	0.02	-0.01	0.01
Perceptions about imported Cut Flower in U.S market								
Answer_import	-0.04	0.12	0.01	0.03	0.01	0.10	0.02	0.05

*, **, *** denotes significance at the 10%, 5%, and 1% levels respectively.

Table 6. Estimated parameters from linear regressions for cut flower expenditure model.

Independent Variables	Parameters Estimates of Expenditure Regressions			
	Expenditure for Own Use (n=218)		Expenditure for Gift Use (n=248)	
	Coef.	Std. Err.	Coef.	Std. Err.
Demographic Variables				
Age	-0.09**	0.04	0.06	0.04
Male	0.34***	0.12	0.24*	0.12
Marital	0.28**	0.12	0.05	0.10
Education	-0.11	0.10	-0.18*	0.10
Income	0.24**	0.11	0.04	0.10
Opinions about Food product characteristics variables				
Foodprice	-0.13*	0.08	-0.24***	0.08
Organicgrow	-0.01	0.05	0.01	0.05
Safegrow	0.04	0.06		
Season			-0.04	0.06
Opinions about Cut flower characteristics Variables				
Color	-0.03	0.08	-0.26***	0.08
Flowerprice	0.02	0.07	0.06	0.07
Enjoy_receiveflower	0.21***	0.07	0.09	0.06
Quality	0.21***	0.08		
Satisfy_longevity	0.10*	0.06		
Knowlevel	0.01***	0.01		
Visual			0.15**	0.07
Satisfy_price			-0.07	0.05
Pricerange			0.17**	0.08
Preference for local				
Growwa	0.03	0.07	-0.04	0.06
Invocomm	0.10*	0.05		

Shoplocal			-0.08	0.06
Perceptions about imported Cut Flower in U.S market				
Answer_import	0.19	0.22	0.12	0.21
Inverse Mills Ratio	0.42*	0.22	-0.52**	0.20

*, **, *** denotes significance at the 10%, 5%, and 1% levels respectively.

CHAPTER THREE

U.S. SOUTHEASTERN PEACH GROWERS PREFERENCES FOR FRUIT QUALITY VERSUS DISEASE RESISTANCE TRAITS

1. Introduction

Consumers are increasingly demanding food products with improved health, environmental, and food safety-related attributes such as free or reduced chemical application (e.g., pesticides, fungicides, among others) (Pimentel and Burgess, 2014). At the same time, consumers' expectations for fresh fruits with superior quality, in terms of external appearance, flavor, and textural attributes, have also increased (Choi et al., 2017; Wang et al., 2017; Zheng et al., 2016). Fresh fruit growers are increasingly seeking to invest in cultivars that combine market-demanded fruit quality combined with durable resistance to major diseases (Iezzoni, 2018). Plant breeders recognize that attaining both sets of attributes, fruit quality and disease resistance, in a single cultivar is a difficult goal to achieve, at least for rosaceous crops (i.e., fruits, nuts and ornamental crops including among others, strawberries, apples, sweet cherries, roses, pears, and plums) (Iezzoni, 2018).

Typically, fresh fruit growers make the ultimate decision on production management strategies (e.g., chemical application) based on the risk of potential losses due to plagues or diseases. In addition, fresh produce growers usually receive the residual of the market price, that is, the price negotiated by the market intermediary minus the receiving, packing, storing, marketing, and other handling operations, also performed by the intermediary. In some cases, growers do not cover all variable and fixed costs (Cook et al., 2015). The fact that growers bear the marketing risk, that is, the losses when handling or when end-consumers at the retail level don't buy the product at the end, is perhaps the reason why special attention is given to consumer-oriented attributes, such as fruit flavor and textural quality.

This study is centered on the southeastern U.S. peach (*Prunus persica*) sector. This region offers an ideal case to analyze growers' preferences for both fruit quality and disease resistance. Southeastern U.S. peach growers have a location advantage over growers in California, the largest in volume peach producer in the United States, in that they are closer to the highly populated eastern U.S. markets. This enables southeastern peach growers to harvest closer to the optimal ripeness where the fruit exhibits superior flavor profiles (Zhao et al., 2017). However, the climatic conditions of the southeast, humid and rainy, triggers pest and disease incidence threatening the economic profitability of the peach operations in these regions (Zhao et al., 2017).

In light of the increasing concerns due to chemical use including fungicides, the need to protect the crop when it is produced in not so favorable climatic conditions, it is crucial for the fresh produce sector to find feasible alternatives to prevent and control diseases. Breeding programs face challenges when attempting to combine disease resistance and fruit quality (Gallardo et al., 2012; Yue et al., 2012). Host plant resistance to diseases are often found in wild species with undesirable attributes like a low concentration of sugars, high concentration of malic acid, and smaller sizes (Moing et al., 2003). Thus, breeding an improved peach cultivar that appeals to both growers and consumers, groups who sometimes have very different trait priorities, is a complex problem requiring careful assessment of breeding priorities and allocation of time and monetary resources. In this context, it would help breeders to have a better understanding of growers' preference when deciding to adopt a new cultivar, that is, the dollar value they are willing to pay for improved fruit quality and disease resistance attributes. In this study, we focus on brown rot disease, caused by the fungus *Monilinia fructicola*, because of the significant damages caused by this disease to the southeast U.S. peach crop (Schnabel, Amiri, and Brannen, 2010).

The objective of this study is to estimate growers' preferences and values for fruit quality-related attributes (i.e., size and external color) and disease resistance (i.e., brown rot). Findings from this study contribute to an improved understanding of southeastern peach growers' decision-making process when selecting a new cultivar and will be useful to breeders in their efforts to develop the ideal peach cultivar. We estimated growers' preferences and values for fresh peach considering three harvest time-windows. In this study, we use the terms early, mid, and late season to refer to the different harvest time-windows. For example, early season cultivars refer to cultivars taking 90 days from full tree flower bloom to harvest, mid-season refers to those taking 91 to 180 days from tree flower full bloom to harvest, and late season refers to those taking 180 days from tree flower full bloom to harvest (Horton et al., 2004). The harvest time-window influences fruit quality. In fact, early season peaches are usually smaller, not freestone at maturity, and have lower soluble solids and a less melting texture compared to mid and late season cultivars (Clemson Cooperative Extension, 2016). Production practices and labor costs also differ in harvest maturity classes. Early season peaches need to be thinned more heavily and ahead of the mid- and late-season cultivars, resulting in increased labor costs (Fadamiro et al., 2009; Parker, 2016). And the harvest time windows for fresh market peaches in the southeast could influence growers' perceptions of the importance of fruit quality and disease resistance (Chavez et al., 2015; Ritchie et al., 2005).

2. Literature Review

Peach growers' preferences associated with new cultivars are complex because of different periods of harvest and standards for different marketing channels (Yue et al., 2014). A number of studies focused on growers' preferences for peach horticultural and fruit quality attributes concluding that taste, external color, size, free of defects, firmness, flavor, and sweetness were important for growers' acceptance of a new cultivar (Park and Florkowski, 2003; Yue et al., 2014; Yue et al., 2017; Zhao et al., 2017).

Peach operation characteristics such as sales revenue has been found to impact the perceived importance of peach quality attributes, as operations with higher revenue sales were willing to pay more for improved firmness but less for flavor enhancement (Yue et al., 2017). Similarly, socio-demographics of the principal operators, also influence the perceived importance of fruit quality, as principal operators with higher education degrees are less sensitive to the increased costs of new peach cultivars due to licensing fees (Yue et al., 2017).

A number of studies investigated consumers' preferences for fruit quality attributes (Campbell, Mhlanga, and Lesschaeve, 2013; Delgado et al., 2013; Olmstead et al., 2015) and found that desirable peach flavor, texture, firmness and larger size, and appealing color were becoming increasingly important determinants of consumer preferences for peaches. Zhou et al. (2018) identified three market segments of U.S. peach consumers based on their preferences for attributes including external color, blemish, size, firmness, sweetness, flavor, and price. The experience attribute-oriented market segment valued fruit quality; the search attribute-oriented market segment valued fruit appearance, and the balanced market segment valued both fruit quality and appearance. Gallardo et al. (2015) elicited peach market intermediaries' preferences for fruit quality attributes and found intermediaries outside California were willing to pay a price premium for improved fruit size, sweetness, and firmness.

Different from previous studies, in this study we estimate growers' willingness to pay for fruit quality and disease resistance, when considering investing in a new cultivar. Both sets of attributes are important in the changing dynamics of consumers' preferences and tastes. This paper addresses a specific region and crop, as the response to diseases often differs according to the environmental conditions of the production area, and the particular production and marketing context of the crop within a region. Nonetheless, the approach and methodology used in this study could apply to other regions and crops.

3. Data

A list of 308 randomly selected peach growers' names and mailing addresses from North, South Carolina, and Georgia was procured from Meister Media Worldwide. The questionnaire for this study was implemented using the Total Design Method (TDM) as presented by Dillman, Smyth, and Christian (2009). On February 26, 2016, the survey package including a paper questionnaire, a cover letter explaining the survey, and a postage paid return envelope was sent to each grower. Reminder postcards were sent one week later on March 7, 2016 to all growers on the list. The second wave of surveys with replacement questionnaires was sent to growers who had not responded on April 7, 2016. Because of the low response rate, by July 2016, a final replacement surveys were mailed on July 12. Out of 308 questionnaires initially sent, 49 were returned as not eligible and 33 were returned as completed, representing a response rate of approximately 13%.

All questions asked referred to the production year 2015. We asked about growers' experiences with brown rot resistance in terms of the percentage of crop damaged and cost of control. We asked respondents to assign a score using a 0-10 scale (0=100% susceptible, 10=100% resistant) of their perceived resistance to brown rot for a list of different peach cultivars. Questions about the peach operation and the principal operator sociodemographic information were included.

To study preferences for different combinations of quality and disease resistance attributes, six discrete choice scenarios were included for each harvest time-windows (early, mid, and late season), making a total of eighteen scenarios. In each choice scenario respondents were given two alternatives that differed in the levels of fruit diameter, external fruit color, brown rot resistance score, and licensing cost (labeled as Option A and Option B). An example choice scenario can be found in Table 1. Growers were asked to choose their preferred alternative, and if neither Option A or Option B was of interest, peach growers could select Option C, which was a "neither" option. The peach cultivar attributes, their value levels, and the licensing cost of a peach cultivar in the choice scenarios were selected through consultation with peach breeders, extension educators, and growers.

For each peach harvest season, there were three levels for fruit skin color: yellow background with 50% red blush color, yellow background with 75% red blush color, and 100% red blush color. Brown rot resistance was measured in a 0-10 scale where 0 is 100% susceptible and 10 is 100% resistant to brown rot. Accordingly, three levels of brown rot resistance were included: score 0-2, 3-7, and >7. Three levels of licensing cost were included: $1, $2, and $3 /tree. Two levels of size expressed in fruit diameter were included: for early harvest peaches levels were 2.5 and 2.75 inches and for mid and late harvest peaches levels were 2.75 and 3 inches (see Table 2).

All attributes combined resulted in a total of $2 \times 3^3 = 54$ combinations, which we considered too many for an individual to reasonably evaluate. To limit the number of choices we used a fractional factorial design to choose 24 options for each of the three harvest maturity categories. To further decrease the number of scenarios presented to respondents, we created two versions of the questionnaire that differed only in the attribute combination in each choice scenario. The sample of respondents were divided into two groups, and each group randomly received one of the two versions of the questionnaire.

4. Methodology

Our empirical estimation builds on the random utility theory. We assume a grower derives utility when he/she sees his/her profits augmented. Growers' profits are a function of expected revenues derived from cultivars with improved fruit quality characteristics and expected licensing fees resulting from planting a cultivar different from the status quo. The willingness to pay (WTP) estimates in our study measure growers' willingness to invest in growing the improved cultivars. A grower would invest in a cultivar with enhanced attributes only when the perceived benefit from the improved attribute was higher than the corresponding licensing cost. For example, a grower was willing to invest in disease resistance improvement if the perceived marginal increase in revenues brought by the improvement in disease resistance was high enough to cover the marginal decrease in net income brought by the increase in the production cost due to the licensing fees. The theoretical framework of estimating grower WTP values was provided by Lusk and Hudson (2004) and Zapata and Carpio (2014). The same derivation was also used by Gallardo et al. (2015).

We use the mixed logit model for estimation, due to its advantages over other approaches including its relaxation of the independence of irrelevant alternatives (IIA) assumption, and its ability to model preference heterogeneity across respondents. Suppose the profit in each harvest time-window *s* (*s* = early, mid, and late season) for a grower *i* (*i* = 1, 2,..., N) choosing alternative *j* (*j* =1, 2,..., M) is given by:

$$\Pi_{ijs} = \alpha_s + \beta x_{js} + \gamma z_i + \varepsilon_{ijs} \quad (1)$$

where x_{js} depicts the peach attributes including diameter, external fruit color, brown rot resistance, and licensing cost, presented in each alternative *j* and for each harvest season *s*; z_i are sociodemographic variables related to individual *i*. β is the marginal utility of each quality attribute, a vector of random parameters with an estimated mean u_i and standard deviation σ. γ represents the effects of the individuals' sociodemographic variable on the marginal utility. α_{ij} is the alternative specific constant (ASC) which captures the effect of choosing to grow a peach cultivar (Option A or Option B) in contrast to the 'Neither A or B' option.[4] The 'Neither A or B' option resemble an actual grow decision, which ensure that the respondents were never forced to grow the new peach cultivar. Therefore, the utility in Option C (Neither A or B Option) was normalized to zero, and, the all attributes variable value for Option C were coded as 0. Since the fruit diameter variable was described using numerical values in the choice scenarios, these values were used for the estimation. Color and brown rot resistance were qualitative variables, each with three levels. Binary variables were created for each of the levels for these variables, with one level serving as the base and was omitted from the estimation (to avoid the dummy variable trap). The base level for external color was 50% red blush color and for brown rot resistance a score of 0-2.

We assume that $f(\beta_i|\Omega)$ is the density function of β_i with $\Omega = N(u_i, \sigma^2)$, and ε_{ijs} is a stochastic iid extreme value error term that varies over individuals, alternatives, and choices with an expected value of zero, and captures the unobservable effect of individual and alternative attributes. The conditional probability for grower *i* to choose alternative *j* in marketing season *s* can be expressed as:

$$L_i(Y_i = j|\beta_i) = \frac{\exp(\alpha_{ij}+\beta_i x_{js}+\gamma z_{is})}{\sum_{k\in M}\exp(\alpha_{ik}+\beta_i x_{js}+\gamma z_{is})} \qquad j \neq k \tag{2}$$

[4] Since A or B label for each peach cultivar is random and not attached to a known cultivar in our discrete choice experiment, we didn't use ASC for each peach cultivar. W used a dummy variable to distinguish the "grow" option (Option A or Option B) from the "don't grow" (Option C) to capture the preferences' heterogeneity for peach cultivars.

When β_i is known, the IIA assumption holds, resulting in the standard logit model. When β_i is not known, the unconditional choice probability is the integral product of $P_i(\beta_i)$ over all values of β_i:

$$P_i(Y_i = j) = \int L_i(Y_i = j|\beta_i)\ f(\beta|\Omega)d\beta \qquad (3)$$

The above choice probability cannot be calculated analytically, and consistent with other studies, it was solved through simulations (Train, 2009). A mixed logit model allows the random components of the alternatives by relaxing the IIA assumption, and here random preference heterogeneity is expected in response to the peach attributes. Therefore, each model is a mixed logit model with random parameters for all peach attributes (fruit diameter, external fruit color, and brown rot resistance). The cost coefficient is assumed fixed to ensure that all respondents have a negative cost coefficient so that the estimated WTP will be normally distributed (Revelt and Train, 1998).

The WTP for a unit level change of a given attribute for a peach cultivar in each peach season is the marginal rate of substitution between the cultivar attribute levels and the licensing cost. Since the peach grower’s profit function was a linear function of peach cultivar attributes, the WTP was simply the ratio between estimated parameters for the attribute and licensing cost. To calculate the standard deviation of each WTP we used the method by Krinsky and Robb (1986) which involved 1000 random draws from a normal distribution and 1000 simulated WTP to calculate the standard error. Since the actual diameter in inches was used in estimation but the choice options only considered 0.25 inch differences, after estimation the WTP values were rescaled to put them relative to the more realistic 0.25 inch diameter changes.

We conducted pairwise t-tests to determine whether the WTPs for peach cultivars differed significantly across the three harvest seasons. Also, the relative ratios between select peach attributes were calculated: peach diameter to brown rot disease resistance, peach diameter to peach color, and brown rot disease resistance to peach color. Specifically, the ratio of peach diameter to brown rot disease resistance was calculated as the average of all growers' ratios and each grower ratio was equal to each grower β_i coefficient for peach diameter divided by his/her β_i coefficient for brown rot disease resistance.

5. Results and Discussion

Data from 32 respondents were available for analysis after one response was dropped because of incomplete information. Of these, 13 peach operations were located in North Carolina, 9 in South Carolina, and the remaining 10 in Georgia (see Table 3). The size of these operations ranged from less than 5 acres to more than 1,000 acres. The average operation size was 11.26 acres in North Carolina, 207.11 acres in South Carolina and 275.15 acres in Georgia. And 29 respondents indicated that they harvested their leading acreage peach cultivar during mid-season or late season. Half of the respondents reported gross income from peach operation greater than $25,000. Also, on average 27.8% of household income was from peach production, and 48.6% of peach acreage was covered by crop insurance. On a 1-10 scale (1= unwilling to take the risk, 10 = very prepared to take the risk), respondents' risk-taking attitude averaged 6.7. The number of years in peach business for the operation's principal operator ranged from no experience to 50 years, with a mean of 19.5 years, as of 2015. Thirty-one out of the 32 peach growers were Caucasian, and, fifty percent had a four-year college degree or higher-level education.

When asked about experiences in controlling for brown rot disease 23% of the respondents indicated they had experienced crop loss due to brown rot in 2015 (see Table 4). On average, respondents reported expenses in 2015 of $140.5/acre to control brown rot, which was

6% of total variable costs. When asked about new cultivars planted in 2015, 45% of respondents indicated they planted a new cultivar, and 69% of those planting a new cultivar reported it was patented. On average, in 2015, 11.6 acres were planted to a new patented cultivar to the grower who planted new cultivars.

Growers were asked about their perceptions of the resistance to brown rot for the cultivar with the leading acres in their peach operation in 2015 and for other familiar varieties (see Table 5), using a 0-10 scale (0=100% brown rot susceptible and 10=100% brown rot resistance). The results indicated that the perceived resistance of ‘Contender’, the cultivar identified as having the greatest percentage of acreage in the peach farm by the greatest number of growers (n=5) was 7; for the next cultivar, Redhaven (n=3), resistance was 2.7; Harvester (n=2), 7; Big red (n=2), 8; and Gloria (n=2), 9. Cultivars with the leading acreage (for each respondent) were perceived as having a higher resistance to brown rot (6.75 on average) compared to other cultivars respondents were familiar with (5.64 on average).

The mixed logit model results for the three harvest time-seasons: early, mid, and late, are presented in Table 6. The grow alternative specific constants were all statistically significant and negative for all three seasons, indicating growers derive lower utility when they grow a peach cultivar as presented in alternatives A and B than when they do not. Mean parameter estimates for peach diameter were consistently positive and statistically significant across early, mid, and late season, indicating that growers would derive higher utility from investing in peach cultivars with the enhancement of fruit size across three harvest seasons. This is consistent with findings in Yue et al. (2017), Zhao et al. (2017), and Gallardo et al. (2015), suggesting that in general U.S. peach growers prefer larger fruit sizes compared to smaller sizes. The current U.S. Grade for peaches does not include an explicit size criterion for the grade level but requires all tray packs to include information on the numeric count (of peaches) in the tray or the minimum diameter of the smallest fruit (USDA AMS, 2018). This information is used by the market intermediaries in the pricing scheme to pay peach growers for higher for larger fruit size (Gallardo et al., 2015).

Differences were observed among the mean parameter estimates for color across the three harvest seasons. Relative to 50% red blush external color, the coefficient for 75% red blush external color was positive and statistically significant for early and mid-season peaches, and the coefficient for 100% red blush external color was positive and statistically significant for early season peaches only. None of the parameter estimates related to 75% and 100% red blush external color were statistically different compared to 50% red blush color for late season peaches, suggesting that growers have different preferences for external color across harvest seasons.

Mean parameter estimates for resistance to brown rot rating scores (> 7) were all positive and statistically significant, compared to 0-2 scores. Recall, the resistance score is measured in a 0-10 scale where 0 is 100% susceptible and 10 is 100% resistant to brown rot; therefore a 0-2 score is the lowest resistance and >7 score is the highest. Mean parameter estimates for resistance to brown rot rating scores (3-7) were positive and statistically significant only for early season peaches, compared to 0-2 scores. This result indicates that in general growers would be more interested in investing in new peach cultivars exhibiting the largest improvements in disease resistance compared to cultivars exhibiting improvements of smaller magnitudes. Mean parameter estimates for licensing costs were all negative and statistically significant for the utility derived from investing in peach cultivars for all harvest seasons.

The standard deviation parameter estimates for all attributes were statistically significant except for middle disease resistance score for the three season peaches, 75% red blush external color for late season peaches, and high disease resistance score for the mid season peaches, indicating heterogeneity in preferences across respondents.

Willingness to pay (WTP) for attributes with statistically significant mean parameters are reported (Table 7). The attribute with the highest WTP was brown rot resistance improvement, followed by fruit size improvement and fruit color improvement across the three harvest seasons. Growers were willing to pay a licensing fee of $2.54 /tree for peach trees with improved brown rot resistance scores if the scores increased from 0-2 (low resistance) to a resistance score 3-7 (middle resistance). Similarly growers are willing to pay across the three seasons a range going from $1.96 /tree to $3.92 /tree for an improvement in disease resistance from 0-2 to >7. For the early season peach cultivars, WTP for improvement from low resistance score to high resistance score is higher than the WTP for improvement from low resistance score to middle resistance score.

The WTP for improvements in fruit size varied across harvest seasons: the highest was for late season ($1.89/tree to improve size from 2.75 to 3 inches diameter), followed by early season ($1.83/tree to improve size from 2.5 to 2.75 inches) and mid-season ($1.43/tree to improve size from 2.75 to 3 inches). The WTP for a 25% increment in the red blush of the external color relative to the baseline that was 50% red blush was $1.83/tree for early season, $1.43/tree for mid season and $1.89/tree for late season peach cultivars.

The WTP results suggest that peach growers responding to this survey assign higher values for a significant improvement in diseases resistance (from 0-2 low to > 7 high) compare to mild disease resistance improvement (from 0-2 low to 3-7 mid) and fruit quality attributes such as size and color.

Paired t-tests for WTP of selected attributes across harvest maturity categories (Table 8) indicate that WTP for size improvement was statistically different across early, mid, and late season peach cultivars. The WTP for 25% external color improvement (relative to 50% external color) was also statistically different between early and mid-season peach cultivars. Also, the WTP for the improvement from low resistance score to high resistance score were statistically different between early and mid-season peach cultivars as well as early and late season peach cultivars. There was no statistically difference on WTP for disease resistance score improvement from low score to high score between mid and late season peach cultivar. Our findings on the differences in willingness to pay for different fruit quality and disease resistance scores across harvest seasons are consistent with previous studies in that extended harvest season was a desirable trait for cultivars to be developed, given that the early season fruit enjoys price premiums (compared mid and late season), given the lack of competition from other peach producing states (Fallahi et al., 2009; Reginato, de Cortázar, and Robinson, 2007). Nonetheless mid and late harvest season peach cultivar could favor the development of regional markets (Byrne, 2005).

To estimate how much of the attribute size and external color peach growers were willing to give up in order to improve disease resistance, we calculated relative ratios across coefficients (see Table 9). If the ratio is close to 1, then growers are indifferent across improvements in disease resistance, size, or external color. Ratios are greater than 1 signal that peach growers would be willing to give up more of either fruit size or skin color to improve disease resistance signaling that, an improvement in disease resistance is considered more important than improvements in size or external color. If the ratio is less than 1, this indicates that peach growers are willing to give up less of size or external color, and improvements in disease resistance are less important than improvements in size or external color. The relative ratio between brown rot high resistance score improvement and 0.25 inch peach diameter increment was 1.72 for early-season peaches, 1.45 for mid-season peaches, and 1.33 for late season peaches. Our results suggest that growers considered improvements in disease resistance more important than improvements in fruit size in all seasons. The relative ratio between brown rot resistance high score and peach skin color for 75% red blush was 3.42 for early season versus 8.46 for mid-season, indicating growers considered improvements in higher disease resistance more important than improvements in external color. Moreover, the relative ratio between a brown rot resistance middle score and peach skin color for 75% red blush was 2.18 for early-season. This ratio was lower than the one with a disease resistance high score, suggesting growers considered improvements in higher disease resistance more important than 25% improvements in external peach color. In addition, the relative ratio between disease resistance high/middle score and 100% external color were less than one, suggesting that 100% external red blush color improvement was more important than improvement of disease resistance score.

6. Conclusion

Differences in the WTP values for each attribute and in the relative importance of disease resistance versus size and external color across seasons underscore the importance of the harvest season for grower decision-making. Also, the information about WTP for peach attribute with higher disease resistance can assist peach breeders and extension educators in their efforts to reduce the amount of pesticide and fungicide use in peach production in the future. In addition, the preference for peach quality attribute (e.g., size and color) suggested the importance of better and consistent quality for new peach cultivars to be developed.

Consumers' preferences for superior quality, in terms of appearance, taste and texture attributes, and safety, health, environmental-related attributes such as reduced chemical application are becoming more important. Plant breeding programs often find it challenging to develop improved cultivars with the optimal combination of attributes to meet the expectations of all supply chain members. In this study, we estimated the WTP for fruit quality and disease resistance attributes for southeastern U.S. peach growers. This specific industry sector presents an interesting case, as growers need to produce cultivars exhibiting superior fruit quality in a humid and rainy environment conducive to the proliferation of pests and diseases. Growers' decisions are specific to the production and marketing context they face. Consequently, we adapted our study to such conditions by eliciting WTP considering cultivars with three different harvest time windows (early, mid, and late season).

For peaches harvested in early season growers stated they were willing to pay higher premiums for peaches with higher resistance to brown rot and but lower premiums for peaches with larger size and a higher percentage of red blush color. Similar results were found for disease resistance, fruit size and external color for peaches harvested in the mid and late harvest seasons except that the WTP values for peaches harvested in mid-season are lower compared to peaches harvested in early and late season.

Peach growers in the U.S. face multiple challenges, including high start-up and labor costs, temperature sensitivities and other weather risks which are intensifying with climate change, disease control, environmental considerations linked to pesticide use, and a decline in consumer demand (Crassweller, Kime, and Harper, 2016). To improve the sustainability of southeastern U.S. peach market, the results from this study could contribute to developing objectives for breeding programs to breed new cultivars to help growers remain profitable producing peaches for the fresh market. Previous studies have evaluated growers' preferences for fruit quality attributes, but few have evaluated preference tradeoffs for fruit quality attributes versus disease resistance. Findings in our study are limited to a crop within a region, and specific numbers might not be generalizable. However, our focus on preferences for attributes that are impacted by both production and marketing conditions our study is valuable for other researchers focused on growers' decision making when deciding to invest in improved cultivars.

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Table 1. Example of a peach cultivar choice scenario.

Peach features	Option A	Option B	Option C:
Fruit diameter (inches)	2.75 inches	2.5 inches	Neither Option A nor B
External fruit color	Yellow background with 75% red blush color	Yellow background with 50% red blush color	
Brown rot resistance score where: 0=100% susceptible 10=100% resistant	Score: 3 – 7	Score: Greater than 7	
Licensing cost – one-time fee ($/tree)	$2	$1	
Which option would You choose?	☐	☐	☐

Table 2. Attribute levels for peach cultivar choice scenarios.

Cultivar Attributes	Level 1	Level 2	Level 3
Peach diameter (inches)	2.5 inches	2.75 inches	3 inches
External fruit color	Yellow background with 50% red blush color	Yellow background with 75% red blush color	100% red blush color
Brown rot resistance score where: 0=100% susceptible 10=100% resistant	0-2	3-7	> 7
Licensing cost – one-time fee ($/tree)	$1	$2	$3

Table 3. Summary statistics of southeastern U.S. peach growers (N=32).

Farm location	
North Carolina state: N=13	Weighted mean =11.26 acres
South Carolina state: N=9	Weighted mean =207.11 acres
Georgia state: N=10	Weighted mean =275.15 acres
Harvest season for cultivar with the largest percentage of acres	
Early season: N=2	
Mid-season: N=10	
Late season: N=19	
Total acres of peaches own or manage	
<5 acres	25.00%
5-14 acres	25.00%
15-24 acres	9.38%
25-49 acres	15.63%
50-99 acres	6.25%
100-249 acres	9.38%
250-499 acres	0.00%
500-1,000 acres	3.13%
> 1,000 acres	6.25%
	Weighted mean=148.86
Gross income from all of peach crop	
< $25,000	50.00%
$25,001-$49,999	12.50%
$50,000-$74,999	6.25%
$75,000-$99,999	0.00%
$100,000-$249,999	15.63%
$250,000-$499,999	3.13%
$500,000-$999,999	3.13%
$1,000,000-$2,499,998	3.13%

More than $2,500,000	6.25%
	Weighted mean=$319,694
Percentage of gross income from Farm	
0%	12.50%
1-25%	56.25%
26-50%	12.50%
51-75%	3.13%
76-99%	12.50%
100%	3.13%
	Weighted mean=27.82%
Percentage of peach acreage was covered under a crop insurance	
	Mean=48.58%, std=47.36
Risk attitude (0-10, 1 =“unwilling to take risk” and 10=“very prepared to take risk)	
	Mean=6.72, std=2.20
Years in peach production as decision maker	
	Mean=19.53, std=13.25
Education level is above four-year college	
	Mean=0.50, std=0.43
Respondents being Caucasian or white	
	Mean=0.96, std=0.02

Table 4. Summary statistics of southeastern U.S. peach growers on experiences with brown rot and viewpoints on planting a new cultivar.

Experience for crop loss due to brown rot (N=32)	
	Yes response %=23.33%
Cost spend managing root and crown rot diseases (N=29)	
$0 - $50 /acre	27.59%
$51 - $100 /acre	31.03%
$101 - $200 /acre	10.34%
$201 - $300 /acre	17.24%
$301 - $400 /acre	10.34%
$401 - $500 /acre	3.45%
More than $500/acre	0.00%
	Weighted mean=$140.5
Variable production cost (include operating, harvesting, and pacing costs) (N=29)	
$0-$2,000/acre	51.72%
$2,001-$3,000/acre	24.14%
$3,001-$4,000/acre	13.79%
$4,001-$5,000/acre	0.00%
$5,001-$6,000/acre	3.45%
$6,001-$7,000/acre	3.45%
$7,001-$8,000/acre	3.45%
$8,001-$9,000/acre	0.00%
$9,001-$10,000/acre	0.00%
More than $10,000/acre	0.00%
	Weighted mean=$2,276.1
In 2015, did you plant new cultivars (N=31)	
	Yes response %=45.16%
Did you pay a fee (per tree/acre/box of fruit sold) to grow this new cultivar (N=13)	
	Yes response %=69.23%

How many acres of this patented new peach cultivar were planted (N=11)
Mean=11.55, std=12.54

Table 5. Summary statistics of the scores in a 0-10 scale (0=100% susceptible, 10=100% resistant) given by southeastern U.S. peach growers on the perceived resistance to brown rot of different peach cultivars.

Cultivar with largest acreage	Average perceived brown rot resistance	**Familiar cultivars**	Average perceived brown rot resistance
Contender (N=5)	7	Caro Red (N=16)	6.31
Redhaven (N=3)	2.67	Rubyprince (N=17)	6
Harvester (N=2)	7	Coronet (N=14)	5.07
Big Red (N=2)	8	Harvester (N=15)	5.8
Gloria (N=2)	9	Blazeprince (N=14)	6.07
Winblo (N=2)	8	Scarletprince (N=14)	6.79
Red Globe (N=2)	6	Summer Lady (N=11)	4.72
Loring (N=2)	6.5	O'Henry (N=18)	5.11
Red Skin (N=1)	5	Big Red (N=20)	5.75
Victoria (N=1)	6	Autumnprince (N=15)	4.6
Flaking (N=1)	7		
Harrow Diamond (N=1)	5		
Ruby Prince (N=1)	8		
Late Monroe (N=1)	5		
New Haven (N=1)	9		
July Prince (N=1)	8		
Scarlet Prime (N=1)	9		
Gulf Crimson (N=1)	9		
Gulf King (N=1)	4		
O'Henry (N=1)	9		
Average	6.75		5.64

Table 6. Mixed logit estimates by southeastern U.S. peach growers

	Season		
	Early	Mid	Late
Random parameters – means			
Peach diameter	7.04***[a]	6.09***	5.01**
	(2.02)[b]	(2.18)	(2.15)
Brown rot resistance score: 3-7	2.45***	0.82	-0.04
	(0.68)	(0.65)	(0.26)
Brown rot resistance score: >7	3.78***	2.09***	1.59***
	(0.80)	(0.77)	(0.43)
External color: 75% red blush color	1.45**	1.15**	0.46
	(0.58)	(0.51)	(0.28)
External color: 100% red blush color	1.77*	-0.05	-0.44
	(0.97)	(0.65)	(0.49)
Random parameters – standard deviation			
Peach diameter	3.28***	1.18***	1.84***
	(1.21)	(0.38)	(0.59)
Brown rot resistance score: 3-7	0.11	0.13	0.49
	(0.74)	(0.35)	(0.43)
Brown rot resistance score: >7	1.13*	0.52	1.02*
	(0.67)	(0.53)	(0.59)
External color: 75% red blush color	1.56***	1.77***	0.53
	(0.51)	(0.64)	(0.38)
External color: 100% red blush color	2.79	2.12**	1.32***
	(1.76)	(0.88)	(0.43)
Fixed parameters			
ASC_grow option	-12.51**	-12.26**	-10.84*
	(5.29)	(5.26)	(5.61)
Licensing cost	-0.96**	-1.07***	-0.66*
	(0.38)	(0.41)	(0.39)
Number of observations	483	486	504
Log Likelihood	-99.33	-103.34	-106.82

[a] *, **, *** denotes significance at the 10%, 5%, and 1% levels respectively.
[b] Standard error in parentheses.

Table 7. Willingness to pay for selected attributes of three harvest time windows of peach cultivars.

Attributes	Willingness to pay ($/tree) [95% confidence interval]		
	Early season	Mid season	Late season
Peach diameter (0.25 inch increments)	1.83 [0.95, 4.26]	1.43 [0.84, 2.57]	1.89 [0.65, 6.96]
Brown rot resistance score from 0-2 to 3-7	2.54 [1.26, 6.65]	_	_
Brown rot resistance score from 0-2 to >7	3.92 [2.05, 11.37]	1.96 [0.36, 8.06]	2.38 [0.36, 15.96]
External color: from 50% red blush color to 75%	1.50 [0.39, 3.61]	1.08 [0.16, 2.84]	_
External color: from 50% red blush color to 100%	1.83 [0.38, 5.04]	_	_

Table 8. Paired t-tests for willingness to pay for selected attributes of three harvest time windows of peach cultivars. (N=1000)[a].

Pairwise comparison	t-value
Early season vs. mid season	
Peach diameter	8.78*** [b]
Resistance to brown rot score: >7	6.03***
External color: 75% red blush color	3.01***
Early season vs. late season	
Peach diameter	1.99**
Resistance to brown rot score: >7	7.18***
Mid-season vs. late season	
Peach diameter	-4.99***
Resistance to brown rot score: >7	0.51

[a] N=1000 is the number of WTPs from bootstrapping sample.

[b] *, **, *** denotes significance at the 10%, 5%, and 1% levels respectively.

Table 9. Relative coefficient ratios between different peach attributes.

	Relative ratio
	Early season
Resistance to brown rot score: 3-7 vs. Peach diameter	2.71
Resistance to brown rot score: >7 vs. Peach diameter	1.72
Resistance to brown rot score: 3-7 vs. External color: 75% red blush color	2.18
Resistance to brown rot score: 3-7 vs. External color: 100% red blush color	0.45
Resistance to brown rot score: >7 vs. External color: 75% red blush color	3.42
Resistance to brown rot score: >7 vs. External color: 100% red blush color	0.78
Resistance to brown rot score: >7 vs. Resistance to brown rot score: 3-7	1.59
	Mid season
Resistance to brown rot score: >7 vs. Peach diameter	1.45
Resistance to brown rot score: >7 vs. External color: 75% red blush color	8.46
	Late season
Resistance to brown rot score: >7 vs. Peach diameter	1.33

Notes: the ratio is equal to the first attribute coefficient divided by the second attribute coefficient.

CHAPTER FOUR

GROWERS' PREFERENCE FOR FRUIT QUALITY VERSUS DISEASE RESISTANCE AND WELFARE IMPLICATIONS OF ADOPTION OF CULTIVARS WITH SUPERIOR DISEASE RESISTANCE: THE CASE OF FLORIDA STRAWBERRY GROWERS

1. Introduction

In the context of farming, an improved plant cultivar is a demand-driven innovation as it responds directly to farming problems perceived and recognized by growers (Pannell and Zilberman, 2001). Disease and pest recurrence in farming is an unavoidable reality and in order to guarantee the farm operation survival -and to ensure a consistent food supply- chemical treatment has become the norm. However, chemical application is not seen by society as a positive practice given the potential health effects to consumers, and the related adverse effects to the environment and farm workers. In fact, literature suggests that consumers are willing to pay price premiums for pesticide-free fruits and vegetables (Boccaletti and Nardella, 2000; Florax et al., 2005; Onozaka et al., 2006).

Farming, in special in subtropical climates, is challenged by the recurrence of diseases. Such is the case of the Florida strawberry (*Fragaria ananassa*) industry and the root and crown rot disease caused by *Phytophthora cactorum, Colletotrichum spp., or Macrophomina phaseolina* (Ivors and DeVetter, 2015). Strawberry farming in Florida provides a unique case to analyze growers' decision making when adopting a new cultivar, given its specific market conditions and a production environment favorable to the recurrence of diseases. Florida is the second largest strawberry producing state in the United States, second only to California. In 2017, the strawberry farm gate value in Florida was at $337 million (USDA NASS, 2018b). In the United States, the strawberry industry, is economically important to a number of rural communities. As of 2017, the two largest strawberry producing states were California and Florida, accounting for 91.3% and 7.5% of the total volume of U.S. production, respectively (USDA NASS, 2018b). The total value of the U.S. crop in 2017 was $3.49 billion, with 94.6% from fresh strawberries, and 5.4% from processed strawberries (USDA NASS, 2018b). Between

2007-2017, the volume of strawberries produced in the United States increased by 23.5%, from 24.45 million cwt in 2007 to 31.95 million cwt in 2017 (USDA NASS, 2017a; 2018b). Mirroring this increase, per capita domestic consumption of strawberries increased by 28%, from 6.1 pounds in 2006 to 8 pounds in 2016 (USDA ERS, 2018).

Management of the root and crown rot disease usually involves the application of fumigants such as methyl bromide (Ivors and DeVetter, 2015; Rosskopf et al., 2005; Schneider et al., 2003). In 2005, the Federal Clean Air Act was passed, forbidding the production and import of methyl bromide due to damages to the ozone layer (US EPA, 2018). While the California strawberry industry qualified for a critical use exemption from the methyl bromide ban until 2016, the Florida strawberry industry did not qualify for such exemption and its use has been banned since 2009 (US EPA, 2018). By 2015, Florida had nearly completed the phase out of methyl bromide for soil fumigation purposes, eliminating a highly effective method to control for root and crown rot disease (Noling, 2016). With less effective alternative fumigants to control for root and crown rot disease, growing cultivars that are resistant to this disease appear as a promising alternative (Mangandi, Peres, and Whitaker, 2015). In this context, when deciding to plant a new strawberry cultivar, growers must balance consumer traits such as fruit quality and production traits such as disease resistance to optimize their returns on investment.

The objective of this paper is twofold. The first, is to investigate strawberry growers' preferences and willingness to pay for selected fruit quality attributes and plant resistance to root and crown rot disease. This information will help guide breeding programs in developing cultivars with trait combinations of significant value to their clientele. It will also help strawberry growers and industry to make informed decisions when adopting new cultivars. The second objective of this paper is to assess the welfare impact of the incidence of the plant disease root and crown rot, in view of the phase-out of a fumigant. This information could help the industry and policy makers understand the economic impact of disease incidence and design strategies to invest in research and development of disease resistant cultivars in light of consumers general preferences for less chemical applications to their food supply.

2. Literature Review

Several studies focused on consumers' preferences for strawberry quality attributes conclude that quality attributes sweetness, freshness, texture, fruit size, and color are determinant of preferences (Bhat et al., 2015; Colquhoun et al., 2012;). Colquhoun et al. (2012) surveyed U.S. strawberry consumers and concluded that the ideal strawberry was sweet, firm with a smooth internal texture flavor. Wang et al. (2016) conducted a latent class segmentation on U.S. strawberry consumers and identified three segments of consumers, referred to as search attribute sensitive consumers, experience attribute sensitive consumers, and balanced consumers. In general, consumers in all segments favored internal color, flavor, and shelf life. These attributes are also important for market intermediaries. Gallardo et al. (2015) surveyed U.S. strawberry packing and shipping operations and found these entities concur with consumers in prioritizing quality attributes such as sweetness, freshness, texture, fruit size, and color.

A number of studies have investigated consumers' preferences for credence attributes in fresh fruits such as organic, fumigant/pesticide-free, environmentally sustainable, and locally grown (Carroll, Bernard, and Pesek, 2013; Moser, Raffaelli, and Thilmany-McFadden, 2011; Yue and Tong, 2009). Studies specifically exploring consumer preferences for pesticide-free attributes in fresh fruits suggest that consumers are willing to pay a premium for pesticide-free fruits because of the perceived personal benefits from avoiding chemicals in their food (Boccaletti and Nardella, 2000; Onozaka, Bunch, and Larson, 2006). Loureiro, McCluskey, and

Mittelhammer (2001) found that consumers who had stronger environmental attitudes were more likely to buy eco-labeled apples that were produced by reducing pesticide application frequency. Ruth, Rumble, and Settle (2016) investigated Florida consumers' preferences for Florida-grown strawberries and found that more than 80% of consumers purchased Florida-grown strawberries because of perceived freshness and to support the Florida economy. These studies suggest that a new strawberry cultivar with improved disease resistance and improved fruit quality would help Florida strawberry growers stay competitive in the market.

Few studies have investigated growers' preferences for fruit quality attributes compared to disease resistance. Yue et al. (2014) found that strawberry growers ranked more important to quality attributes such as fruit firmness, flavor, and shelf life compared to root rot resistance. The attribute ranking varied by the growing state. Florida strawberry growers ranked fruit firmness as more important compared to California growers. Florida growers ranked fruit flavor as less important compared to growers in Michigan and Oregon. In a different study, Yue et al. (2017) found that strawberry growers were willing to pay premiums for strawberry cultivars with improved external color, size, firmness, flavor, internal color, or shelf life. Also, Yue et al. (2017) found that larger-scale strawberry growers were more sensitive than small-scale growers to the cost increase of new strawberry cultivars.

A number of studies suggest that models for the decision to invest in a new cultivar need to control for growers' heterogeneous preferences (Birol, Villalba, and Smale, 2009; Zhao et al., 2017). Choi et al. (2017) identified strawberry growers' heterogeneous preferences for strawberry cultivars associated with quality attribute color, firmness, flavor, and shelf life; however, disease resistance was not included. Other studies (Yue et al., 2014; Yue et al., 2017) identified strawberry growers' preferences for fruit attributes when selecting a new cultivar, but most do not allow for heterogeneous preferences for both quality attributes and disease resistance.

Also, the total effects of strawberry disease control include direct effects such as crop loss due to the disease and indirect market effects such as reduced fruit quality and public welfare due to environmental concerns (Peres, Seijo, and Turechek, 2010). Empirical studies suggest that disease outbreaks generally imply a considerable social welfare loss for the fresh fruit industry (Kwon et al., 2015). As growers attempt to differentiate their produce with high fruit quality and low fumigant application levels in response to the dynamic strawberry demand and facing disease challenges, a promising alternative is breeding of cultivars with superior quality and disease resistance, appealing to both consumers and growers.

Concerning breeding programs, the literature suggests that resource limitation and perceived lack of consensus between grower and consumer needs were challenges faced by a number of rosaceous breeding programs (Gallardo et al., 2012; Yue et al., 2012). Specific to strawberry breeding programs, Gallardo et al. (2012) found that the top five important traits clusters selected by strawberry breeders were post-harvest quality, yield, texture, flavor, and appearance. The likelihood of selecting for resistance to disease traits was higher than selecting for abiotic stress resistance, yield, post-harvest quality, and phytonutrient content but lower than selecting for texture, flavor, and appearance. Yue et al. (2012) concluded that strawberry breeders were more challenged by time limitations of senior investigator but less challenged by the availability of genetic material, trait heritability, genetic variation, and lack of facilities when implementing traits priorities compared to other breeding programs.

This study will add to the existing literature on fresh produce growers' preferences and values and the tradeoffs they make among various attributes associated with quality attributes and disease resistance. Also, this study examined the welfare effects of strawberry crop loss due to root and crown disease after the methyl bromide phase-out. This study is focused on Florida strawberry growers, but the methodology are applicable to the more general population of specialty crop growers across the United States.

3. Data

We procured a random sample of 400 Florida strawberry growers, including their names and mailing addresses, from Meister Media Worldwide. The questionnaire distribution strategy followed the Total Design Method (TDM) (Dillman, Smyth, and Christian, 2009). A mixed mode survey was implemented, specifically including online and paper versions of the questionnaire. During the third week of October 2016, researchers distributed a survey package including a printed paper questionnaire, a postage paid return envelope, a $1 pre-incentive, and a cover letter explaining the study and how to access the survey online if the respondent opted for the online version. Reminder postcards were sent one week later to the non-respondents. A second wave of surveys with replacement questionnaires was sent to growers who had not responded by the second week of November 2016. Because of the low response rate, reminder phone calls were made to non-respondents during the last week of January 2017. Out of 400 questionnaires initially mailed, 189 of the respondents were identified as not eligible because the grower did not grow strawberries in 2015-2016. Out of the 211 respondents remaining, 31 questionnaires were returned as completed, for a response rate of 14.7%. To increase the response rate, in March 2017, a second-round open access survey was made public in the Florida Strawberry Growers Association website, in cooperation with the University of Florida breeding program. We received six more completed questionnaires from this last effort. In sum, the total number of completed questionnaires was 37, with 22 paper and 15 online.

The questionnaire requested information related the production marketing year of 2015, and included questions about strawberry growers' choices of cultivars, experiences with root and crown rot disease, perceptions on resistance to root and crown rot disease and flavor as well as root and crown rot disease caused crop loss percentage for cultivars including Sweet Sensation® and 'Florida Radiance' and others, choice experiment questions on preferences for improved cultivars, socio-demographic information on the principal operator, and general farm characteristics. For the choice experiments, each respondent was presented with eight choice scenarios with different combinations of strawberry attributes, including flavor, size, transplant cost, and disease resistance attributes. In each choice scenario, strawberry growers were given two alternatives that differed by the levels of fruit size, flavor, a percentage of plant loss from root and crown rot disease prior to first harvest, and transplant plus royalty cost (labeled as Option A and Option B). An example of a choice scenario can be found in Table 1. Growers were asked to select their preferred alternative, and if neither option A nor option B was of interest, strawberry growers could choose Option C, which is a "neither" option. The strawberry cultivar attributes, the attributes value levels, and the transplant plus royalty cost in the choice scenarios were obtained through consultation with strawberry breeders, extension educators, industry representatives, and growers. The detailed attributes levels for choice scenarios can be found in Table 2. There were three levels for fruit size, flavor, percentage of plant loss from root and crown rot disease, and transplant plus royalty cost. This resulted in a total of $3^4 = 81$ possible combinations. To limit the number of choices we used a fractional factorial design and ended with 16 random combinations.

4. Methodology

4.1. Grower preference and willingness to pay to strawberry fruit quality and plant attributes

Based on Lancaster’s model of consumer choice (Lancaster, 1966), consumers derive utility from the attributes of goods. We assume a strawberry grower derives utility when she sees her profits augmented, where growers’ profits are a function of expected revenues derived from strawberry cultivars with improved fruit quality characteristics and expected costs resulting from planting a new cultivar. We use the choice experiment approach because it includes an econometric basis in models of random utility (McFadden, 1986). According to McFadden (1986), random utility theory is defined by a deterministic (V_{ijt}) and a stochastic (ε_{ijt}) component.

$$\mathrm{U_{ijt}} = V_{ijt} + \varepsilon_{\mathrm{ijt}} \tag{1}$$

where $\mathrm{U_{ijt}}$ is the utility grower *i* (*i* = 1, 2,..., N) choosing alternative *j* (*j* =1, 2,..., M) in a choice scenario *t* (t = 1, 2,..., T), V_{ijt} is the non-stochastic portion determined by new strawberry cultivar attributes and their value levels, and ε_{ijt} is extreme error term that is identically and independent distributed. The probability that grower *i* choose alternative *j* in a choice scenario *t* is given by:

$$\mathrm{Prob}\left(V_{ijt} + \varepsilon_{\mathrm{ijt}} > V_{ikt} + \varepsilon_{\mathrm{ikt}}\right), \text{where } k \neq j, k, j = 1,2, \dots, M$$

$$= \mathrm{Prob}(\delta_{\mathrm{ij}} + \theta_{\mathrm{i}}\mathrm{x_{ijt}} + \gamma \mathrm{z_{it}} + \varepsilon_{\mathrm{ijt}} > \delta_{\mathrm{ij}}{}' + \theta_{\mathrm{i}}{}'\mathrm{x_{ikt}} + \gamma' \mathrm{z_{it}} + \varepsilon_{\mathrm{ikt}}) \tag{2}$$

where δ_{ij} is the alternative specific constant (ASC) which captures the effect of choosing to grow a new strawberry cultivar (option A or option B) in contrast to the 'do not grow' option; $\mathrm{x_{ijt}}$ are the observed strawberry attributes variables relating to individual *i*, and $\mathrm{z_{it}}$ are the observed individual characteristics variables to grower *i* at choice scenario *t*; θ_{i} is a vector of random parameters for each individual *i* that varies in the population and assumed θ_{i} to follow a normal distribution with a density function of $f(\theta_i|\Omega)$, where $\Omega = N(u_i, \sigma^2)$; γ is a vector of fixed parameters; ε_{ijt} is a stochastic iid extreme value error term that varies over individuals, alternatives, and choices with an expected value of zero, and captures the unobservable effects of individual and alternative attributes.

We used the mixed logit model because of its advantages over other approaches including its relaxation of the independence of irrelevant alternatives (IIA) assumption, and its ability to model preference heterogeneity across respondents (Revelt and Train, 1998). Conditional on the value of θ_i, the probability that grower *i* chooses alternative *j* in a choice scenario *t* is given by:

$$\mathrm{Prob}_i(Y_i = j|\theta_i) = \frac{\exp(\delta_{ij}+\theta_i x_{ijt}+\gamma z_{ijt})}{\sum_{k=1}^{M}\exp(\delta_{ik}+\theta_i x_{ikt}+\gamma z_{ijt})} \quad where\ k \neq j, k, j = 1,2, \ldots, M \qquad (3)$$

since θ_i is unknown, the unconditional choice probability is the integral product of $\mathrm{Prob}(\theta_i)$ over all values of θ_i:

$$\mathrm{Prob}(Y_i = j) = \int \mathrm{Prob}_i(Y_i = j|\theta_i)\, f(\theta_i|u_i, \sigma^2)d\theta \qquad (4)$$

A simulated maximum likelihood method is used to solve expression (4) (Train, 2009). Based on the estimation results, the willingness-to-pay (WTP) values are calculated as the ratio between the estimated parameters for the attribute and transplant cost (multiplied by -1). To calculate the confidence interval of each WTP we used the method by Krinsky and Robb (1986) which involves using 1000 random draws from a normal distribution and 1000 simulated WTP to calculate the standard error. In the estimation, both actual percentage of plant loss and number of fruits were used, but the choice options represented in the survey considered 5% crop loss difference and 5 units of fruit change. Hence the WTP for percentage of plant loss was divided by 20 to transform the WTP per 100% change for plant loss from disease to WTP per 5% crop loss change from disease to match the design in the choice experiment and the WTP for number of fruits was multiplied by 5 to transform the WTP per 1 unit of fruit increase in 1 lb clamshell change to WTP per 5 unit of fruits change to match the design in the choice experiment.

4.2. Economic welfare analysis

We use a partial equilibrium model to estimate the social welfare changes after the methyl bromide phase-out and the root and crown rot disease incidence shock. See Figure A1 and A2 in Appendix A. Two consequences are assumed to occur after the methyl bromide phase-out, strawberry productivity increase (Figure A1) or productivity decrease (Figure A2). We assume a change in productivity to justify the shift of the supply curve. In both figures, S_0 and D_0 are the initial supply and demand curve, and p_0 and Q_0 are the equilibrium price and quantity respectively. The consumer surplus is represented by I_0ap_0, producer surplus is J_0ap_0 and the total welfare before the shock is the I_0aJ_0. Further, we assume the Florida strawberry industry follows a closed competitive commodity economy market, implying that the price of Florida grown strawberries are determined within the state, and there is no trade outside the state borders.

Case 1: Welfare changes after the methyl bromide phase-out, under a productivity increase.

Assume there is a productivity increase caused by a technology change such as cultivar disease resistance improvement, new fumigant alternatives or new disease control management after the methyl bromide fumigant ban. Therefore, we expect a parallel shift to the right of the strawberry supply curve from S_0 to S_1resulting in a supply increase equivalent to $k = P_0 - d$. The change of producer surplus after the phase out is $\Delta PS_1 = J_1bp_1 - J_0ap_0 = area\ p_1dcb,$ the change of consumer surplus after the phase-out is $\Delta CS_1 = I_0bp_1 - I_0ap_0 = area\ p_0p_1ba,$ the resulting total welfare increase due to the phase out is J_0J_1ab (equivalent to the sum of ΔPS_1 and ΔCS_1).

Then, we assume a percentage of strawberry crop loss because of the incidence of root and crown rot disease, which cause a parallel left-ward shift of the supply curve from S_1 to S_2. Assume the crop loss percentage is λ $(0 \leq \lambda \leq 1)$, resulting in a change in equilibrium quantities, $\Delta Q = Q_1 - Q_2 = \lambda Q_1$. The producer surplus decrease after the incidence of root and crown rot disease is at $\Delta PS_2 = J_1bp_1 - J_2fp_2 = area\ p_1geb$, and the consumer surplus decrease is $\Delta CS_2 = I_0bp_1 - I_0fp_2 = area\ p_1p_2fb$. The total welfare decrease is the sum of ΔPS_2 and ΔCS_2.

Case 2: Welfare changes after the methyl bromide phase-out, under a productivity decrease.

Assume a productivity decrease caused by methyl bromide phase-out, resulting in a parallel left-ward supply curve shift from S_0 to S_1 and the supply shift down due to phase-out is, $k = P_1 - d$. The resulting producer surplus decrease is $\Delta PS_1 = J_0bp_0 - J_1ap_1 = area\ p_0dca$, and consumer surplus decrease is $\Delta CS_2 = I_0ap_0 - I_0bp_1 = area\ p_0p_1ba$, and the total welfare loss is equivalent to the sum of ΔPS_1 and ΔCS_2. After the incidence of the root and crown rot disease, a left-ward shift of the strawberry supply curve from S_1 to S_2, takes place. Next, the supply curve shifts further to the left, from S_1 to S_2. The crop loss is λ $(0 \leq \lambda \leq 1)$ and the change in the equilibrium quantity is at $\Delta Q = Q_1 - Q_2 = \lambda Q_1$. The producer surplus decrease is $\Delta PS_2 = J_1bp_1 - J_2ep_2 = area\ p_1gfb$ and the consumer surplus decrease is $\Delta CS_2 = I_0bp_1 - I_0ep_2 = area\ p_2p_1be$.

4.3. Empirical approach and data

The supply and demand for Florida grown strawberries are specificied as linear functions, with the phase-out shock as the intercept change,

$$Q_D = \beta_0 - \beta_1 p \quad (5)$$

$$Q_s = \alpha_0 + \alpha_1(p + k) = \alpha_0 + \alpha_1 k + \alpha_1 p \quad (6)$$

where Q_D is demand function for Florida grown strawberry of intercept parameter β_0 and slope parameter β_1, p is the price of Florida grown strawberry that grower received, Q_s is supply function for Florida grown strawberry of intercept parameter α_0 and slope parameter α_1, k is supply shift due to phase-out shock and its value is positive when assuming a productivity increase, negative otherwise, and 0 when there is no phase-out.

At equilibrium $Q_D = Q_s$, then we solve for $p_1 = \frac{\beta_0 - \alpha_0 - \alpha_1 k}{\alpha_1 + \beta_1}$, and $p_0 = \frac{\beta_0 - \alpha_0}{\alpha_1 + \beta_1}$ when k=0.

Calculating the producer surplus and consumer surplus change, we obtain,

$$\Delta PS_1 = \frac{1}{2}\frac{\varepsilon_D}{\varepsilon_s + \varepsilon_D}|k| p_0 (Q_0 + Q_1) \quad (7)$$

$$\Delta CS_1 = \frac{1}{2}\frac{\varepsilon_s}{\varepsilon_s + \varepsilon_D}|k| p_0 (Q_0 + Q_1) \quad (8)$$

$$\Delta PS_2 = \frac{\lambda p_1 Q_1}{\varepsilon_s}(1 - 0.5\lambda) \quad (9)$$

$$\Delta CS_2 = -\frac{\lambda p_1 Q_1}{\varepsilon_D}(1 - 0.5\lambda) \quad (10)$$

To calculate the values for the producer and consumer surplus (equations 7 to 10), we define the values for ε_s and ε_D. The demand elasticity (ε_D) for Florida grown strawberries was obtained from Suh, Guan, and Khacharyan (2017) and is equal to -1.05. We estimated the supply elasticity for Florida grown strawberries (ε_s), using an ordinary least squares approach. To estimate the supply elasticity, we used Florida strawberry production volume, price grower received, wage rate, Mexico fresh strawberry imports, and California fresh strawberry price, for the period 1980-2017. We used this range because 1980 was the earliest year of data for Mexico strawberry imports. All data were obtained from the USDA (USDA NASS, 2017a). See Table B1 in Appendix B. Other variables included were a binary variable to account for the North America Free Trade Agreement (NAFTA), equaling 1 for the year 1994 and later (NAFTA was implemented in 1994), and 0 otherwise. The other binary variable represented the methyl bromide phase-out, equaling 1 for the year 2009 and later (2009 was the year when the Florida strawberry industry was mandated to phase-out the methyl bromide). The coefficient for the methyl bromide phase-out shock is the supply shift k. Cultivar 'Strawberry Festival' was used to investigate welfare loss from both methyl bromide phase-out and crop loss[5]. Cultivar 'Florida Radiance' was used to only investigate welfare loss from crop loss because it was commercialized after 2009. For cultivar 'Strawberry Festival', the annual yield per plant four years before (2004-2005) and after 2009 (2013-2014) were used to account for Q_0 and Q_1, the average annual Florida strawberry price before and after 2009 from USDA NASS[6] was used to account for p_0 and p_1 respectively. In addition, we identified the effects of surplus loss across different harvest months using cultivar 'Florida Radiance'.

5. Results and Discussion

Summary statistics for Florida strawberry farm characteristics and principal operator socio-demographics are presented in Table 3. The weighted average farm size for our survey sample of respondents was 188 acres. The weighted average grows income for the strawberry operations in our survey, was at about $1 million. Respondents reported that 50% of their total gross farm income was from the strawberry operation. Also, 74% of the respondents reported the

[5] 'Florida Radiance' is the currently the leading strawberry cultivar in Florida and it was commercialized in 2009 (Whitaker et al., 2017). The 'Strawberry Festival' was commercialized in 2000 (Chandler et al., 2009).
[6] See Appendix B (Table B1) for the price information.

use of crop insurance. When asked about the marketing channel for the strawberries produced, 70% reported using direct sales to consumers, 61% reported selling to broker, 60% reported selling to grocery retailers, and 55% percent to supercenters. Most survey respondents used a mixture of marketing channels for their strawberries (Table 3). About the principal operator, the self-reported rate for attitude towards risk was at 6.4. This was measured in a 0-10 scale (0= unwilling to take risk, 10= very prepared to take risk). The average number of years as principal operator in the strawberry agri-business was at 18 years. About 52% of the respondents had a four-year college degree or higher-level education.

Summary statistics for growers' experiences with strawberry cultivars are presented in Table 4. Out of the responses obtained, 16 growers reported 'Florida Radiance' as the cultivar with the largest acreage in the operation, 9 growers reported growing other cultivar (e.g., 'Albion', 'Camarosa', 'Chandler', 'Strawberry Festival', and 'Sweet Charlie'), and 2 growers reported 'Sweet Sensation®'. The average rating for the respondents' perceived disease resistance varied across different cultivars using a 0-10 scale, where 0=100% root and crown rot susceptibility and 10=0% root and crown rot susceptibility (i.e., 100% resistant) varied across different cultivars. Disease resistance for other cultivars was rated 7, followed by 'Sweet Sensation®' rated at 6, and 'Florida Radiance' at 5. In addition, we asked about the perceived rating for the flavor exhibited by the cultivar they grew, using a 1-7 scale, where 1=extremely weak/mild flavor and 7=extremely full/intense flavor. Respondents assigned a 5.9 to 'Sweet Sensation®', 5.6 to other cultivars, and 4.5 to 'Florida Radiance'.

Summary statistics for the control of root and crown rot disease and growing new strawberry cultivars are presented in Table 5. All respondents who grew the cultivar 'Albion', 'Camarosa', and 'Strawberry Festival' indicated they experienced crop losses due to root and crown rot disease prior to first harvest. Similarly, 81.3% of the respondents who grew the ‘Florida Radiance’ cultivar reported crop losses due to this disease. None of the respondents who grew ‘Sweet Sensation®’ reported losses due to this disease.

On average, respondents reported losing 4% of the crops due to crown and root rot disease prior to first harvest when growing the cultivar ‘Camarosa’, 5% when growing ‘Albion’, 6.5% when growing ‘Strawberry Festival’, and 9.8% when growing ‘Florida Radiance’. These values align with findings by Mangandi, Peres, and Whitaker (2015) who concluded that Florida strawberry growers lost on average 5% of their crop to root and crown rot disease usually at the beginning (November) and at the end (March) of the strawberry season. On average, respondents reported expenses of $443.8 /acre to control root rot, which was 2% of total variable costs ($19,998.55 /acre as of 2015-2016). These root rot control costs were lower than the $740 /acre fumigation cost and $24,466 /acre total operation variable cost reported in the 2012-2013 study (Guan, Wu, and Whidden, 2017). These differences might be due to time periods considered, or size differences in growers in the two surveys. When asked about plans to grow a new strawberry cultivar in the next year (2016-2017 by the time the survey was conducted), 46.7% of respondents indicated an interest in growing a new cultivar. Similarly, when asked if they grew a new cultivar in the previous year (2015-2016), 46.7% of the respondents answered positively.

5.1. Grower preference and willingness to pay results

Table 7 reports the mixed logit model parameter estimates based on the discrete choice experiment applied to Florida strawberry growers. Mean parameter estimates for strawberry flavor were positive and statistically significant, indicating Florida strawberry growers derive a higher utility from investing in strawberry cultivars exhibiting a flavor improvement from extremely weak/mild flavor to neutral and from extremely weak/mild flavor to extremely full/intense flavor. This finding is consistent with findings in Colquhoun et al. (2012) and Wang et al. (2016) that consumers preferred strawberry flavor improvement from mild to intense strawberry flavor. Findings are also consistent with Choi et al. (2018) and Yue et al. (2017) in that U.S. strawberry growers preferred a full/intense flavor versus a weak/mild and with preferences of market intermediaries (Gallardo et al., 2015).

The mean parameter estimate for fruit size was negative and statistically significant (Table 7). Fruit size is measured as the number of fruits that fit in a 1 lb clamshell (the larger the size number, the smaller the fruit). It is not surprising that our respondents prefer larger-sized strawberries, as U.S. Grades and Standards for fresh market strawberries includes size as one criterion, and the grade of the fruit impacts the prices received by growers (Gallardo et al., 2015). This preference for larger sizes result coincides with findings in Choi et al., (2017), Gallardo et al., (2015) and Yue et al., (2017).

The mean parameter estimates for the percentage of plant loss from root and crown rot disease before first harvest was negative and statistically significant, suggesting that Florida strawberry growers generally prefer new cultivars with improved disease resistance with less percentage of crop loss (Table 7). The standard deviation parameters for fruit quality attribute estimates (e.g., fruit flavor improvement and size) except disease resistance coefficient estimates were all statistically significant, suggesting heterogeneity in preferences for Florida strawberry growers regarding fruit flavor and size.

The alternative specific constant (chose to grow Option A or B) was positive and statistically significant, indicating Florida strawberry growers were more likely to invest in the hypothetical cultivars containing the attributes included in the choice experiment scenarios. The mean parameter estimate for transplant plus royalty costs was negative and statistically significant, indicating it impacts the utility growers derive from investing in new strawberry cultivars. The parameter estimate for the size of operations was positive and statistically significant indicating that strawberry farms with more than 50 acres derive higher utility compared with smaller in acreage farms, from the alternatives presented in the choice scenarios (Table 7).

Table 8 reports the willingness to pay (WTP) and 95% confidence intervals. Our results show that Florida strawberry growers were willing to pay $76.9 /1,000 plants for improvements in flavor from extremely weak/mild to extremely full/intense. Similarly, the price premium respondents stated were willing to pay for an improvement from extremely weak/mild to neutral flavor was at $36.3 /1,000 plants. Relative to the base category that was 15 strawberry units in a 1-lb clamshell, respondents were willing to pay $20 /1,000 plants, for a 5-unit reduction in the number of strawberry units that could fit in a 1-lb clamshell. Also, relative to the base category that was 0% loss in plant loss from root and crown rot disease, a 5% of plant loss prior to first harvest due to root and crown rot disease reduced growers' willingness to pay by $11.4 /1,000 plants.

5.2. Economic welfare results

The economic welfare was calculated considering two strawberry cultivars 'Strawberry Festival' and 'Florida Radiance'. The choice is based mainly on data availability and 'Strawberry Festival' was the cultivar with the largest acreage in Florida before 2012. 'Florida Radiance' was commercialized only after 2009 and it is the leading cultivar in Florida (Whitaker et al., 2017). Therefore, the effect of both the methyl bromide phase-out and crop loss due to crown and root rot disease was estimated for 'Strawberry Festival' and the only the effect of crop loss due to crown and root rot disease was estimated for 'Florida Radiance'. Further, due to data availability, the welfare analysis for 'Strawberry Festival' is on an annual basis and for 'Florida Radiance' on a monthly basis. The monthly basis analyses enable capturing the different welfare effects at different market prices paid to growers during the production season (Seonghee Lee, personal communication).

A summary of all parameters used in the economic surplus model for the methyl bromide phase-out and crop loss induced supply shift for the Florida grown 'Strawberry Festival' cultivar is presented in Table 8. The parameters include annual yield per strawberry plant, annual price per strawberry plant, demand and supply elasticity. The supply shift (*k*) after the methyl bromide phase-out was estimated at -0.22, suggesting that the phase-out had, in general, a negative impact on growers' welfare. Parameters used in the economic surplus model for the crop loss, only, for cultivar 'Florida Radiance' are presented in Table 9. Here, the parameters include monthly yield per strawberry plant (November to March), monthly price per strawberry plant (November to March), and demand and supply elasticity. For both cultivars, the demand elasticity for Florida grown strawberries was obtained from Suh, Guan, and Khacharyan (2017) and was -1.05. The Florida strawberry supply elasticity was estimated after the supply model explained in detail in Appendix C Table C1; and was at 0.59.

The total welfare loss after the methyl bromide phase-out was $1,484.6[7] /1,000 plants for the cultivar 'Strawberry Festival' (see Table 10). For this same cultivar, the welfare loss due to the incidence of root and crown rot disease, assuming a 5% crop loss was $262[8] /1,000 plants as

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[7] The producer surplus loss was calculated as $= 0.5 * \frac{\varepsilon_D}{\varepsilon_D+\varepsilon_s}|k|p_0(Q_0+Q_1)*1000 = 0.5*\frac{-1.05}{-1.05+0.59}*0.00241*(0.22)*(928+642.8)*1000 = \$950.5$, the consumer surplus was calculated as $= 0.5*\frac{\varepsilon_s}{\varepsilon_D+\varepsilon_S}kp_0(Q_0+Q_1)*1000 = 0.5*\frac{0.59}{-1.05+0.59}*0.00241*(-0.22)*(928+642.8)*1000 = \$534.1$, then the total welfare loss from the methyl bromide was summation of $950.5 and $534.1 and it was $1,484.6 for every 1,000 plants.

[8] The producer surplus loss from 5% crop loss in 2013-2014 per 1000 plants was calculated as $= \frac{\lambda p_1 Q_1}{\varepsilon_s}(1-0.5*\lambda)*1000 = \frac{0.05*0.00316*642.8}{1.05}(1-0.5*0.05)*1000 = \$94.3$, the consumer surplus loss for 5% crop loss in 2013-2014 per 1000 plants was

of 2013-2014. We notice that a larger percentage of the total welfare loss was accounted to producers compared to consumers, after both the methyl bromide phase-out and the crop losses due to root and crown rot disease. Also, the estimated producer surplus loss from the methyl bromide phase-out, was at $950.5 /1,000 plants. This was higher compared to the loss in producer surplus due to the losses due to the disease at $167.8 /1,000 plants. These results suggest that the methyl bromide phase-out generated a larger surplus loss to strawberry growers cultivating 'Strawberry Festival', relative to the loss due to the incidence (assumed at 5% crop loss) of the disease root and crown rot.

For the "Florida Radiance' cultivar the total economic welfare loss due to a 5% crop loss was at $336.6 /1,000 plants for 2016-2017 (see Table 11). We estimated the producer, consumer, and total welfare losses at different percentages of crop loss due to the crown and root rot disease for 2016-2017 at different harvest months during the season. If the first harvest happens in December, then the average producer surplus loss (November and December) from a 5% crop loss is $20.4 /1,000 plants, which is higher than the stated WTP for the improving disease by decreasing by 5% the crop loss prior to first harvest at $11.4 /1,000 plants. The difference might be due to that the strawberry price in November and December is higher compared to other months, therefore the perceived negative impact of the incidence of the disease might not be as high in relation to other harvest months. Also consider that the WTP calculation is after the mixed logit model parameters calculated following the ceteris paribus assumption; and that there might be other factors affecting the real dimension of the cost of the disease. These results also reflect the value of procuring a cultivar with improved disease resistance at different months

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calculated as= $\frac{\lambda p_1 Q_1}{\varepsilon_D}(1 - 0.5 * \lambda) * 1000 = \frac{0.05 * 0.00316 * 642.8}{0.59}(1 - 0.5 * 0.05) * 1000 = \$167.8$, then the sum of welfare loss was equal to $262.

during the season. For example, an improvement in the crop loss due to root and crown rot disease, from 10% to 5% crop loss, represents $3.6 ($7.5-$3.9 in November), $34.9 (in December), $47.1 (in January), $80.5 (in February), and $38.2 (in March) with a total of $204.5 /1,000 plants during the whole harvest season. The surplus loss change in February is the highest because of the highest yield per plant. Similar findings are observed from both the consumer and the total surplus.

We also estimated the welfare impacts for the Florida strawberry industry. For this calculation we assumed: (1) the cost of transplant for Florida strawberry growers at $2,610 /acre (Guan, Wu, and Whidden, 2017), (2) the cost of 1,000 strawberry plants is $150, (3) the total number of strawberry acres in Florida is 10,800 (USDA NASS 2018b). Therefore a 5% crop loss or an improvement in the root and crown rot disease resistance by 5% gain, represents a $40[9] million saving to the Florida strawberry producer, $22 million gain to the Florida strawberry consumer, and $63 million in total economic gains.

6. Conclusion

We estimated Florida strawberry growers' preferences and willingness to pay for strawberry fruit and plant attributes. In addition, we investigated the welfare losses associated with the methyl bromide phase-out event and crop loss due to the incidence of the root and crown rot disease. Our results suggest that Florida strawberry growers value a larger fruit flavor improvement and fruit size more compared to improvements in disease resistance. Further, our findings suggest that the phase-out of methyl bromide represented a larger welfare loss compared

[9] A 5% crop loss would cause $215.5 loss per 1,000 plants and $121.1 to producer and consumer respectively, then for all Florida strawberry grower the loss is $= \frac{2,610}{150} * 215.5 * 10,800 = \$40,496,760$, for Florida strawberry consumer, the loss is $= \frac{2,610}{150} * 121.1 * 10,800 = \$22,757,112$.

to the loss due to the incidence of root and crown rot disease. Nonetheless, cultivars with improved resistance to the disease, represent annual savings to the Florida strawberry growers ranging from $204.5 - $182.4 /1,000 plants, to Florida strawberry consumers, from $114.9 to $102.5 /1,000 plants, and to the total, from $319.4 - $284.9 / 1,000 plants. In addition, for the Florida strawberry industry, a cultivar with an improved disease resistance could save about $40 million /year for growers and $60 million /year to the Florida economy from the crop loss. We observed discrepancies in the growers stated WTP for a cultivar with improved disease resistance and the actual savings that could be experienced when adopting such cultivars.

This study adds to the existing literature regarding growers' decision making in front of two aspects deemed important to guarantee the commercial success of a new cultivar, fruit quality and disease resistance attributes. Growers face challenges given consumers' increasing concerns about pesticide use in fresh fruits and the phase-out of exceptionally effective fumigants to control for diseases. Breeders face the challenge of combining production and consumer-oriented traits in a single improved cultivar. The findings from this study provide important information to breeders on identifying priority attributes for new cultivars for different sizes of strawberry growers. Such improved cultivars will improve the competitiveness of Florida strawberry growers in an increasingly competitive marketplace.

Our study also analyzes the potential welfare impact of the methyl bromide phase-out and crop loss due to the root and crown rot disease using an ex ante partial equilibrium demand-supply framework. Based on the numerical results reported in the study, the total welfare loss from methyl bromide phase-out and crop loss suggest comes disproportionately from a decrease in producer surplus. These results have important implications to Florida strawberry industry and breeders in the development of improved cultivars with superior disease resistance.

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Table 1. Example of a strawberry cultivar choice scenario.

Strawberry features	Option A	Option B	Option C:
Percentage of plant loss from root and crown rot diseases prior to first harvest	5%	0%	Neither Option A nor B
Flavor on a scale of 1-7 **(combination of sweet, tart/sweet balance, and aroma)**	Weak/mild (score 1-2 * see below)	Neutral (score 3-4-5 * see below)	
Size (number of fruit in a 1 lb clamshell)	20	15	
Cost of transplant + royalty ($/1000 plants)	$140	$150	
Which option would you choose?	☐	☐	☐

*Please use this 7-point scale when considering your preference for flavor (combination of sweetness, sweet/tart balance and aroma).

Extremely weak/mild flavor		Neutral flavor		Extremely fully/intense flavor		
1	2	3	4	5	6	7

Table 2. Attribute levels for strawberry cultivar choice scenarios.

Cultivar attributes	Unit	Level 1	Level 2	Level 3
Plant loss due root and crown rot disease prior to first harvest	%	0%	5%	10%
Flavor	Score	1-2 (weak/mild)	3-5 (neutral)	6-7 (full/intense)
Fruit size	Number of fruits in a 1 lb clamshell	15	20	25
Cost of transplant + royalty	$/1,000 plants	140	150	160

Table 3. Summary statistics of the Florida strawberry operations and grower socio-demographics.

Item		Value (%)
Respondents indicating the category for the total acres of strawberries owned or managed		
<5 acres		46.7
5-14 acres		0.0
15-24 acres		0.0
25-49 acres		3.3
50-99 acres		16.7
100-249 acres		13.3
250-499 acres		6.7
500-1,000 acres		10.0
> 1,000 acres		3.3
	Weighted average	188.0
Respondents indicating the category for the gross income from the strawberry farm		
< $25,000		53.6
$25,001-$49,999		0.0
$50,000-$74,999		3.6
$75,000-$99,999		3.6
$100,000-$249,999		0.0
$250,000-$499,999		0.0
$500,000-$999,999		3.6
$1,000,000-$2,499,998		7.0
More than $2,500,000		28.6
	Weighted average	$ 1,020,876
Respondents indicating the category for the percentage of gross income from the strawberry farm		
0%		6.7

1-25%		33.3
26-50%		16.7
51-75%		6.7
76-99%		6.6
100%		30.0
	Weighted average	50.5 %
Respondents indicating the use one or more of the following marketing channels		
Broker (N=23)		60.9
Supercenter (N=22)		54.6
Grocery, retailer (N=22)		59.1
Direct sale (N=23)		69.6
Supported agriculture, roadside stand (N=17)		35.3
Processor (N=17)		23.5

Note: To calculate the weighted mean, for size the upper cutoff point of 1,500 was used and for income the upper cutoff point of $3,000,000 was used. And other categories used the midpoint as cutoffs.

Table 4. Florida strawberry growers' production experiences by cultivars as of 2015.

Item	Mean	St. deviation
Number of respondents indicating that the following cultivar corresponds to the largest acreage in the farm		
'Sweet Sensation®'	2	
'Florida Radiance'	16	
Other	9	
'Albion'	1	
'Camarosa'	2	
'Chandler'	2	
'Strawberry Festival'	2	
'Sweet Charlie'	2	
Growers' perceived level of resistance to root and crown rot disease for the largest strawberry cultivar planted, in a 0-10 scale, 0=100% susceptible and 10=100% resistant		
'Sweet Sensation®'	6	2.6
'Florida Radiance'	5	3.1
Other	7	2.9
Growers' perceived flavor for the largest strawberry cultivar planted, in a 1-7 scale, 1=extremely weak/mild flavor and 7=extremely full/intense flavor		
'Sweet Sensation®'	5.9	0.7
'Florida Radiance'	4.5	0.9
Other	5.6	1.4

Table 5. Summary statistics of Florida strawberry grower experiences with root and crown rot and viewpoints on planting a new cultivar as of 2015.

Item	Unit	Value
Respondents who experienced crop loss due to crown and root rot disease when growing the cultivar with the largest acreage in the farm		
‘Albion’	%	100
‘Camarosa’	%	100
‘Strawberry Festival’	%	100
‘Florida Radiance’	%	81.3
‘Sweet Sensation®’	%	0
Average crop loss due to root and crown rot disease when growing the cultivar with the largest acreage in the farm		
‘Camarosa’	%	4
‘Albion’	%	5
‘Strawberry Festival’	%	6.5
‘Florida Radiance’	%	9.8
Respondents who indicated their cost of managing root and crown rot disease, followed in the category:		
$0 - $100 /acre	%	20
$101 - $300 /acre	%	36
$301 - $500 /acre	%	12
$501 - $700 /acre	%	4
$701 - $900 /acre	%	0
$901 - $1,100 /acre	%	20
$1,101 - $1,300 /acre	%	0
$1,301 - $1,500 /acre	%	8
More than $1,500/acre	%	0
	Weighted average	$ 443.8
Respondents who indicated their variable production costs (operating, harvesting, and packing) followed in the category:		
$0-$17,500/acre	%	33.3
$17,501-$20,000/acre	%	16.7
$20,001-$22,500/acre	%	12.5
$22,501-$25,000/acre	%	0.0
$25,001-$27,500/acre	%	4.2
$27,501-$30,00/acre	%	16.6
$30,001-$32,500/acre	%	12.5
$32,501-$35,000/acre	%	0.0
$35,001-$37,500/acre	%	0.0
$37,501-$40,000/acre	%	0.0
More than $40,000/acre	%	4.2
	Weighted average	$ 19,998.6
Respondents who indicated they planted a new strawberry cultivar in 2016-2017		
	%	46.7
Respondents who indicated they planted a new strawberry cultivar in 2015-2016		
	%	46.7

Table 6. Mixed logit estimates by Florida strawberry growers.

Variables	Parameter estimate (Standard error)
Random parameters – means	
Flavor score: full/intense	6.3***[a]
	(1.3)[b]
Flavor score: neutral	2.9***
	(0.6)
Fruit size (number of fruits in a 1 lb clamshell)	-0.3***
	(0.1)
Plant loss from root and crown rot disease prior to first harvest	-18.8***
	(5.6)
Random parameters – standard deviation	
Flavor score: full/intense	2.6***
	(0.7)
Flavor score: neutral	2.1***
	(0.6)
Fruit size (number of fruits in a 1 lb clamshell)	0.1***
	(0.1)

Plant loss from root and crown rot disease prior to first harvest	12.7
	(7.9)
Fixed parameters	
ASC_grow option	15.4*
	(8.0)
Cost of transplant and royalty	-0.1*
	(0.1)
Acre >50 X ASC_grow option	2.6*
	(1.5)
Number of observations	693
Log Likelihood	-153.1

[a] *, **, *** denotes significance at the 10%, 5%, and 1% levels respectively.
[b] Standard errors are in parentheses.

Table 7. Willingness to pay by Florida strawberry growers.

Attributes	Willingness to pay ($/1000 plants) [95% confidence interval]
Extremely weak/mild to extremely full/intense flavor	76.9 [34.4, 226.1]
Extremely weak/mild to neutral flavor	36.3 [15.5, 137.5]
Size (number of fruits in a 1 lb clamshell)	-20.2 [a] [-60.4, -9.5]
Percentage of plant loss from root and crown rot disease prior to first harvest	-11.4 [b] [-21.5, -4.5]

[a] The WTP for number of fruits was multiplied by 5 to transform the WTP per 1 unit of fruit increase in 1 lb clamshell change to WTP per 5 unit of fruits change to match the design in the choice experiment.
[b] The WTP for percentage of plant loss was divided by 20 to transform the WTP per 100% change for plant loss from disease to WTP per 5% crop loss change from disease to match the design in the choice experiment.

Table 8. Parameters used in the economic surplus model for analyzing the welfare effects of the methyl bromide phase out and crop loss due to crown and root rot disease in Florida grown cultivar ‘Strawberry Festival’.

Parameter	Description	Unit	Value
Q_0[a]	Yield per strawberry plant in 2004-2005	g /plant	928
Q_1[b]	Yield per strawberry plant in 2013-2014	g /plant	642.8
P_0[c]	Price of strawberry plant in 2004-2005	$ /g	0.00241
P_1[c]	Price of strawberry plant in 2013-2014	$ /g	0.00316
k	Methyl bromide phase- out indicator	-	-0.22
λ	Crops loss percentage	%	5
Plants	Number of plants	Units	1,000
ε_D	Demand elasticity	-	-1.05
ε_s	Supply elasticity	-	0.59

[a] Obtained from Chandler et al., 2009.
[b] Obtained from Whitaker et al., 2015. The cultivar ‘Strawberry Festival’ had been the most popular in Florida for almost a decade until 2012. https://gcrec.ifas.ufl.edu/fruit-crops/strawberry-cultivars/.
[c] From Appendix Table A1, transformed to $/g.

Table 9. Parameters used in the economic surplus model for analyzing the welfare effects of crop loss due to crown and root rot disease in Florida grown cultivar ‘Florida Radiance’.

Parameter	Description	Unit	Value
Q_1 [a]	Yield per strawberry plant	g /plant	
	November 2016		6.3
	December 2016		102.3
	January 2017		157.2
	February 2017		413.9
	March 2017		174.1
	Total		853.8
P_1 [b]	Price of strawberry plant	$ /g	
	November 2016		0.00744
	December 2016		0.00435
	January 2017		0.00383
	February 2017		0.00248
	March 2017		0.00279
λ	Crops loss percentage	%	5
Plants	Number of plants	Units	1,000
ε_D	Demand elasticity	-	-1.05
ε_S	Supply elasticity	-	0.59

[a] Obtained from Whitaker et al., 2017.
[a] ‘Florida Radiance’ was commercialized after 2009 (Whitaker et al., 2017), we assume there was no methyl bromide phase-out change for this cultivar.
[b] Obtained from Agricultural Marketing Service from the USDA. https://marketnews.usda.gov/mnp/fv-report-config-step1?type=shipPrice, transformed to $/g.

Table 10. Welfare effects after the methyl bromide phase out and crop loss from the root and crown rot disease experienced by Florida strawberry growers and consumers, considering the cultivar ‘Strawberry Festival’.

	Annual welfare effect measured as surplus loss ($ /1,000 plants)	
	Methyl bromide phase-out	Crop loss due to root and crown rot disease assumed at 5%
Producer	950.5	167.8
Consumer	534.1	94.3
Total	1,485.6	262.1

Table 11. Welfare effects after the different levels of crop loss due to root and crown rot disease experienced by Florida strawberry growers and consumers, considering the cultivar ‘Florida Radiance’.

	Welfare effect measured as surplus loss ($ /1,000 plants), at different levels of crop loss due to root and crown rot disease, measured as the following %			
	5	10	15	20
Producer				
November	3.9	7.5	11.0	14.3
December	36.8	71.7	104.8	135.9
January	49.8	96.9	141.6	183.7
February	84.8	165.3	241.4	313.2
March	40.3	78.5	114.6	148.7
Total	215.5	420.0	613.4	795.8
Consumer				
November	2.2	4.2	6.2	8.1
December	20.7	40.3	58.9	76.4
January	27.9	54.5	79.6	103.2
February	47.7	92.9	135.7	175.9
March	22.6	44.1	64.6	83.6
Total	121.1	236.0	344.7	447.2
Total				
November	6.1	11.7	17.2	22.4
December	57.5	112.0	163.7	212.3
January	77.7	151.4	221.2	286.9
February	132.5	258.2	377.1	488.4
March	62.9	122.6	179.0	232.3
Total	336.6	656.0	958.1	1,242.9
	Welfare effects measured for the state of Florida[a] ($ /year)			
Producer	40,496,760			
Consumer	22,757,112			
Total	63,253,872			

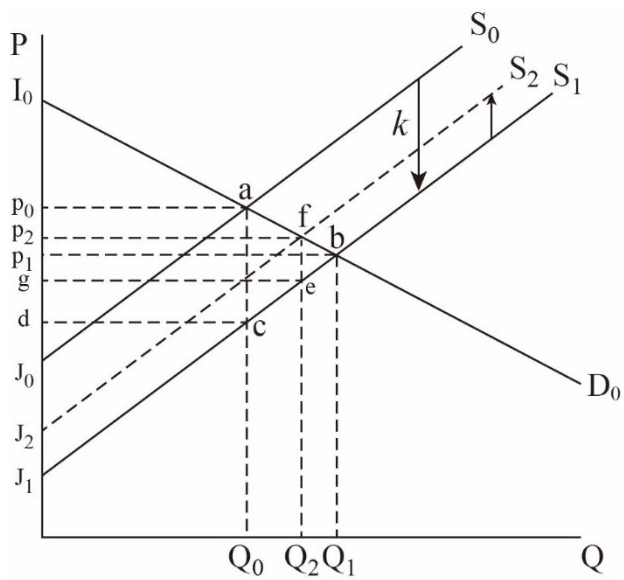
[a] These estimations followed the assumptions: transplant cost: $150 / 1,000 plants, transplant cost in 2012-2013: $2,610/acre (Guan, Wu, and Whidden, 2017), Florida strawberry acre in 2016-2017: 10, 800 acres (USDA NASS, 2018b).

Appendix A

This section includes the conceptual framework for welfare changes after the methyl bromide phase out and algebraic calculations for the change in the producer and consumer surplus. We discuss the two cases: productivity increase and decrease after the phase-out.

Case 1. Welfare changes after the methyl bromide phase-out, under a productivity increase.

Figure A1: Schematic analysis of the welfare change after a production increase due to the methyl bromide phase out



The quantities demanded and supplied of strawberries follow,

$$Q_D = \beta_0 - \beta_1 p \quad \text{(A1)}$$

$$Q_s = \alpha_0 + \alpha_1(p + k) \quad \text{(A2)}$$

where Q_D is the quantities of strawberry demanded, β_0 is the intercept parameter for the demand curve, β_1 is the slope of the demand curve and *p* is the price. Q_s is the quantities of strawberry supplied, α_0 is the intercept parameter for the supply curve, α_1 is the slope of the supply curve, *p* is price and *k* is the production shift due to the methyl-bromide phase-out.

At equilibrium, $Q_D = Q_s$, price in time 0 (p_0) and 1(p_1)follows,

$$p_0 = \frac{\beta_0 - \alpha_0}{\alpha_1 + \beta_1} \quad (k = 0) \tag{A3}$$

$$p_1 = \frac{\beta_0 - \alpha_0 - \alpha_1 k}{\alpha_1 + \beta_1} \tag{A4}$$

Then,

$$p_0 - p_1 = \frac{\alpha_1 k}{\alpha_1 + \beta_1} \tag{A5}$$

We assume a production increase implying a rightward supply shift from S_0 to S_1, then,

$$p_0 - d = k \tag{A6}$$

Then, p_1- p_0, that is equation (A6) minus equation (A4) equals,

$$p_1 - d = \frac{\beta_1 k}{\alpha_1 + \beta_1} \tag{A7}$$

Multiplying the denominator and numerator by $\frac{p_0}{Q_0}$ and the demand shift weighted by the innitial equalibrium price, we obtain,

$$p_1 - d = \frac{\varepsilon_D}{\varepsilon_D + \varepsilon_S} k p_0 \tag{A8}$$

$$p_0 - p_1 = \frac{\varepsilon_S}{\varepsilon_D + \varepsilon_S} p_0 \tag{A9}$$

The producer and consumer surplus follow,

$$\Delta PS_1 = area\, p_1 dcb = (p_1 - d)Q_0 + 0.5(p_1 - d)(Q_1 - Q_0) = 0.5 \frac{\varepsilon_D}{\varepsilon_D + \varepsilon_S} k p_0 (Q_0 + Q_1) \tag{A10}$$

$$\Delta CS_1 = area\, p_0 p_1 ba = (p_0 - p_1)Q_0 + 0.5(p_0 - p_1)(Q_1 - Q_0) = 0.5 \frac{\varepsilon_S}{\varepsilon_D + \varepsilon_S} k p_0 (Q_0 + Q_1) \tag{A11}$$

Now consider the appearance of the crown rot disease, resulting in a crop loss λ $(0 \leq \lambda \leq 1)$ leading to a left-ward shift of the strawberry supply curve from S_1 to S_2; where $\Delta Q = Q_1 - Q_2 = \lambda Q_1$.

The supply ealsticity follows,

$$\varepsilon_S = \frac{\Delta Q}{\Delta P} \tag{A12}$$

Further assuming,

$$\Delta P = p_1 - g = \frac{\Delta Q}{\varepsilon_S} \frac{p_1}{Q_1} = \frac{\lambda Q_1}{\varepsilon_S} \frac{p_1}{Q_1} = \frac{\lambda p_1}{\varepsilon_S} \tag{A13}$$

Then the producer surplus follows,

$$\Delta PS_2 = area\, p_1 geb = (p_1 - g)Q_2 + 0.5(p_1 - g)(Q_1 - Q_2) = \frac{\lambda p_1 Q_1}{\varepsilon_s}(1 - 0.5\lambda) \quad \text{(A14)}$$

Similarly the elasticity of demand follows,

$$\varepsilon_D = \frac{\Delta Q}{\Delta P}\frac{p_1}{Q_1} \quad \text{(A15)}$$

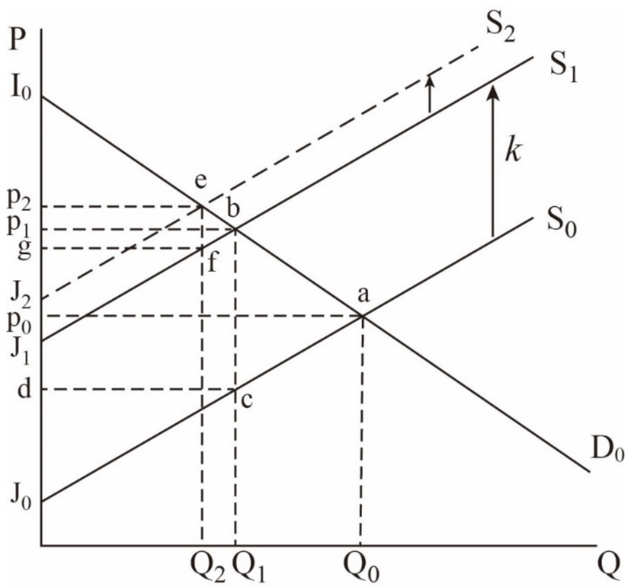
$$\Delta P = p_2 - p_1 = \frac{\Delta Q}{\varepsilon_D}\frac{p_1}{Q_1} = \frac{\lambda p_1}{\varepsilon_D} \quad \text{(A16)}$$

Then the consumer surplus follows,

$$\Delta CS_2 = area\, p_1 p_2 fb = (p_2 - p_1)Q_2 + 0.5(p_2 - p_1)(Q_1 - Q_2) = \frac{\lambda p_1 Q_1}{\varepsilon_D}(1 - 0.5\lambda) \text{ (A17)}$$

Case 2. Welfare changes after the methyl bromide phase-out, under a productivity decrease.

Figure A2: Schematic analysis of the welfare change after a productivity decrease due to the methyl bromide phase out.



Because of the productivity decrease by the methybromide phase-out, a left-ward supply shift along with a price change takes place, following,

$$k = d - p_1 \quad \text{(A18)}$$

$$p_1 - p_0 = -\frac{\alpha_1 k}{\alpha_1 + \beta_1}\ , \ k < 0 \quad \text{(A19)}$$

Adding (A18) and (A19), we obtain

$$\frac{\beta_1 k}{\alpha_1+\beta_1} = d - p_0 \qquad \text{(A20)}$$

Including elasticities of supply and demand and weighted the demand shift by the innitial equalibrium price we have,

$$p_0 - d = -\frac{\varepsilon_D}{\varepsilon_D+\varepsilon_S} k p_0 \qquad \text{(A21)}$$

$$p_1 - p_0 = -\frac{\varepsilon_S}{\varepsilon_D+\varepsilon_S} k p_0 \qquad \text{(A22)}$$

Therefore, the producer and consumer surplus can be expressed as,

$$\Delta PS_1 = area\, p_0 dca = (p_0 - d)Q_1 + 0.5(p_0 - d)(Q_0 - Q_1) = -0.5\frac{\varepsilon_D}{\varepsilon_D+\varepsilon_S} k p_0 (Q_0 + Q_1) \qquad \text{(A23)}$$

$$\Delta CS_1 = area\, p_0 p_1 ba = (p_1 - p_0)Q_1 + 0.5(p_1 - p_0)(Q_0 - Q_1) = -0.5\frac{\varepsilon_S}{\varepsilon_D+\varepsilon_S} k p_0 (Q_0 + Q_1) \qquad \text{(A24)}$$

Considering the appearance of the crown rot disease, would result in a similar producer and consumer surplus as in ΔPS_2 and ΔCS_2, but the magnitude for p_1 and Q_1 would be different.

Appendix B

Table B1. Strawberry production, strawberry grower price, wage rate, and Mexico imports: 1980-2017.

Year	Production	Florida grower price	Mexico imports	Farm labor wage rate	Producer price index for fruits	California grower price
Units	Million lbs	Cents per lb	Million lbs	$/hour	%	Cents per lb
1980	47.5	58.8	34.4	4.64	85.7	46.3
1981	67.2	41.5	20.65	4.95	96.3	47.1
1982	97.5	53.7	17.72	4.97	100	55.7
1983	102.6	51.2	18.86	4.89	119.6	53.2
1984	86.7	44.8	22.96	4.665	112.3	49.1
1985	106	57.8	19.76	4.0375	118.6	51.9
1986	90.7	55.3	27.41	5.0775	132.8	58.2
1987	110.3	60.8	25.56	5.465	104.3	58
1988	125	59.1	30.12	5.6	99.9	52
1989	137.8	66.9	33.76544	5.75	88.4	49.3
1990	116.6	64.6	35.51182	6	104.9	50.5
1991	132	64.3	29.50828	6.28	103	50.9
1992	162	67.2	21.89667	6.38	113.5	59.2
1993	162.4	74.7	29.11489	6.62	102.5	46.8
1994	168.2	60.3	46.46091	7.04	93.1	59.1
1995	168	70.6	56.7643	7.48	102.2	57.4
1996	156	72.2	64.70666	7.3	100.1	52.5
1997	176.9	82.6	29.68094	7.47	113.2	61.4
1998	161.2	100	57.24543	7.91	109.3	68.7
1999	186	81	91.61909	8.21	116.3	72.5
2000	220.5	76	74.56541	8.49	114.4	61.4
2001	169	99	70.72592	8.54	148	70.6
2002	176	87.2	89.89837	8.69	119	67.4
2003	156.2	82.7	90.34016	9.14	132.6	72.8

2004	163.3	109	94.44273	9.04	138.8	62.2
2005	178.9	110	122.7121	9.46	129.6	62.6
2006	204.4	117	153.4232	9.38	135.7	65.1
2007	211.2	124	157.6694	9.73	144.1	75.7
2008	179.4	139	143.0066	10.06	160.3	77.3
2009	237.6	132	187.1508	10.42	154.3	79
2010	193.6	187	198.3172	10.67	159.8	80.3
2011	247.5	148	243.517	10.92	163.4	86.1
2012	249.3	110	351.2656	10.97	157.4	88.8
2013	261.18	143	353.83	11.6	170.1	90.4
2014	231.95	148	355.31	11.18	170.1	100
2015	273.5	119	312.57	11.76	130	73.9
2016	245.67	166	362.15	12.21	133.3	123
2017	269.64	140	364.55	12.61	112.6	123

Source: USDA National Agricultural Statistic Service (NASS): 1980-2017.
https://usda.library.cornell.edu/concern/publications/8s45q876k?locale=en

Appendix C

Table C1. Supply response equation result

Variables	Coefficients
Log own price [a]	0.59***
	(0.19) [b]
Log own price lagged	-0.05
	(0.15)
Log wage rate	0.67**
	(0.29)
NAFTA	-0.72***
	(0.21)
Log Mexico imports X NAFTA	-0.05*
	(0.03)
Methyl bromide phase out	-0.22**
	(0.09)
Log California strawberry price	0.06
	(0.14)
Constant	4.17***
	(0.03)
Adjusted R-square	0.88
Number of observations	37.00

[a] In the estimation, the price was real price and it was equal to the price grower received divided by the producer price index to account for the average change in prices that grower received.
[b] Standard errors are in parentheses.