CONSUMER PERCEPTIONS OF AND WILLINGNESS TO PAY FOR LETTUCE FROM DIFFERENT AGRICULTURAL PRODUCTION SYSTEMS

BY

BRADFORD DAVID COYLE

THESIS

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Adviser:

Assistant Professor Brenna Ellison

ABSTRACT

Vertical farming is a technologically advancing agricultural production method with the potential to change the way lettuce (and other produce) is grown. However, less is known about how consumers will react to this new technology in the marketplace. In this study, we examine consumers' perceptions of and willingness to pay (WTP) for lettuce produced in three different production systems: vertical farm, greenhouse and field farm. Additionally, we assess whether providing information on the three production systems alters perceptions and/or WTP, particularly in the case of vertical farming. We conducted Becker-DeGroot-Marschak revealed preference auctions with over 100 participants to determine WTP, where participants were randomly assigned to receive (or not receive) information on the three production systems. Results suggest that consumers generally perceive vertical farming favorably and at comparable levels to greenhouse and field farm production systems for attributes such as safety, quality and cost expectations, yet is viewed as less natural and less likely to be purchased by the average consumer. Further, we find that consumer WTP for vertically farmed lettuce was not significantly different than lettuce produced by either a greenhouse or a field farm, but WTP was lower for participants who received the information treatment.

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CHAPTER 1

INTRODUCTION

The global population is expected to increase to 9.7 billion people by 2050, which is approximately 2.4 billion more mouths to feed than we have today (United Nations, 2015). To feed more people, it likely means more food will need to be produced; however, there are concerns over the scarcity and/or quality of critical inputs for food production in the future. Lotze-Campen et al. (2008) noted land that was previously used for agricultural production will likely be converted for other purposes such as urbanization, infrastructure development, bioenergy production, or biodiversity protection. Other research has cautioned that high quality water and soil inputs may also be constrained (Tilman et al., 2002; Ehrlich, Ehrlich, and Daily, 1993). Climate change is also expected to be a major challenge for agricultural production in the coming years due to warming temperatures, increased carbon dioxide emissions, and more severe weather events (Howden et al., 2007). Climate change models predict agricultural losses will be greatest in the developing world (Rosenweig and Parry, 1994), especially in southern Asia and Africa (Parry, Rosenweig, and Livermore, 2005).

One potential method of increasing agricultural production (and ultimately the food supply) that is largely impervious to climate change is vertical farming. Vertical farming is a type of controlled environment agriculture that primarily uses artificial lighting and hydroponics to grow plants stacked in layers (Banerjee and Adenaeuer, 2014). Because the climate in a vertical farm is controlled, plants can grow faster and be harvested year-round. By stacking layers of plants on top of each other, vertical farms can produce much higher yields per unit of land than a traditional farm.

Vertical farms also have the benefit of being able to produce crops like lettuce in non-traditional areas (Despommier, 2010). Currently, vertical farms produce fresh lettuce in cities in the northern United States, Northern Europe and East Asia – areas where lettuce production is typically uncommon. The presence of vertical farms allows consumers in those areas to buy locally produced food, an attribute that has been shown to be highly valued by consumers (e.g., Loureiro and Hine, 2002; Darby et al., 2008; Hu et al., 2011; Onozaka and McFadden, 2011) . Additionally, an increased availability of produce crops via vertical farms could potentially lead to increases in fruit and vegetable intake. Research has shown that availability is a positive predictor of intake for fruits and vegetables in both children and adults (Bodor et al., 2008; Blanchette and Brug, 2005; Neumark-Sztainer et al., 2003). While research has not formally assessed the relationship between vertical farms and dietary intake, it is argued that vertical farms may be a good means for increasing produce availability in highly urbanized areas and urban food deserts which could improve community food security (Specht et al., 2014).

Critics, though, contend that vertical farming presents more problems than it solves. Cox and Van Tassel (2010) argue that because vertical farming depends on artificial lights to grow plants, energy usage is high, and the production of additional electricity for vertical farms will result in increased pollution and greenhouse gas emissions. Furthermore, the cost to purchase the LED lights used in a vertical farm are prohibitively expensive for many small farmers. Critics also contend that the crops that can both grow in a vertical farm and be economically viable are limited to the extent that it will not be a meaningful solution to our agricultural problems.

While there are arguments for and against vertical farming, it is rarely discussed whether consumers are even willing to buy vertically farmed produce – an important consideration in the

cost-benefit discussion. Recent agricultural technologies, such as genetically modified (GM) crops, food irradiation, and nanotechnology, have often been met with consumer skepticism (Frewer et al., 2011; Dannenberg, 2009; Siegrist et al., 2007; Ragaert et al., 2004), so it is unclear how vertical farming will fare with consumers. While vertical farms are relatively widespread in Japan and Taiwan (Bateman, 2016), they represent only a very small part of total lettuce production. In the U.S., the number of large commercial vertical farms has increased in recent years but is still limited. As vertical farming remains unknown to consumers in many areas, it is difficult to predict how consumers will react to this alternative production system.

The overall purpose of our research is to investigate consumers' perceptions of and willingness to pay (WTP) for lettuce grown in a vertical farm production system. We compare perceptions and WTP values to those for greenhouse and field grown lettuce as these are more common agricultural production systems. Results from this study should provide insight on the potential for consumer acceptance of vertical farming as a new production technology. This study will also examine the impact of information on perceptions and WTP for vertically farmed lettuce. Since vertical farms are likely unfamiliar to consumers, we provide an information sheet to a subset of consumers that compares vertical farm, greenhouse, and field farm production systems on a number of attributes to determine whether and how increased familiarity with vertical farming affects perceptions and WTP values.

CHAPTER 2

METHODOLOGY

2.1 AUCTION MECHANISM

Our study uses the Becker-DeGroot-Marschak (BDM) auction mechanism to elicit consumers' WTP (Becker, DeGroot, and Marschak, 1964). In the BDM procedure, each participant places a bid on a good or goods. A random number is then drawn and if a participant's bid is greater than the random number, he receives the good and pays the value of the random number. If his bid is less than or equal to the random number, no transaction is made. In different variants of a BDM auction, participants' bids are limited by minimum and maximum values to fall in a certain range. In our study, we limited bids to values between $0 and $5 (just above the maximum value we thought participants would be willing to pay) to ensure that any purchase transactions could be covered by the participant recruitment fee. Participants placed bids on lettuce grown from three different agricultural production systems (vertical farm, greenhouse, field farm); we randomly chose one of the three bids to be binding.

One advantage of the BDM auction mechanism is that it is theoretically incentive compatible. That is, each individual has a dominant bidding strategy that reveals their actual valuation (Lusk, Feldkamp, and Schroeder, 2004). Another benefit of using the BDM auction is that participants are unlikely to be influenced by other bidders. Each participant is bidding against a random number, so the result of the auction does not depend on the bids of other participants. The BDM auction also allows participants to bid on multiple goods in a single round rather than placing sequential bids as in an English auction. Reducing the number of bids and responses required from participants minimizes the potential for respondent fatigue (Savage

and Waldman, 2008). BDM auctions are widely used in the economics literature and have been used to determine WTP for consumer goods as various as beef and baseball cards (Corrigan and Rousu, 2008; Lusk, Feldkamp and Schroeder, 2004; Noussair, Robin, and Ruffieux, 2004; Rozan, Stenger, and Willinger, 2004).

A potential limitation of our BDM procedure is that we conducted our auctions in a computer laboratory on a college campus. Since this is not the typical setting consumers make lettuce purchase decisions in (e.g., grocery store), it is possible their bidding behavior may differ in the laboratory. In other words, the external validity may be limited (Harrison and List, 2004). Lusk and Hudson (2004) further note that bids can also be affected by alternatives. If a participant can easily purchase the same lettuce outside of our study, there is no incentive to bid above the market price. Additionally, the BDM auction mechanism can produce many zero bids if participants are not interested in purchasing the good (Lusk and Hudson, 2004); however, this concern is mitigated in the current study by recruiting subjects who are consumers of the product in question. Finally, the minimum and maximum allowable bids can affect consumer valuation of a good. If the upper bound is unrealistically high, participants in previous studies have seemingly mistakenly placed bids higher than their actual WTP (Bohm et al., 1997).

2.2 PARTICIPANTS AND RECRUITMENT

This study was conducted in January 2016. In total, 117 participants were recruited from the University of Illinois campus and the surrounding community. To be eligible for the study, participants were required to be at least 18 years of age and consumers of lettuce. Participants were paid $5 for attending a 20-minute session that included the BDM auction and an accompanying survey. Across the study period, 20 sessions were held, averaging almost six

subjects per session. One observation was removed from the sample due to a participant misunderstanding auction procedures, leaving 116 observations in the final sample.

2.3 EXPERIMENTAL DESIGN

Upon arrival at the research sessions, participants received their remuneration, and the session moderator explained the consent form to all participants. Next, the session moderator explained how the BDM auction procedure would work. This was accomplished through a practice candy bar auction – a common practice in the literature (see Huffman et al., 2003; Corrigan and Rousu, 2008 for examples). The moderator selected a volunteer to participate in the practice auction. The volunteer came to the front of the room and placed bids for three different types of candy bars to mimic the bidding process for the three types of lettuce. One of the candy bars was randomly selected to be binding, and a random price was generated in accordance with the BDM procedure. In the event that a participant bid higher than the randomly generated price, the participant paid the researcher for the candy bar to emphasize that bids could indeed be binding, leading to a monetary transaction.

After the practice auction, sessions were randomized to either receive information about the three agricultural production systems of interest (referred to as the treatment group) or to receive no information (referred to as the control group). For the treatment sessions, a table with information about vertical farms, greenhouses and field farms was provided to all participants. The table contained a picture typical of each production system as well as nine pieces of information such as water use, electricity use and pest control use for each of the production systems (see figure 1; Green Spirit Farms; Mossler & Dunn, 2005; Takele, Aguiar, & Walton, 1996; Dickie, 2015). The moderator discussed the information sheet, allowed participants to ask any clarification questions, and then had participants answer comprehension questions at the start

of their surveys to ensure they understood the information presented. Participants had to correctly answer the questions before they proceeded to the rest of the survey. Participants in the control group did not receive any information about agricultural productions systems and proceeded directly from the practice candy bar auction to the survey. The remainder of the study was the same for the treatment and control groups.

The survey was hosted on the Qualtrics survey platform and began by repeating the instructions for a BDM auction to ensure subjects fully understood the BDM mechanism. All subjects then participated in a second practice auction, this time for three different kinds of pizza. After completing the auction, participants answered comprehension questions on the BDM auction mechanism. Correct answers were required before continuing on to the lettuce auction.

For the lettuce auction, participants placed three bids for 5 ounce boxes of lettuce produced by a vertical farm, greenhouse and field farm. The order of the bidding was randomized to control for order effects. The session moderator showed participants a sample box of lettuce in order to communicate the quantity of lettuce they were bidding on. After placing the three bids, participants were told they would find out the result of the auction after completing the rest of the survey. We follow the lead of other studies in using WTP as the most appropriate measure of consumer acceptance (Henson, 1995).

The remainder of the survey began with comparison questions about the three agricultural production systems. Participants were asked to rate their perceptions of lettuce grown from each production system with regard to safety, quality and naturalness. These perceptions have been studied with regard to other food production technologies such as cheese processing (Frewer et al., 1997). Additionally, subjects were asked to indicate their knowledge level of each of the production systems as well as how willing or unwilling they expected the average consumer to

be to buy lettuce grown in each of the production systems. Responses were indicated on a five point scale (e.g. 1=very unsafe, low quality, unnatural, low knowledge, very unwilling to buy and 5=very safe, high quality, natural, high knowledge, very willing to buy).

In addition to perceptions, participants were asked to respond to nine statements related to their beliefs about farming. The statements corresponded to the information given to the treatment group, but both the control and treatment groups were asked about their beliefs to determine if the information impacted them. Sample statements included "Farmers use too much water," "Farms should only use natural lighting" and "Farmers should always maximize production per acre." For each statement, subjects indicated their level of agreement on a five point scale where 1=strongly agree and 5=strongly disagree.

In the next section, participants were asked about their beliefs related to vertical farming specifically, including potential benefits and concerns with this production system. For example, subjects indicated the extent to which they agreed with "Vertical farming will improve the standard of living for future generations" and "Vertical farming will cause health risks in human beings" using the same five point scale described above. These questions followed the work done in previous research on consumer acceptance of genetically modified food products (Bredahl, 2001). To learn more about consumers' perceptions of vertically farmed lettuce, subjects were questioned about where they expected this product to be sold. Since this survey was restricted to a single community, specific store names were used; however, several broad store types were represented such as supercenters (Walmart, Target, Meijer), supermarkets (Schnucks, County Market), specialty stores (Common Ground Food Co-op, Strawberry Fields), and discount stores (Aldi).

The final portion of the survey was dedicated to demographic questions such as age, income, gender and education. Upon completion of this section, participants learned the result of the BDM auction, and lettuce was distributed to those with winning bids.

2.4 DATA ANALYSIS

We modeled WTP as a function of several variables that other studies have shown to have an effect on WTP. We include our information treatment, as well as demographic characteristics such as gender, age, education and income, as these factors have been shown to affect consumer acceptance of other products such as irradiated prawns, GM soybean oil and GM salmon (Cox, Evans, and Lease, 2007, Chern et al., 2003). Previous studies have shown a link between perceptions of risk and consumer acceptance and have noted a "white male" effect in which white males perceive less risks related to various technologies (Slovic, 1999). We include race in our model to measure differences in WTP by racial group. Other studies have also noted a link between beliefs such as religion and acceptance of technology (Ronteltap et al., 2007). In our context, we see political beliefs as a potentially larger influence on WTP. As such, we have included political beliefs in our model.

In addition to factors that have been linked to consumer acceptance in previous research, we also include several other variables in our model. The variable *Children*, which indicates the presence of children under 18 in the home, may be related to WTP as parents with children may be more conscious of risk than those without children. We also include measures of the frequency of lettuce consumption, experience working on a farm and growing one's own vegetables in a garden. These factors may have an effect on WTP in our specific context as we measure WTP for lettuce produced in 3 different production systems.

To determine the drivers of WTP, we analyzed our data using ordinary least squares[1] regression. WTP for individual *i* for production system *s* is modeled as:

$$
\begin{aligned}
(1)\quad WTP_i^s = {} & \beta_0^s(Intercept) + \beta_1^s(Treatment_i) + \beta_2^s(Male_i) + \beta_3^s(Young_i) \\
& + \beta_4^s(MiddleAge_i) + \beta_5^s(HighEduc_i) + \beta_6^s(White_i) + \beta_7^s(Asian_i) \\
& + \beta_8^s(Children_i) + \beta_9^s(LowIncome_i) + \beta_{10}^s(MedIncome_i) + \beta_{11}^s(Liberal_i) \\
& + \beta_{12}^s(Conservative_i) + \beta_{13}^s(FarmWork_i) + \beta_{14}^s(Garden_i) \\
& + \beta_{15}^s(LoveLettuce_i) + \varepsilon_i^s
\end{aligned}
$$

where WTP is the bid placed for a 5 ounce box of lettuce in dollars; Treatment is an indicator variable for receiving information about the three agricultural production systems; Male is an indicator variable for gender; Young is an indicator variable for being 18-24 years of age; MiddleAge is an indicator variable for being 25-44 years of age; HighEduc is an indicator variable for having a bachelors, graduate or professional degree; White is an indicator variable for ethnicity; Asian is an indicator variable for ethnicity; Children is an indicator variable for having children under 18 in one's home; LowIncome is an indicator variable for having household income less than $50,000; MedIncome is an indicator variable for having a household income between $50,000 and $99,999; Liberal is an indicator variable for reporting one's political views as liberal or very liberal; Conservative is an indicator variable for reporting one's political views as conservative or very conservative; FarmWork is an indicator variable for having ever worked on a farm; Garden is an indicator variable for growing one's own vegetables in the past year; LoveLettuce is an indicator variable for consuming lettuce at least twice per

[1] We tested WTP using Shapiro –Wilk W and Shapiro –Francia W` tests for normality and found that we cannot reject the hypothesis that WTP is normally distributed.

week. We dropped variables from the model related to perceptions and attitudes as they had minimal explanatory power.

To determine the different effects of production system and the information treatment on consumer perceptions and WTP, we use repeated measures analysis of variance (ANOVA). We test for main effects of production system and information treatment, as well as for interaction effects between production system and the information treatment. We hypothesize a significant main effect of the production system, such that consumers will rate vertically farmed lettuce differently than the greenhouse or field farm alternatives. We also expect a significant interaction effect on perceptions and WTP where the information differentially impacts perceptions about vertically farmed lettuce. Depending on consumers' attitudes toward agricultural production system attributes, the impact may be favorable or unfavorable; therefore, we do not make a hypothesis on the directionality of this effect. To make multiple comparisons simultaneously, we use Bonferroni adjustments.

CHAPTER 3

RESULTS

3.1 SAMPLE CHARACTERISTICS

Table 1 shows the demographic characteristics of the study participants. Most participants were young (62.1% between 18 and 24 years of age) and female (77.6%). The majority of participants were white (49.1%) or Asian (35.3%). Overall, 56.9% of participants were undergraduate students. There were no significant differences between the control and treatments groups for any of the demographic characteristics measured.

3.2 WILLINGNESS TO PAY FOR LETTUCE BY AGRICULTURAL PRODUCTION SYSTEM

Figure 2 presents the average WTP values from the lettuce auctions for each production system in aggregate as well as by information treatment. On average, participants' WTP for a 5-ounce box of vertically farmed lettuce was $2.23. WTP for the greenhouse grown and field farmed lettuce was $2.28 and $2.36, respectively. An analysis of variance (ANOVA) reveals there were no significant main effects for production system or information treatment. While the information treatment appears to have the largest impact on WTP for vertically-farmed lettuce, the ANOVA indicates there is no significant interaction between production system and information treatment. It is important to note that the differences we observed in WTP for all three types of lettuce were not only statistically insignificant but also practically small. Our measurements for WTP also broadly reflect the market price for commensurate lettuce.

3.3 PREDICTORS OF WILLINGNESS TO PAY

A secondary objective of the study was to see which (if any) consumer characteristics influence WTP. To examine this, we estimated three regression models as specified in equation 1, with WTP for lettuce from each production system serving as the dependent variables (table 2). We find that gardening is associated with a $0.40 decrease in WTP for vertically farmed lettuce, whites had a $0.78 lower WTP for field farmed lettuce compared to people of other ethnicities and Asians had a $0.61 lower WTP for vertically farmed lettuce and a $0.64 lower WTP for field farmed lettuce compared to people of other ethnicities. However, there were no other significant effects for socio-demographic variables such as age, income and gender across the three model specifications.

Beyond socio-demographic variables, we find that the information treatment was associated with a $0.53 decrease in WTP for vertically farmed lettuce (table 2). The estimates for the effect of the information treatment on WTP for greenhouse lettuce and field lettuce were also negative, but smaller in magnitude and not statistically significant. The negative direction of our three coefficient estimates may be because the information sheet highlighted aspects of each system regarding resource usage (water, electricity, etc.) that many consumers were not aware of or may not have found to be desirable.

It is also possible that the information had a larger impact in the case of vertically farmed lettuce because consumers were less familiar with vertical farming (and therefore more willing to change/update their valuation after learning about it). Table 3 shows that participants indicated they were, on average, less familiar with vertical farming than greenhouse or field farming, so consumers may be most responsive to information on this particular system.

To better understand bidding behavior, we asked participants to explain how they developed their bids for the vertically farmed lettuce. The most commonly cited factors participants listed for determining their bid were expectations about production costs. For participants who received the information treatment, the effect was even more pronounced, with participants focusing on the potential of vertical farms to produce large amounts of lettuce. These responses were likely referencing the part of the information sheet that listed production for a vertical farm at 5,000,000 heads of lettuce/acre/year (in comparison to field farming producing 50,000 heads of lettuce/acre/year). One participant wrote that a vertical farm's production is "enormous… it produces a whopping 5,000,000 heads of lettuce…." Another wrote that since the production in a vertical farm is "significantly higher" than a greenhouse or field farm, "the cost of each 5 ounce container of lettuce from a vertical farm would be less.…"

The likelihood that differences in production per acre between agricultural systems resulted in lower cost expectations, and therefore lower WTP, may indicate a lack of consumer literacy among our participants. An underlying assumption of numerous qualitative responses seems to be that higher yield per acre is associated with lower cost lettuce. However, we did not provide any information directly regarding costs of production. Further, the fact that participants seemed willing to base their WTP on what they perceived as costs of production does not fit neatly with neoclassical economic theory. It may be the case that participants considered other factors beyond their own costs and benefits when determining WTP.

3.4 CONSUMER PERCEPTIONS OF LETTUCE BY AGRICULTURAL PRODUCTION SYSTEM

Participants rated their perceptions of lettuce grown in three agricultural production systems – vertical farming, greenhouse farming and field farming – with respect to naturalness,

safety, quality and willingness of the average consumer to buy (table 3). For each variable of interest, there were significant main effects of production system. For safety and quality ratings, vertically farmed lettuce was rated lower than greenhouse grown but higher than field grown lettuce; however, only the safety ratings significantly differed across the three production systems. Despite strong quality and safety ratings, vertically farmed lettuce was considered to be the least natural (average ratings were 3.1, 3.5, and 4.4 for vertical farm, greenhouse, and field farm, respectively) and the least likely to be purchased by the average consumer (vertical farm=3.0; greenhouse=3.6; field farm=4.3). The information treatment had little impact on the ratings within or across production systems; the only significant production system*information treatment interaction was for the natural rating (interaction p=0.020). Here, we observed that participants in the control group rated vertically farmed and greenhouse grown lettuce as equally natural; however, once information was provided, vertically farmed lettuce was perceived to be significantly less natural than both greenhouse and field grown lettuce.

Knowledge of the three production systems was also assessed. Not surprisingly, the average knowledge level of the vertical farm system was significantly lower than knowledge of greenhouse and field farm production systems, but the information treatment improved consumers' knowledge of vertical farming (p=0.068).

Lastly, participants indicated how much they expected a 5-ounce container of lettuce to cost that was grown in each production system. Overall, we observed a significant production system main effect such that participants expected vertically farmed lettuce to cost significantly less than field grown lettuce ($2.45 vs. $2.77). It should be noted, though, that this result is driven primarily by the participants who received the information treatment. Participants in the control group did not expect any significant cost differences for lettuce grown in the three

production systems. However, participants in the treatment group expected the cost of a 5-ounce box of vertically farmed lettuce to be $0.68 cheaper than a box of field farmed lettuce.

3.5 ATTITUDES AND BELIEFS ABOUT VERTICAL FARMING AND AGRICULTURAL PRODUCTION PRACTICES

To gain more insight as to how consumers may react to vertically farmed lettuce (and eventually other produce) in the marketplace, we asked participants to rate their level of agreement with several statements related to vertical farming (table 4). Generally, it appears that consumers viewed vertical farming positively. The statements that received the highest levels of agreement were "Vertical farming can be used to solve environmental problems" and "Vertical farming will reduce the price of lettuce." Conversely, the statements with the lowest levels of agreement were "Vertical farming will cause health risks in human beings" and "Vertical farming will cause environmental problems." Participants were less certain about whether vertical farming will produce healthier lettuce and whether vertical farming is unnatural. The information treatment had no significant impact on the level of agreement with any of the statements.

Looking at participants' beliefs about agricultural production practices more broadly, this further suggests certain aspects of vertical farming are desirable (table 5). We observed high levels of agreement in response to the statement "Growing crops year-round is a good thing" and low levels of agreement with "Pesticides should be used to grow lettuce". Further, participants in the information treatment group had significantly higher levels of agreement with the statements "Growing crops at a faster rate is a good thing" ($p=0.048$) and "Farmers should always maximize production per acre" ($p=0.017$). These beliefs about agricultural practices

suggest that participants are open to a type of agriculture, such as vertical farming, that uses land intensively to grow pesticide-free plants at an accelerated pace year-round.

As an alternative indicator of how participants see vertically farmed lettuce fitting into the current marketplace, we asked participants to identify which type(s) of stores they expected to sell vertically farmed lettuce. As shown in figure 3, store expectations were quite different between the treatment and control groups. Those participants who did not receive information envisioned vertically farmed lettuce to be sold at a variety of stores, with high-end, specialty food stores such as Common Ground Food Co-op and Strawberry Fields being two of the three retailers most frequently selected. For those participants who received information, however, the specialty food stores were the two least frequently selected as potential sellers of vertically farmed lettuce. Instead, supercenters such as Walmart, Meijer and Target were most frequently selected as stores that would sell vertically farmed lettuce. Additionally, the proportion of individuals selecting Aldi (a discount retailer) was significantly higher in the treatment group. These results indicate that consumers who are unfamiliar with the vertical farming production system view vertically farmed lettuce as a premium product that would be sold in premium stores. As consumers learn more about the production efficiencies of vertical farming, though, their perceptions may adjust such that vertically farmed produce is a low-cost product that would be sold in supercenters and other discount grocers.

CHAPTER 4

CONCLUSION

Our measurements of WTP suggest that many consumers see vertical farming as a comparable – and perhaps acceptable – form of agricultural production. WTP observed for vertically farmed lettuce was similar to that of greenhouse or field farm produced lettuce. In addition to having similar WTP values across production systems, consumers rated the safety and their expected quality of produce from all three production systems at similar levels (table 3). We see this as evidence that consumers largely fail to distinguish between these agricultural production methods when purchasing lettuce. That being said, it should be noted that study participants still rated vertically farmed lettuce as significantly less natural than other alternatives as well as significantly less likely to be purchased by the average consumer. Thus, while vertical farming may be one marketable solution to the problem of slowing yield growth and limited food supplies in the future, producers and retailers alike need to be prepared for hesitation on the part of consumers – a common occurrence with the introduction of many new food technologies (Bieberstein et al., 2013; Grunert, Bredahl, and Scholderer, 2003; Henson, 1995; Honkanen and Verplanken, 2004; O'Connor et al., 2006; Sparks, Shepherd, and Frewer, 1994).

However, consumer acceptance may change over time as people become more familiar with vertical farming. Participants in our study were largely unfamiliar with vertical farming. When asked to rate their own knowledge of vertical farming, participants in our control group, on average, had a rating of 2.0 on a scale of 1 to 5 (1=No Knowledge, 5=Very Knowledgeable) compared to 3.2 for greenhouse and 3.4 for field farming. When controlling for demographic factors, the information treatment about the three production systems caused a $0.53 drop in WTP for vertically farmed lettuce. We did not observe a significant decrease in WTP for

greenhouse or field farm produced lettuce. It is possible that some of the information about vertical farming, such as its high electricity usage, caused participants to lower their WTP. Assuming the public becomes more knowledgeable of vertical farming as the technology becomes more widespread, WTP for vertically farmed lettuce may decrease across consumer groups. It is also possible that WTP may change in the future due to changes in production costs. Many of our participants linked their WTP with expectations of production costs. Since vertical farming is still a developing technology, production costs could decrease greatly as the industry makes improvements in lighting efficiency and production yields. This improvement could further reduce cost expectations, and consequently also reduce consumer WTP.

4.1 LIMITATIONS

Due to time and budget considerations, our sample size was limited to 116 participants. Although we did not detect significant differences in WTP by production system, average bids for lettuce from each system were not identical (vertical farm: $2.23, greenhouse: $2.28, field farming: $2.36). If these averages correctly identify average WTP for lettuce from each system, it would take a sample of 1197 participants to detect a significant difference between WTP for vertical farm and field farm lettuce at the 5% level, though one may question whether detecting a statistically significant difference of $0.13 would be practically significant.

Another limitation of our study was the brevity of the information treatment. We provided a brief overview of 9 aspects related to production (see figure 1). However, we did not include other relevant information such as location of production, and therefore food miles. Where a product is grown has been shown to be an important consideration for consumers (Loureiro & Hine, 2002).

4.2 AREAS FOR FUTURE RESEARCH

Our research focused on lettuce, as it is one of the most commonly produced crops in vertical farms. However, future research should seek to determine whether our results are generalizable to other crops grown in vertical farms, such as tomatoes. Future research should also examine whether consumers in other geographic areas are willing to accept vertical farming as a production technology.

The indoor nature of vertical farming also presents an interesting research opportunity. A number of restaurants and cafes in Taiwan and elsewhere in East Asia have opened that grow their leafy green vegetables on-site. Consumers can view the lettuce growing behind glass before making a purchase. As such, vertical farming has the possibility to influence consumer behavior in a way that other forms of agriculture cannot. Previous research has shown information at the point-of purchase to be especially influential on consumers (Glanz, Hewitt, and Rudd, 1992; Glanz and Hoelscher, 2004; Kozup, Creyer, and Burton, 2003). An on-site vertical farm could be considered as point-of-purchase information that conveys details about growing conditions, freshness and locality of production to the consumer. Hence, there is the possibility that the presence of a vertical farm in restaurants, lunchrooms and school cafeterias could increase consumption of the fresh vegetables produced in the vertical farm.

FIGURES

	Vertical Farm	Greenhouse	Field Farming
Picture			
Light Source	Artificial lighting	Sunlight and/or artificial lighting	Sunlight
Land Use	365 days/year	365 days/year	About 275 days/year
Soil use	None. Plants grown hydroponically*.	None. Plants usually grown hydroponically*.	Yes. Plants grown in soil.
Harvests per year	8 - 12 for lettuce	6 - 7 for lettuce	Usually 2 for lettuce
Water source	Local water network	Local water network	Rainfall and irrigation
Water use	Low 0.3 gallons/head of lettuce	Low 0.3 gallons/head of lettuce	High 6.5 gallons/head of lettuce
Electricity use	High. Lights run for 12-16 hours per day and heating system must be run in the winter.	Medium. Lights run for a 2-4 hours per day and heating system must be run in the winter.	Low
Pest control use (most common forms)	Enclosed building	Enclosed building	EPA-approved herbicides, insecticides and fungicides as well as traditional methods such as weeding, mulching and plowing.
Production	5,000,000 heads of lettuce/acre/year	1,600,000 heads of lettuce/acre/year	50,000 heads of lettuce/acre/year

*The roots are immersed in water and soak up nutrients from a solution added to the water.

Figure 1. Information Treatment Handout

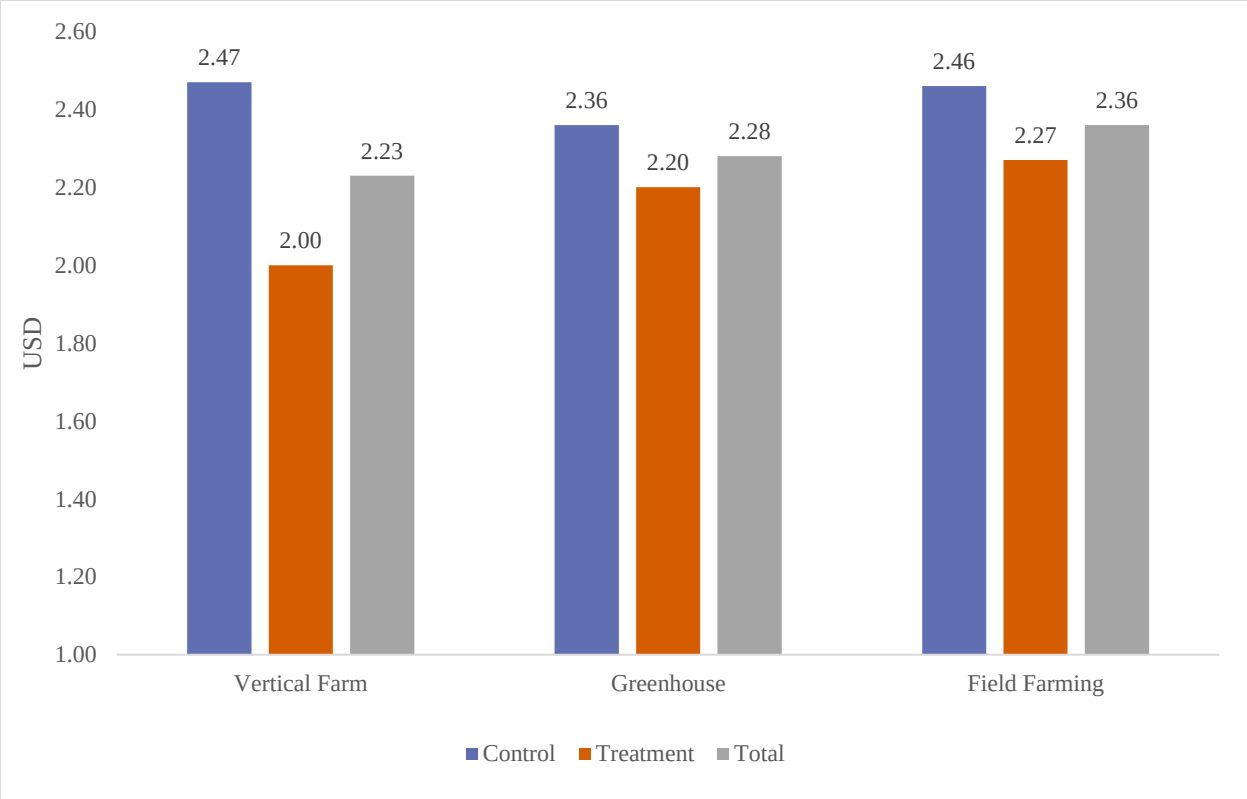

Figure 2. Average Bids for 5 Ounce Box of Lettuce by Production System

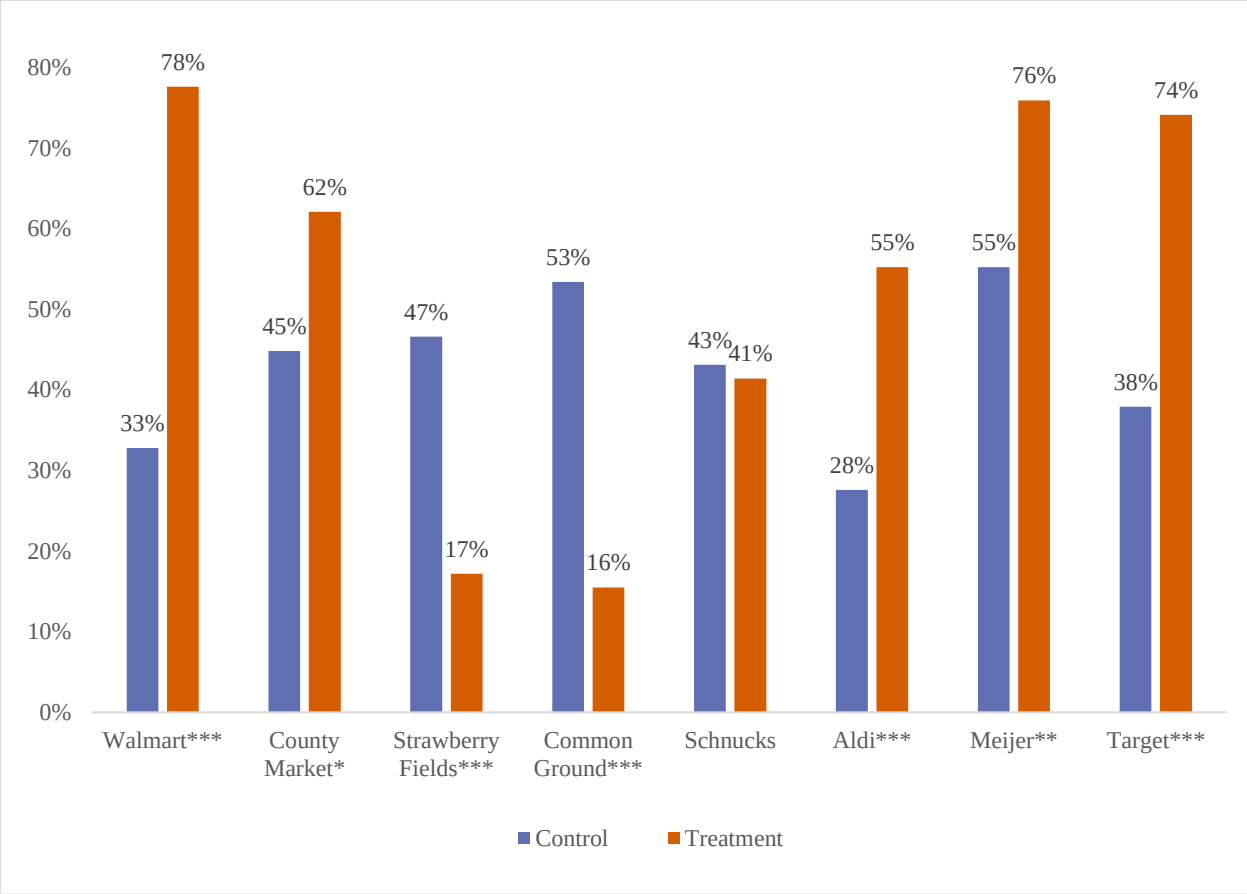

Figure 3. Proportion of Participants who Expect a Grocery Store to Sell Lettuce Produced in a Vertical Farm, by Grocery Store (Note: Asterisks indicate statistical significance between control and treatment groups: * 10%, ** 5%, * 1%)**

TABLES

Table 1. Characteristics of Study Participants and Definition of Variables

Variable	*Definition*	*Sample Proportion (N=116)*
Gender	Male	21.6%
	Female	77.6%
	Other	0.9%
Education	High School Diploma/GED	15.5%
	Some College	38.8%
	Associate's or Technical Degree	0.9%
	Bachelor's Degree	22.4%
	Graduate or Professional Degree	22.4%
Age	18-24	62.1%
	25-34	18.8%
	35-44	12.1%
	45-54	7.8%
	55-64	2.6%
	65-74	1.7%
Annual Household Income	Less than $25,000	29.3%
	$25,00 to $49,999	19.8%
	$50,000 to $74,999	13.8%
	$75,000 to $99,999	16.4%
	$100,000 to $124,999	8.6%
	$125,000 to $149,999	2.6%
	$150,000 or more	9.5%
Ethnicity	White/Caucasian	49.1%
	Asian or Pacific Islander	35.3%
	Hispanic/Latino	4.3%
	Black/African American	1.7%
	More than one	5.2%
	Other	2.6%
	Prefer not to say	1.7%
Children in Home	Yes, children under 18 in household	22.4%
	No children under 18 in household	77.6%

Table 1 (cont.)

Affiliation with University of Illinois	Undergraduate Student	56.9%
	Graduate Student	15.5%
	Faculty	3.5%
	Staff	18.1%
	Other	6.0%
Previous Farm Work Experience	Yes	25.9%
	No	74.1%
Grow Own Vegetables	Yes	44.8%
	No	55.2%
Frequency of Lettuce Consumption	Less than once/month	2.6%
	Once/month	4.3%
	2-3 times/month	21.6%
	Once/week	13.8%
	2-3 times/week	33.6%
	Almost every day	24.1%
Political Views	Very liberal	10.3%
	Liberal	34.5%
	Moderate	44.8%
	Conservative	9.5%
	Very conservative	0.9%
Treatment	No treatment	50.0%
	Information treatment	50.0%

Table 2. Drivers of Willingness to Pay

	Bid for Vertical Farm Lettuce	*Bid for Greenhouse Lettuce*	*Bid for Field Farm Lettuce*
Treatment	-0.530*	-0.218	-0.225
	(0.203)	(0.206)	(0.223)
Male	-0.315	-0.369	-0.201
	(0.256)	(0.260)	(0.281)
Young	-0.091	0.099	0.019
	(0.396)	(0.403)	(0.435)
MiddleAge	-0.200	-0.029	0.015
	(0.362)	(0.368)	(0.397)
HighlyEducated	0.430	0.308	0.159
	(0.315)	(0.320)	(0.345)
White	-0.287	-0.257	-0.784**
	(0.311)	(0.316)	(0.342)
Asian	-0.608*	-0.408	-0.636*
	(0.318)	(0.323)	(0.349)
Children	0.179	0.091	0.164
	(0.251)	(0.255)	(0.276)
LowIncome	-0.129	-0.152	-0.098
	(0.287)	(0.291)	(0.315)
MedIncome	-0.404	-0.220	-0.462
	(0.301)	(0.306)	(0.330)
Liberal	-0.049	-0.175	-0.284
	(0.224)	(0.227)	(0.246)
Conservative	0.280	0.092	0.030
	(0.346)	(0.352)	(0.380)
FarmWork	-0.184	-0.145	-0.119
	(0.240)	(0.244)	(0.264)
Garden	-0.401*	-0.249	-0.381
	(0.225)	(0.228)	(0.247)
LoveLettuce	0.108	0.156	0.172
	(0.206)	(0.210)	(0.227)
Intercept	3.579***	3.147***	3.761***
	(0.868)	(0.882)	(0.953)

Note: Asterisks indicate statistical significance: * 10%, ** 5%, *** 1%
Standard errors are reported in parentheses.
Explanation of variables:
Treatment: received information about agricultural production systems
Male: reported gender as male
Young: age 18-24
MiddleAge: age 25-44
Note continued on following page

Table 2 (cont.)

HighlyEducated: completed Bachelor's, Master's, or professional degree
White: reported ethnicity as white/Caucasian
Asian: reported ethnicity as Asian
Children: children under 18 in household
LowIncome: Less than $50,000/year
MedIncome: $50,000 - $99,999/year
Liberal: identify as liberal or very liberal
Conservative: identify as conservative or very conservative
FarmWork: Previous farm work experience
Garden: grew vegetables in a garden in the past year
LoveLettuce: Eat lettuce at least 2 times/week

Table 3. Average Consumer Perceptions and Attitudes by Production System

Production System	*Knowledge of System*[1]	*Naturalness Rating*[1]	*Safety Rating*[1]	*Quality Expectation*[1]	*Willingness of Average Consumer to Buy*[1]	*Price Expectation*[2]
Vertical Farm	2.3[a]	3.1[a]	3.7[a]	3.8[ab]	3.0[a]	$2.45[a]
Greenhouse	3.1[b]	3.5[b]	4.0[b]	4.1[a]	3.6[b]	$2.57[ab]
Field Farming	3.4[b]	4.4[c]	3.4[c]	3.6[b]	4.3[c]	$2.77[b]

NOTE: Averages that share a common letter in the superscript are not significantly different at the 5% significance level (determined using a repeated measures ANOVA test with Bonferroni corrections for multiple comparisons).
1: Participants were asked to rate their response on a 5 point scale where 1=No Knowledge, Unnatural, Very Unsafe, Low, Very Unwilling and 5=Very Knowledgeable, Natural, Very Safe, High, and Very Willing.
2: Participants were asked to indicate the amount (between $0 and $5) that they expected a 5 ounce box of lettuce to cost.

Table 4. Consumer Attitudes Toward Vertical Farming

Statement	*Level of Agreement**
Vertical farming produces healthier lettuce than field farming.	3.0
Vertical farming will improve the standard of living for future generations.	3.5
Vertical farming can be used to solve environmental problems.	3.6
Vertical farming will reduce the price of lettuce.	3.6
Vertical farming will cause health risks in human beings.	2.4
Vertical farming will cause environmental problems.	2.5
Vertical farming will only benefit producers.	2.6
Vertical farming is unnatural.	2.9

*Level of agreement/disagreement was measured on a 5-point scale where 1=Strongly Disagree and 5=Strongly Agree. There were no significant differences at the 5% level found between control and treatment groups.

Table 5. Consumer Attitudes Toward Farming Practices

Statement	*Level of Agreement**			*Sig.*
	Total	*Control*	*Treatment*	
Farms should only use natural lighting.	2.9	2.9	2.9	0.9236
Growing crops year-round is a good thing.	3.7	3.7	3.8	0.5997
Lettuce should be grown in soil.	3.3	3.4	3.1	0.1119
Growing crops at a faster rate is a good thing.	3.2	3.0	3.4	0.0478
Plants should be exposed to rainfall directly.	3.1	3.3	3.0	0.0847
Farms use too much water.	3.3	3.4	3.3	0.5185
Crops should be grown without the use of electricity.	2.9	2.8	2.9	0.9206
Pesticides should be used to grow lettuce.	2.3	2.3	2.4	0.6273
Farmers should always maximize production per acre.	3.2	2.9	3.4	0.0169

*Level of agreement/disagreement was measured on a 5-point scale where 1=Strongly Disagree and 5=Strongly Agree.

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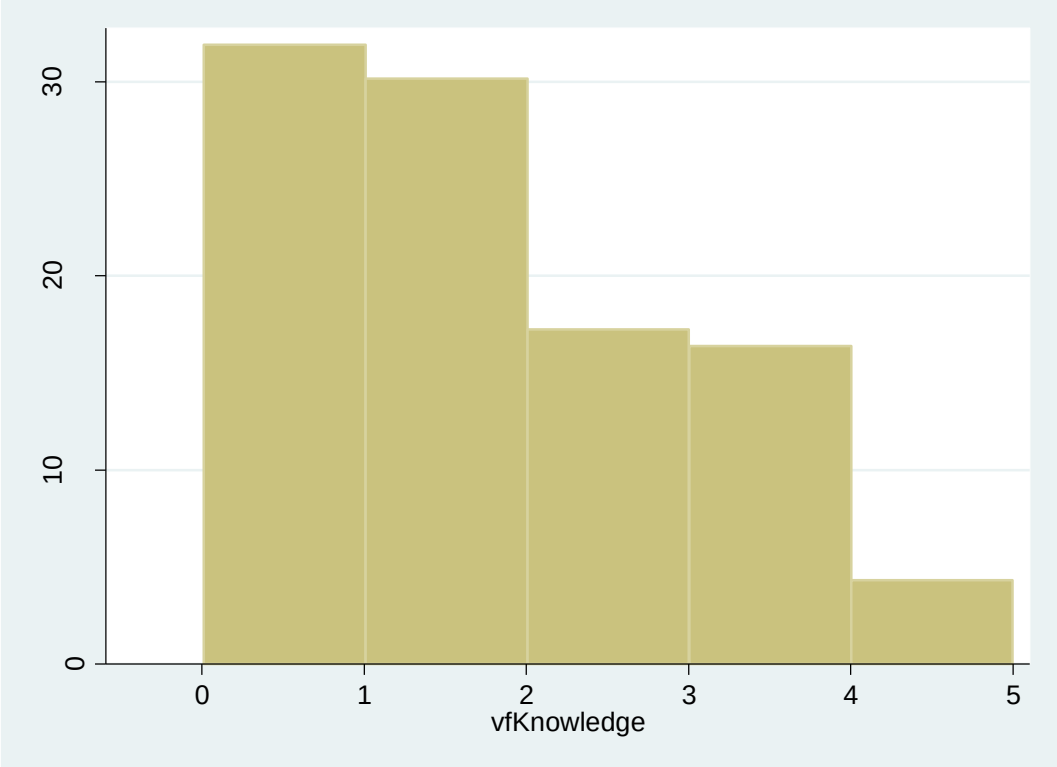
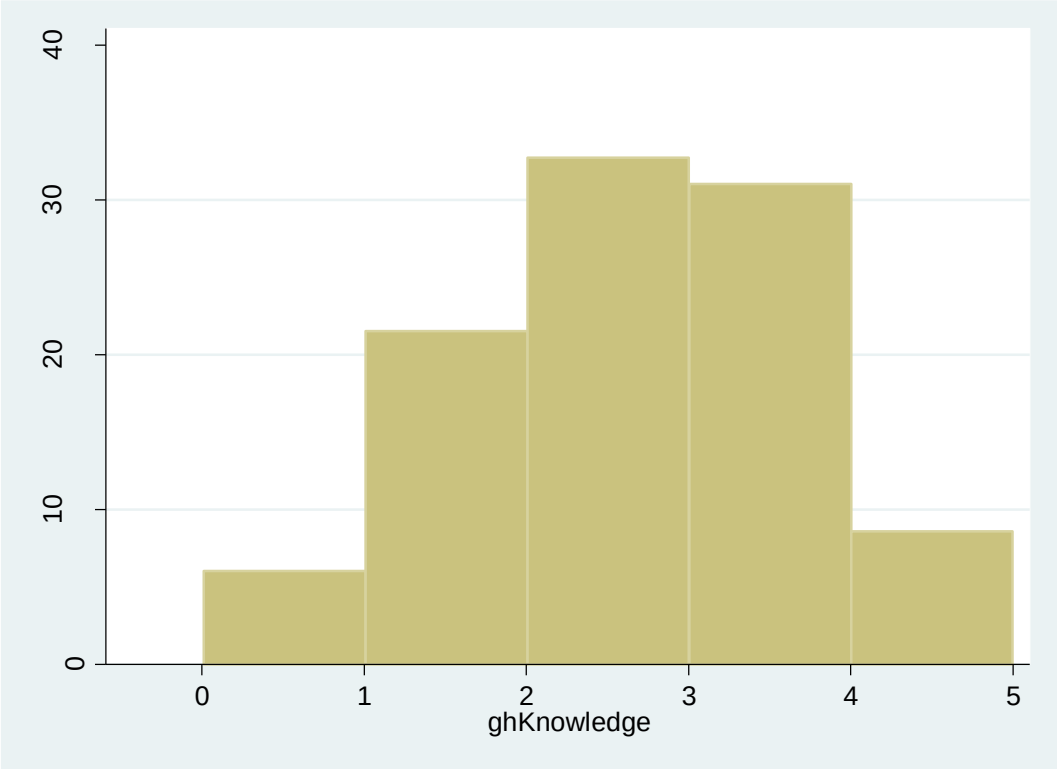
APPENDIX A: Histograms of Responses to Various Statements by Production System

Note: Participants were asked to rate vertical farming, greenhouses and field farming on 6 attributes: knowledge, naturalness, safety, quality, willingness of the average consumer to buy and price expectation. Responses were on a 5 point scale where 1=No Knowledge, Unnatural, Very Unsafe, Low, Very Unwilling and 5=Very Knowledgeable, Natural, Very Safe, High, and Very Willing.

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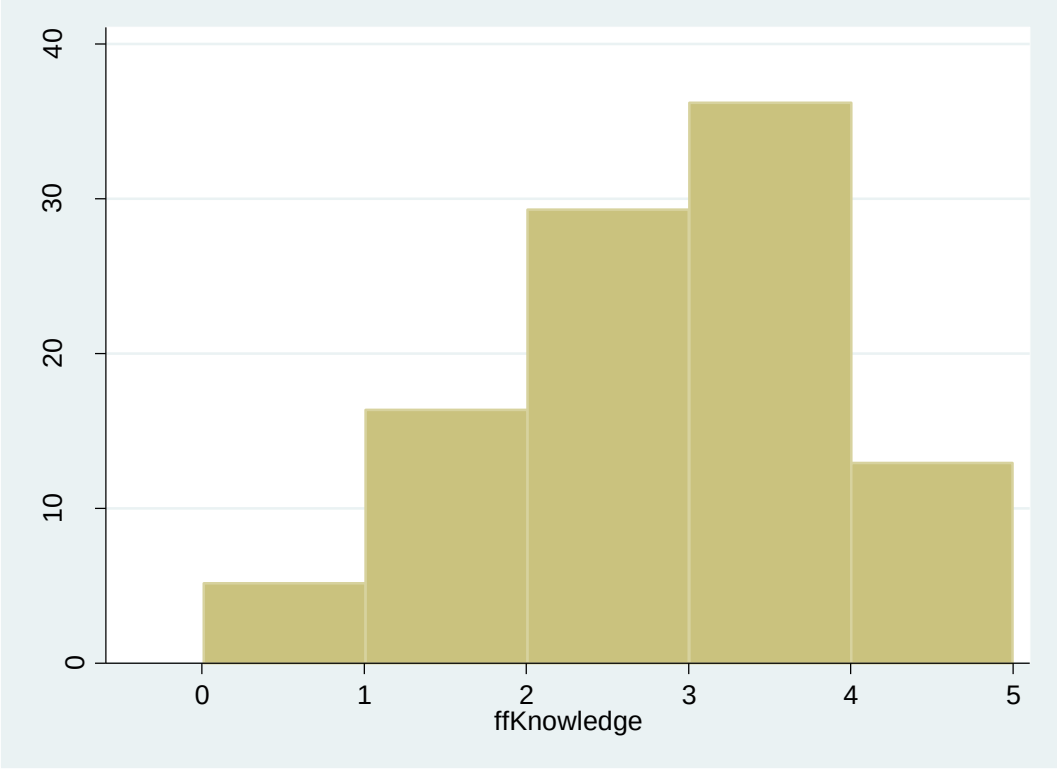
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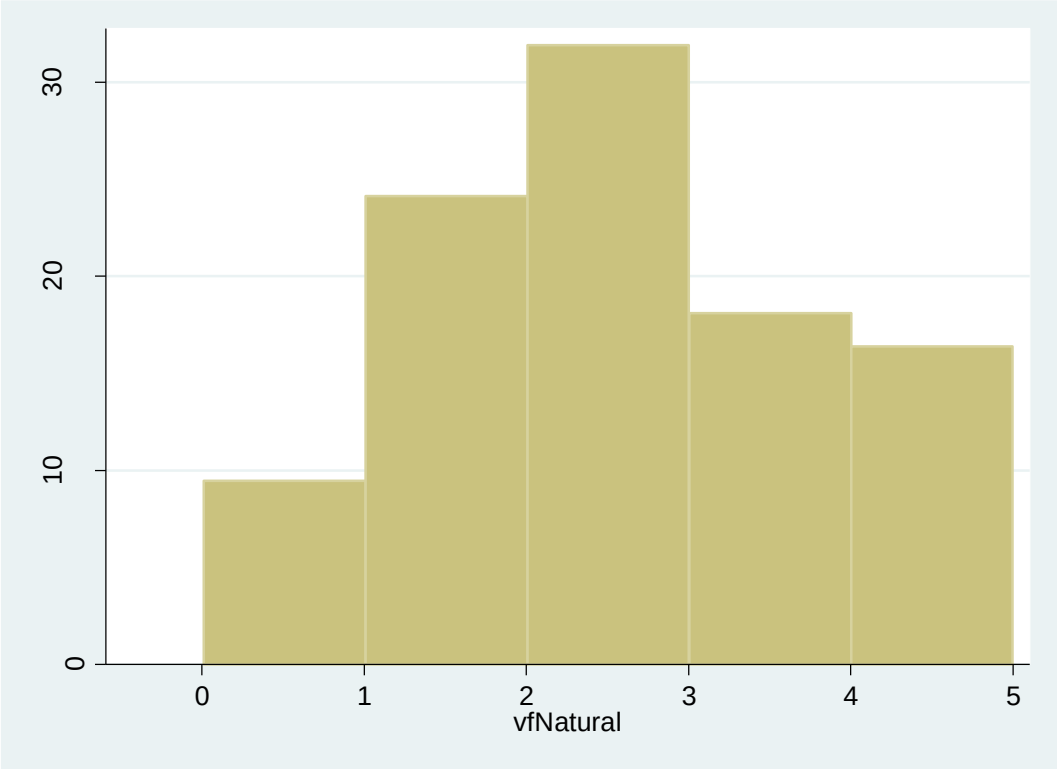
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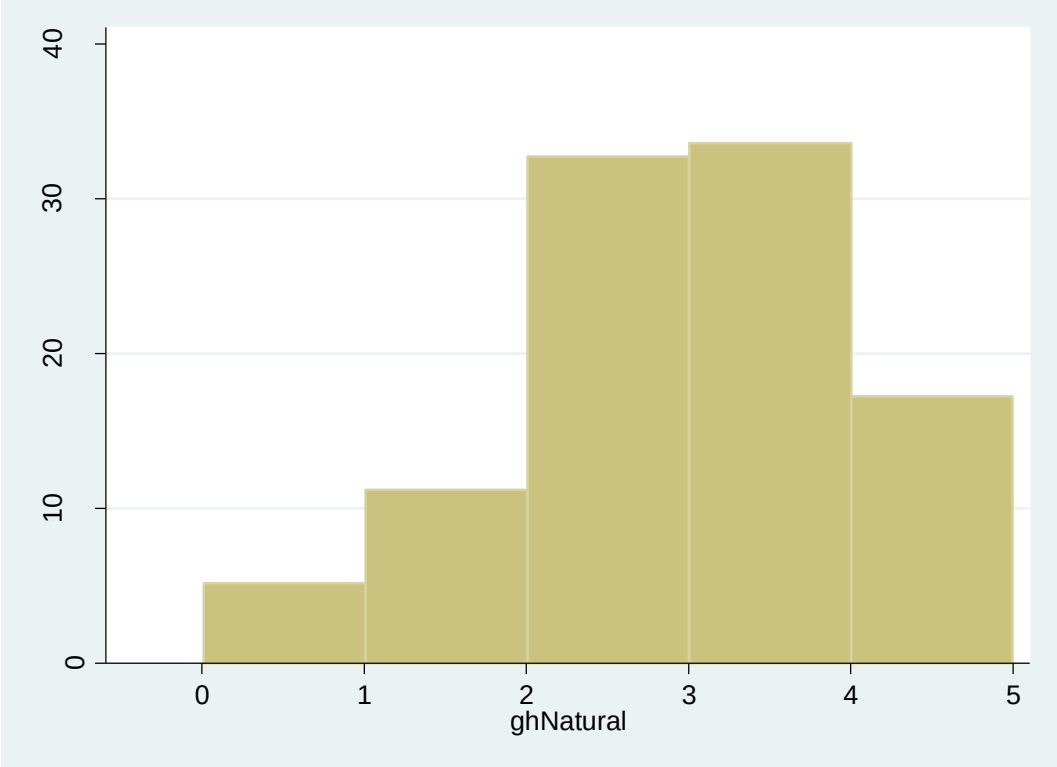
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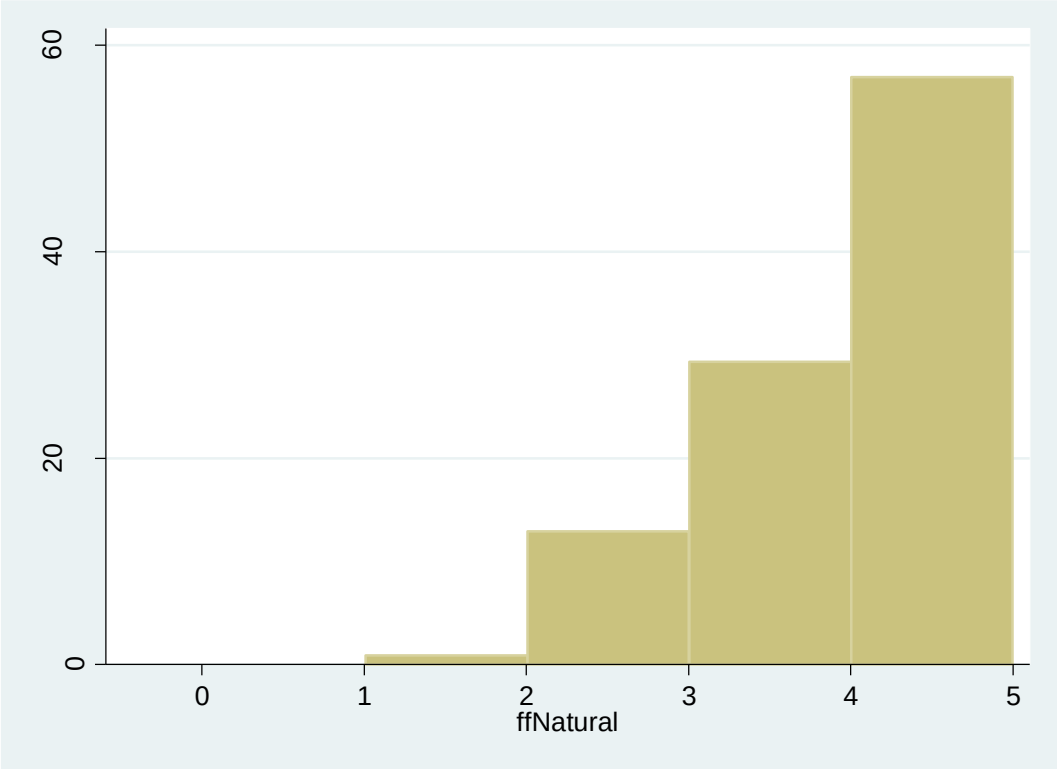
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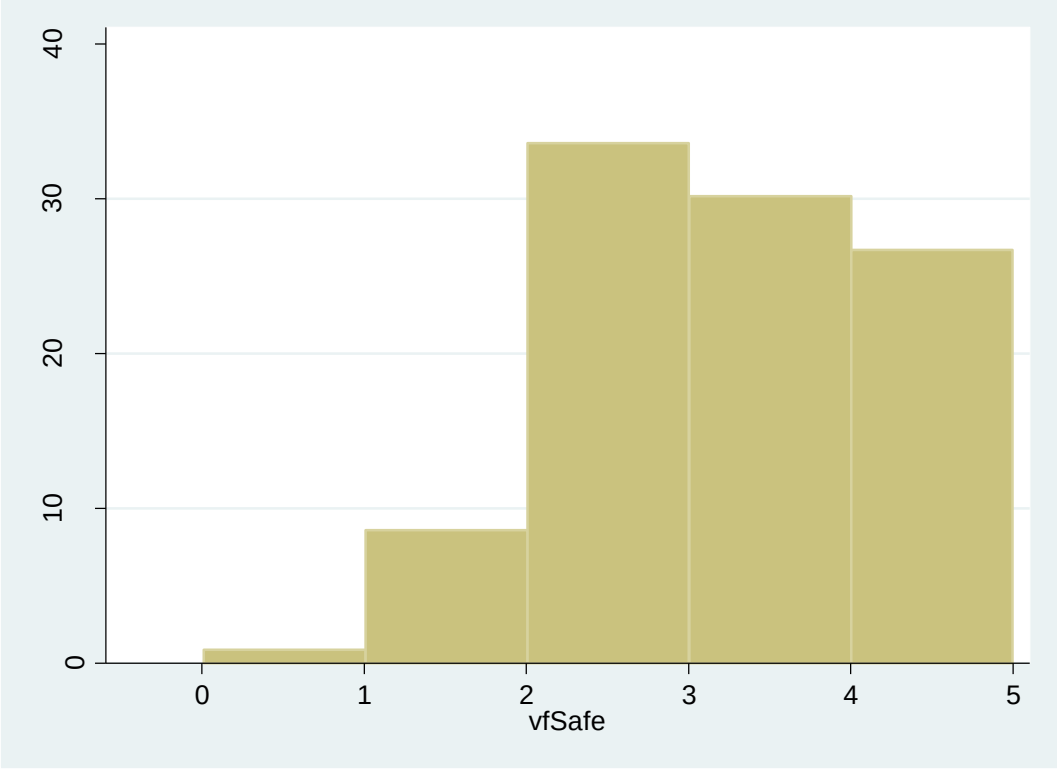
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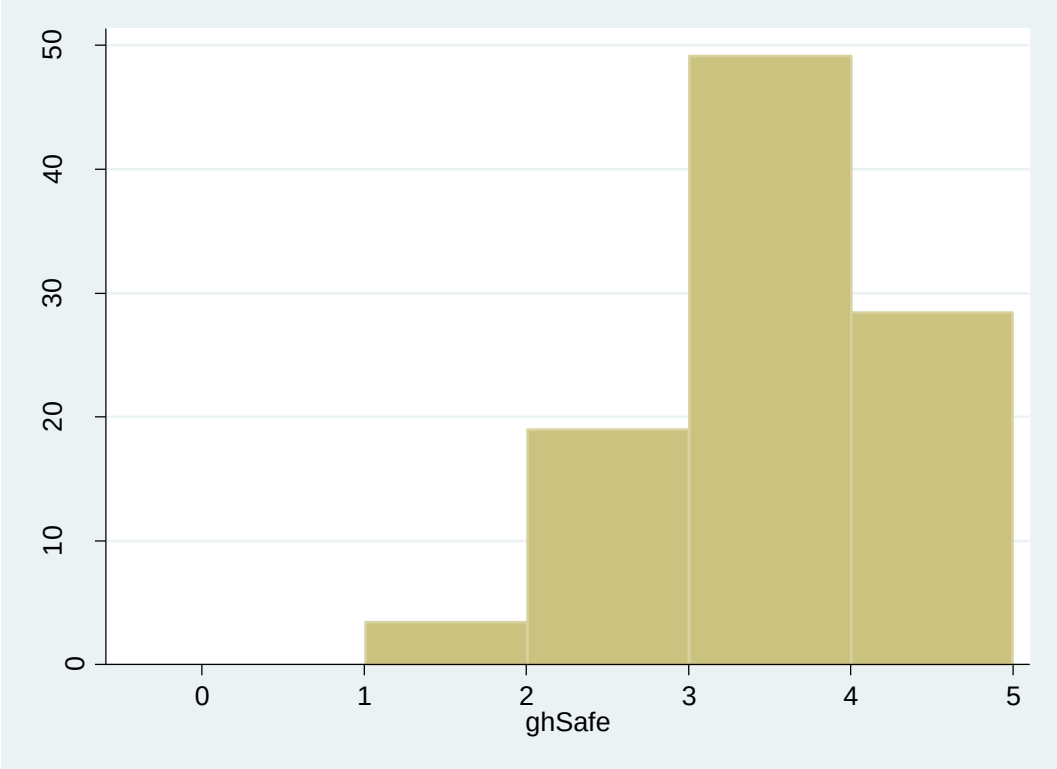
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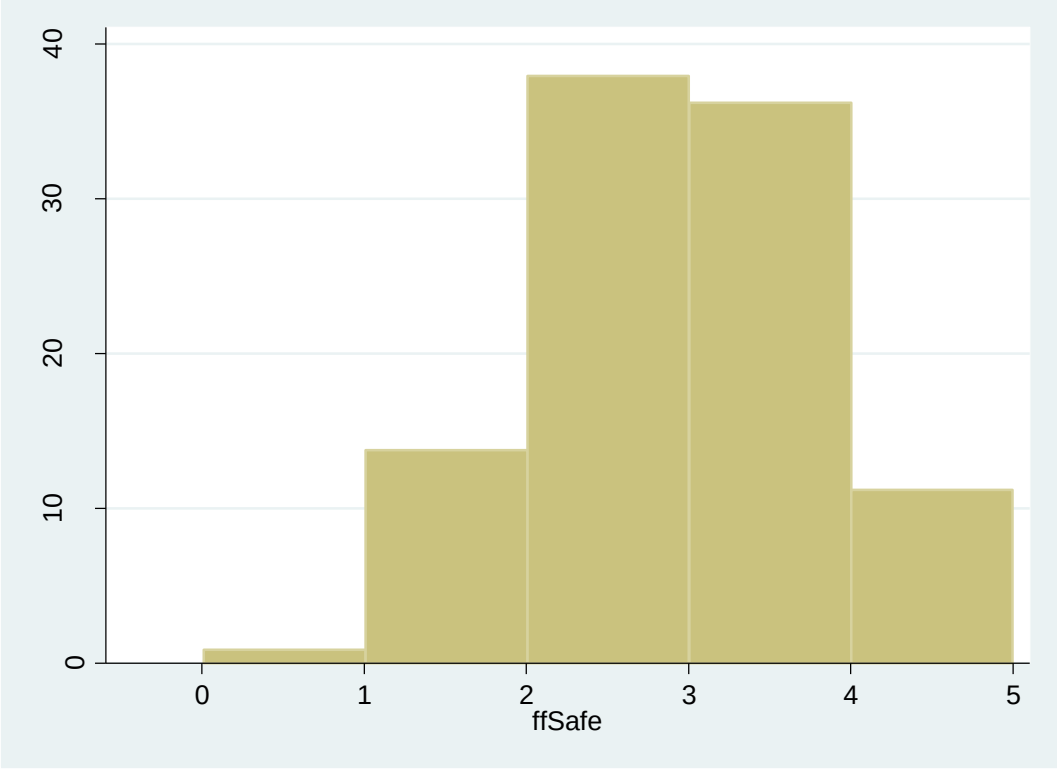
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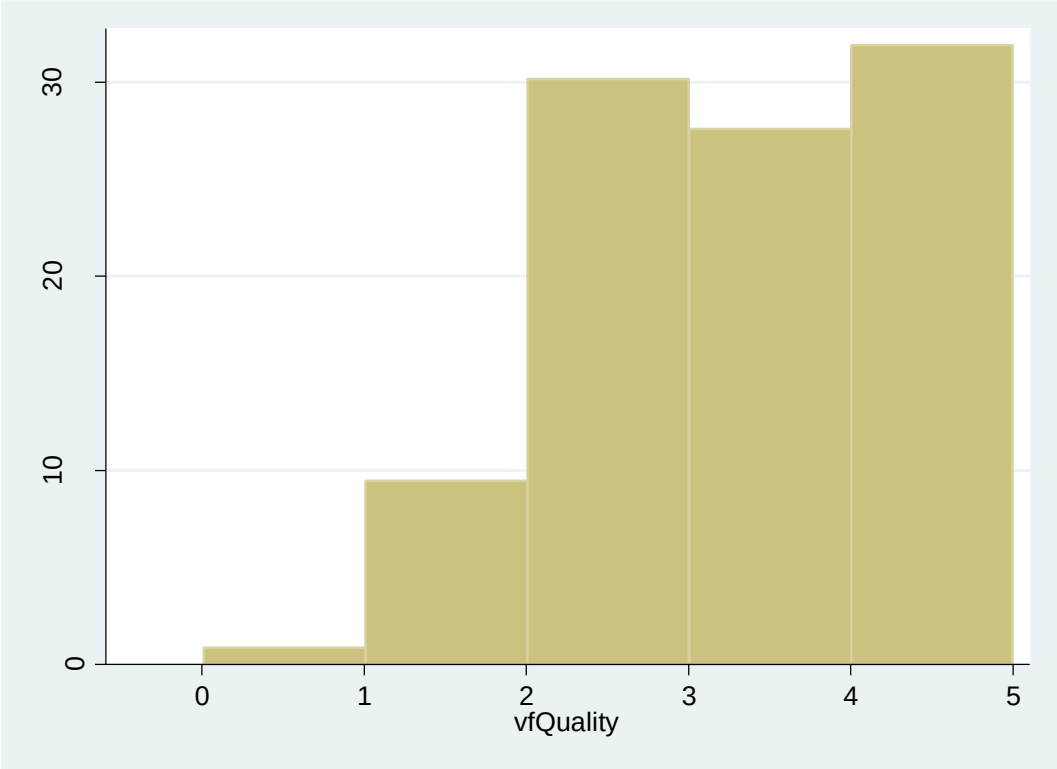
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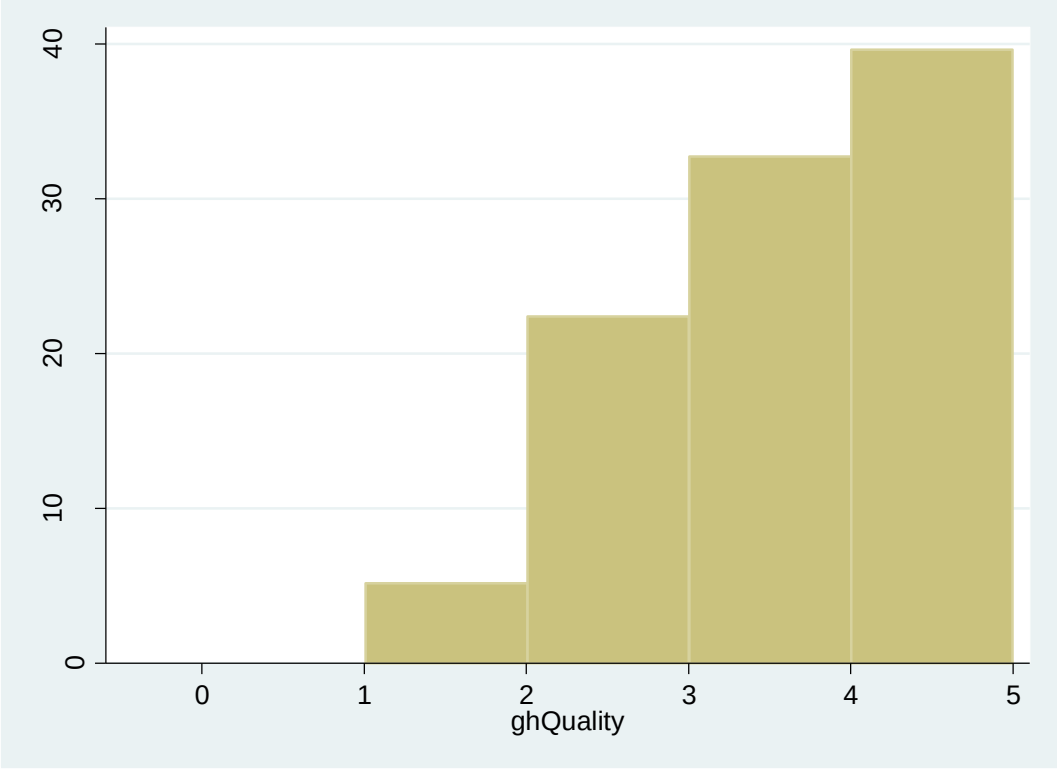
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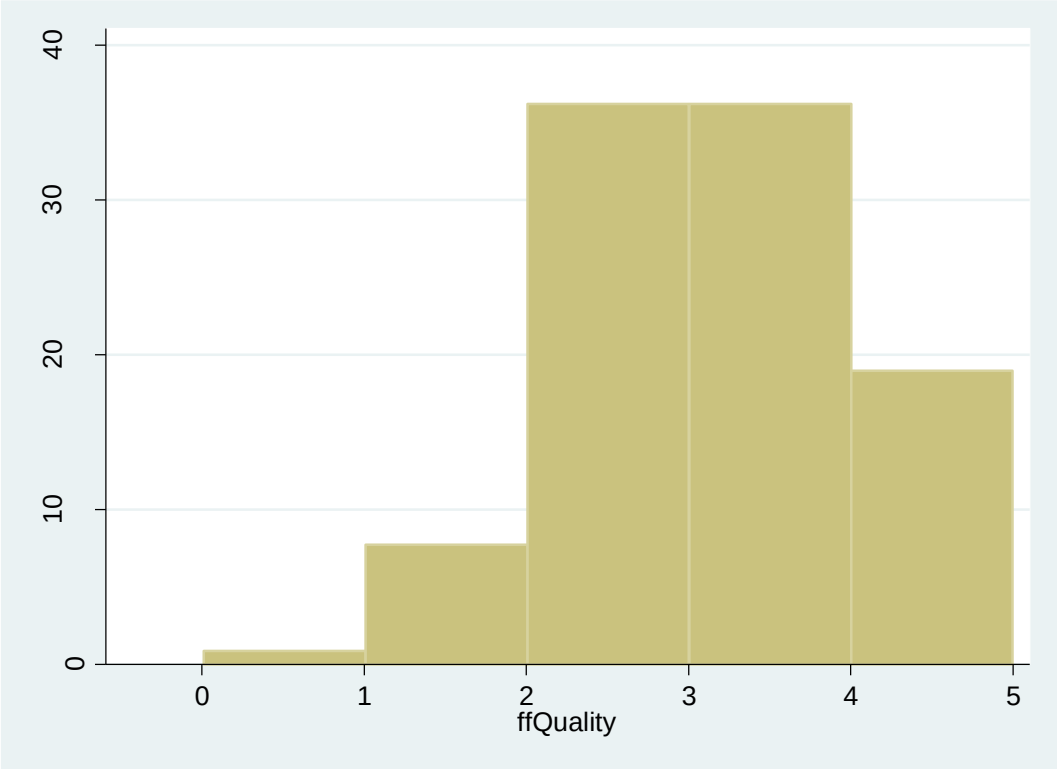
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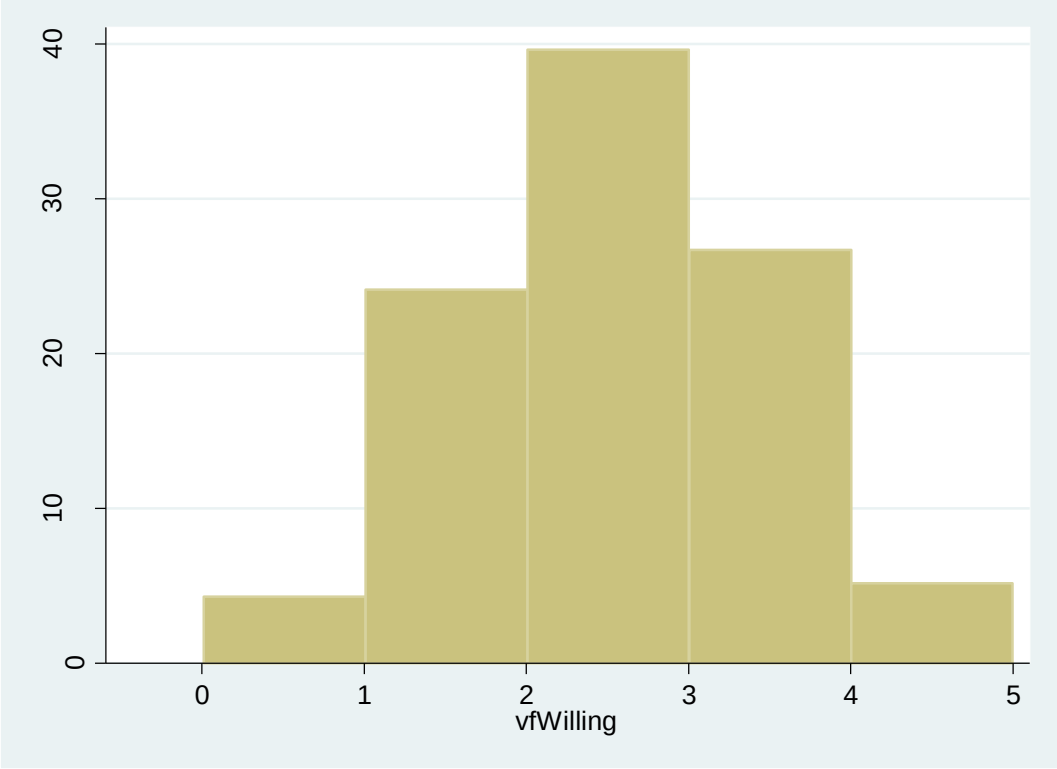
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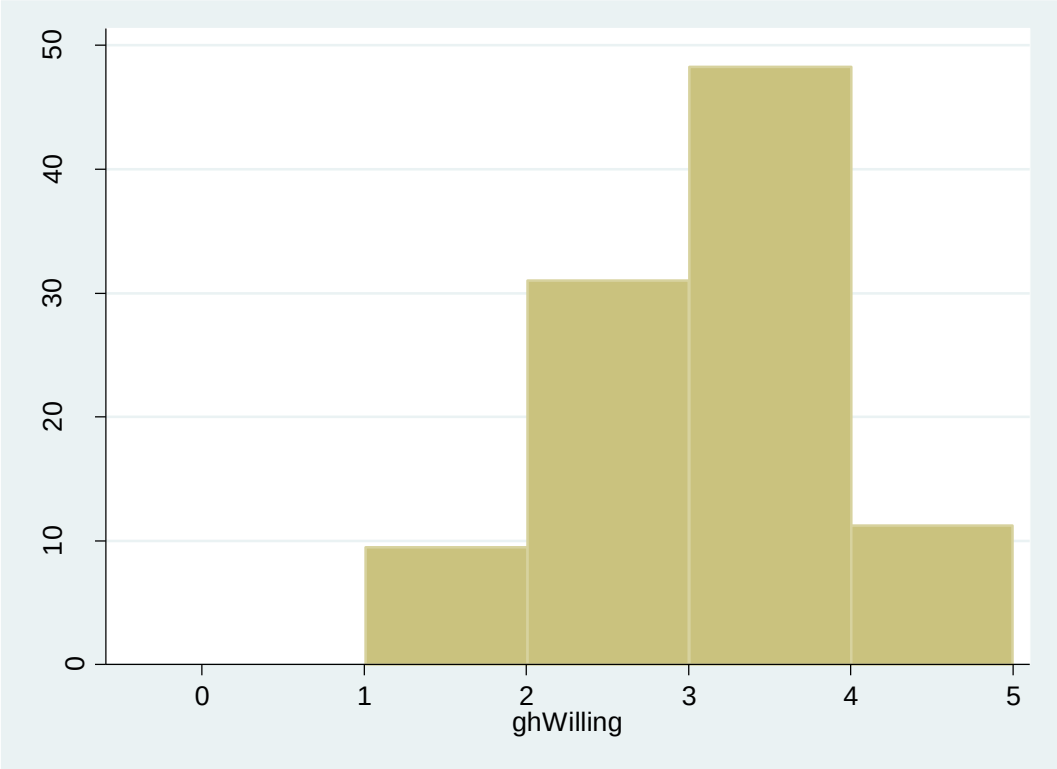
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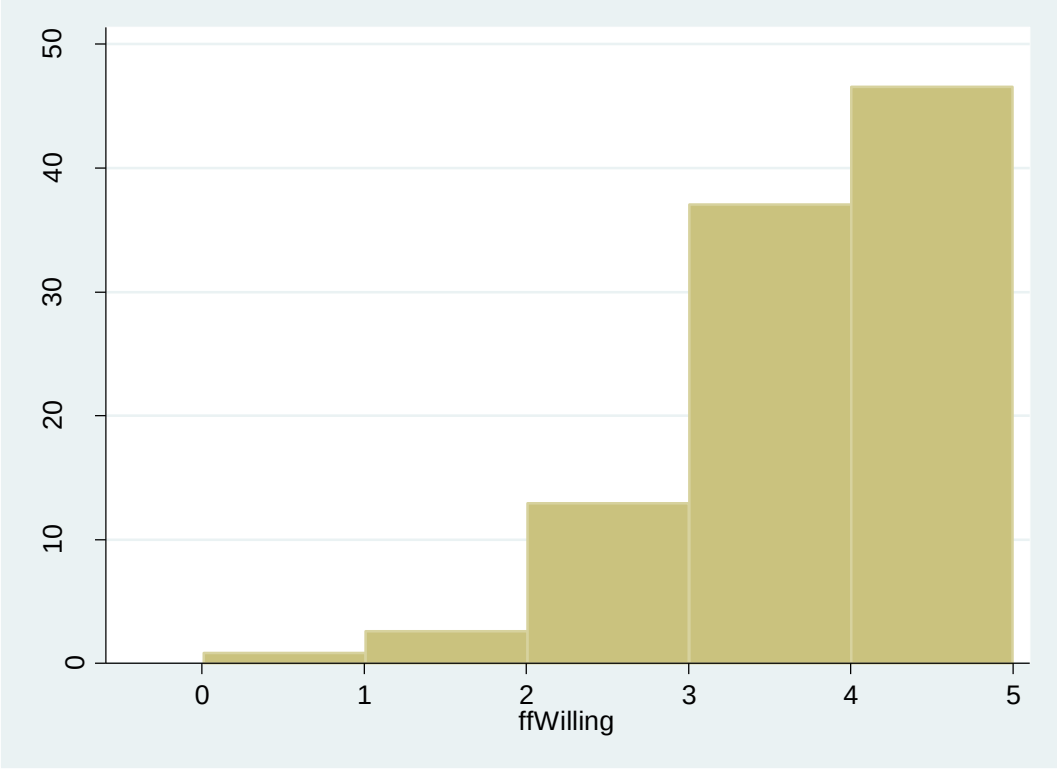
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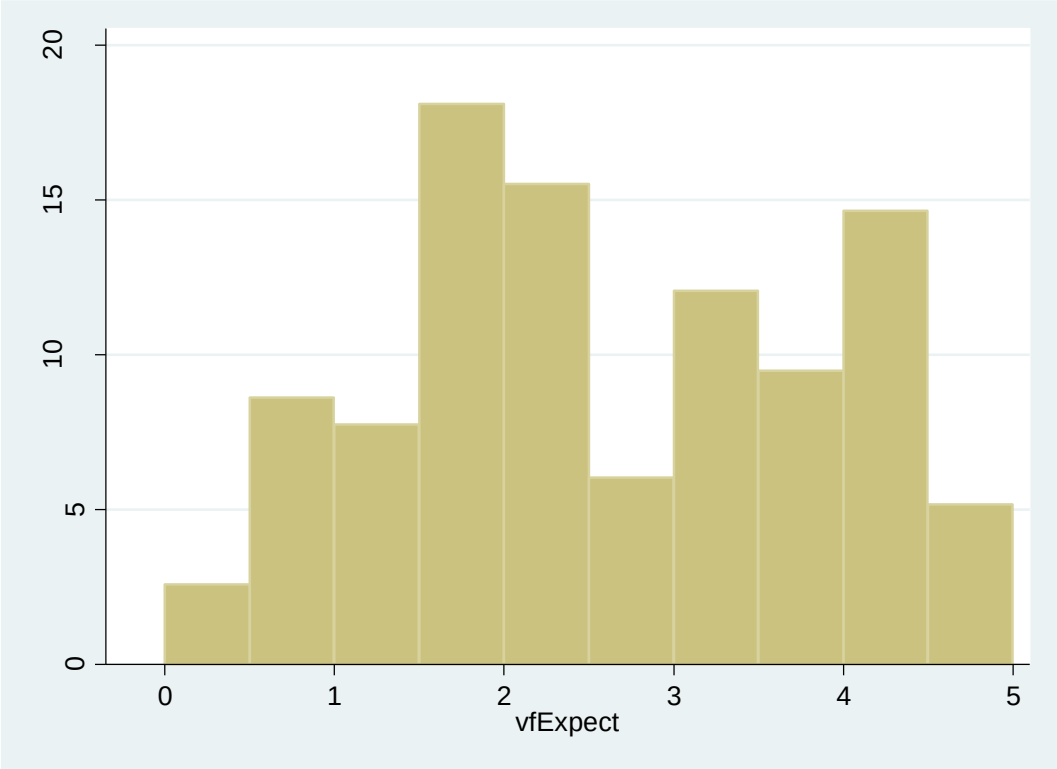
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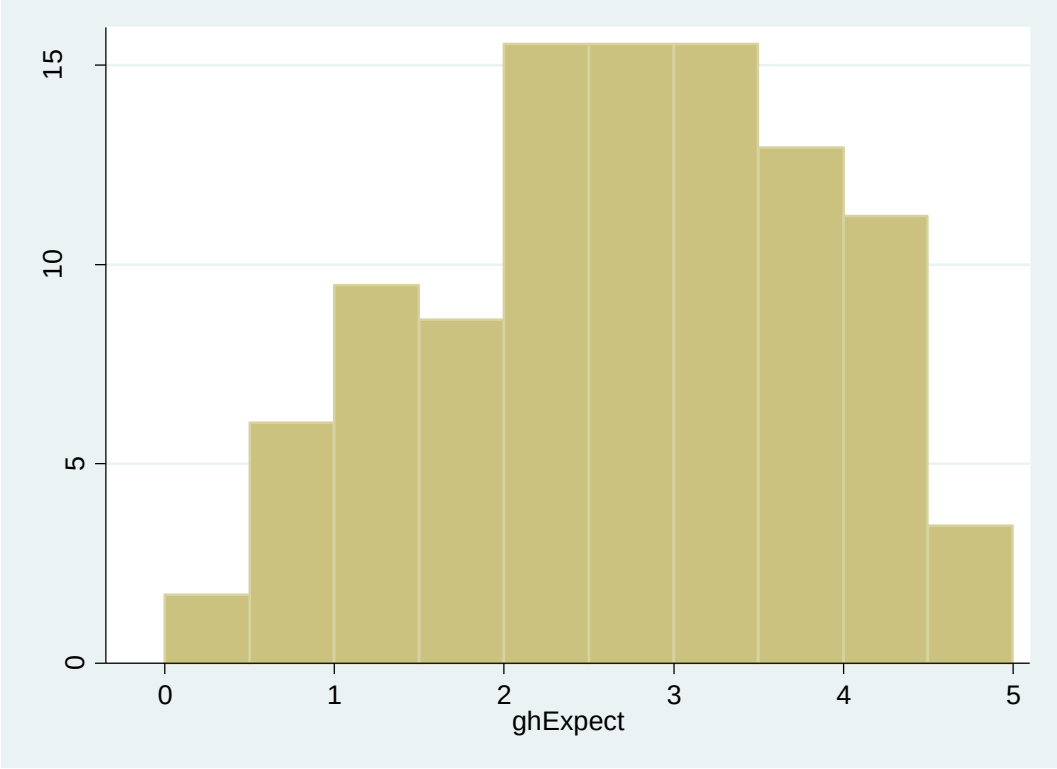
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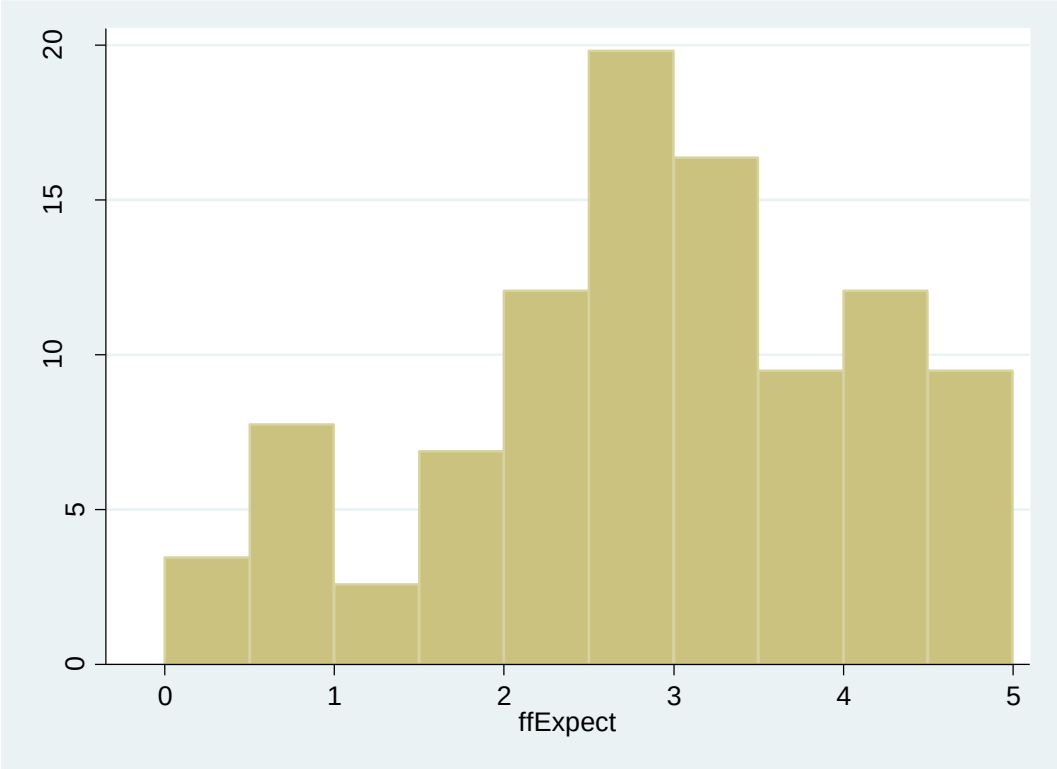
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