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Fresh Produce Donations in California: Opportunities for and Challenges to Increasing Volume and Reducing Food Insecurity

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Abstract

This study explores opportunities for increasing access to fresh produce by the emergency food system. Results of extensive interviews of managers of farming operations, food bank distributors, food banks, and food pantries were analyzed using thematic analysis to gain insights into the major challenges to increasing access to fresh produce by the emergency food system. The principal recommendations focus on the need to increase the availability of fresh produce in order to meet expected future growth in demand, better utilizing and communicating grower tax incentives, and investing in building the capacity of the food bank system.

Keywords: food security, food loss, thematic analysis, food banks

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Introduction

Approximately 1 out of every 9 U.S. households experience food insecurity at some time during the year (Coleman-Jensen et al., 2019). Food insecurity is defined by the U.S. Department of Agriculture (USDA) as having difficulty in providing enough food for all household members at some time during the year due to a lack of resources (Coleman-Jensen et al., 2019). The unprecedented nature of the COVID-19 pandemic has made this situation increasingly worse, leading Feeding America to project that millions of Americans will be at risk of food insecurity because of the pandemic (Feeding America, 2020).

Food-insecure households are disproportionately affected by chronic health conditions, such as diabetes, obesity, and hypertension (Seligman, Laraia, and Kushel, 2009; Larson and Story, 2011). To prevent and manage these adverse conditions, it is important that food insecure households have access to healthy, nutritious foods, especially fresh fruits and vegetables (Sacks et al., 2001; Li et al., 2014). Broad Lieb et al. (2016) note that while food bank systems do not address the underlying causes of poverty that force people to rely on food donations, they address an important need by providing food-insecure households with the food, especially fresh produce, that they require for a healthy diet.

Traditionally, food banks have not provided their clients with significant amounts of fresh produce because they were largely reliant on mislabeled and/or damaged shelf-stable foods supplied by the food industry (Campbell et al., 2015). Over the last decade, this outsized reliance on shelf-stable products has become a relic of the past. Food banks are switching to more nutrition-focused food banking, with fruits and vegetables now making up more than half of the weight of total inventory (Campbell et al., 2015). According to research that focused on six case studies of California food banks, this is especially true in California where fruits and vegetables made up more than half of the total weight of product distributed by the food banks studied (Ross, Campbell, and Webb, 2013). More importantly, this switch to fruits and vegetables is also in line with the preferences of users of the food bank system (Campbell, Webb, and Crawford, 2011; Webb, Ross, and Campbell, 2013; Cooksey-Stowers, Martin, and Schwartz, 2019).

Although the emergency food system provides substantial amounts of food to food bank clients, including large amounts of fruits and vegetables, as indicated above, food insecurity remains a pervasive issue throughout the United States (Coleman-Jensen et al., 2019). While the data are limited, recent research has shown that vast amounts of edible, fresh produce are being lost at the field level. Baker et al. (2019), based on 123 in-field surveys of 20 crops in California (all hand harvested), found that an average of 33.7% of marketable fresh produce was left behind in growers' fields. A study in North Carolina, based on 68 field surveys (all hand-harvested crops, except for 2 out of 68 fields), found that an average of 42% of fresh produce was lost at the field level (Johnson et al., 2018).

It is against this backdrop of continuing high levels of food insecurity, the need for nutritious foods by food banks and their clients, and the large amount of produce left in growers' fields, that we undertook this research. We focused on three principal objectives: evaluate the current supply and demand for fresh produce in the California emergency food system; investigate the challenges to and opportunities for fresh produce donation faced by stakeholders along the fresh produce donation supply chain; and develop recommendations to increase and improve the utilization of surplus produce for emergency food services.

According to the jointly created USDA and EPA food recovery hierarchy, the best outcome for food loss is to prevent it from occurring in the first place (U.S. Department of Agriculture, 2015). Absent prevention, the second-best option is to utilize the surplus produce to provide food-insecure families with fresh fruits and vegetables. Research focusing on growers' participation in food recovery efforts provides insights into growers' perspectives. A 2019 study found that farmers often support these food donation efforts because they like to know that the food they grow gets consumed (Mount, Valentine, and Gibson, 2019). However, the researchers learned that farmers often do not have the time or resources to support these efforts. Researchers in North Carolina interviewed large, commercial vegetable growers and found that a majority of farmers found current donation practices to be unfavorable (Johnson et al., 2019).

Other studies discuss the major barriers to increasing the flow of surplus produce into the emergency food system. These include the cost of harvesting and packing, liability concerns, fragmented regulation, transportation and storage costs, inadequate refrigerated transportation, and capacity limitations within the emergency food system (Berkenkamp and Meehan, 2016; ReFED, 2016).

Research that focuses on the broader emergency food recovery system provides a more complete perspective on the issue. Wetherill et al. (2018) interviewed food bank executives and identified pick and pack-out (PPO) fees, transportation to food banks, regional variations in production that make it difficult to maintain a stable supply, competition for the surplus product from other, non-donation, outlets, and the prevalence of inedible donations as significant challenges to increasing produce donations.

A study by Meagher et al. (2020) took a different approach and examined the relational strategies that might overcome the barriers to increasing food recovery to address food insecurity. The study of California growers and food recovery organizations resulted in the development of a conceptual model of agricultural food recovery that "focuses on the intersection of economic and logistical considerations with stakeholders' social relations." They also "identified several relational strategies that successfully enabled stakeholders to overcome economic, logistical, and/or social challenges" to food recovery efforts.

Tax incentives for produce donation have been the subject of considerable research as they represent an important mechanism for growers to offset the high costs of harvesting and packing surplus produce. Broad Leib et al. (2016) examined the existing challenges surrounding food and produce donations and focused on the current tax incentives for donations. They found that many

farmers struggle to utilize the federal tax deductions for produce donations because most farms operate on small profit margins. Without much profit, these farms have low levels of taxable income that greatly reduce the value of tax deductions, which in turn largely eliminates any financial incentive to harvest, pack, and donate unharvested produce (Broad Lieb et al., 2016). They recommended that the federal tax deduction be replaced with a tax credit that would allow low-margin businesses, such as farms, to gain more of a benefit from the incentives. Another study calls into question the effectiveness of tax credits, finding that a 25% Ontario tax credit has not played a significant factor in producers' decisions to donate (Kinach, Parizeau, and Fraser, 2020). Instead of a tax credit, they recommend that more opportunities be created for producers to sell their fresh produce instead of donating it, a recommendation that was supported by producers and food bank representatives alike.

In California, some of the challenges noted above have been overcome by the establishment of food bank distributors and a state tax credit for donations. These food bank distributors act as aggregators and, in some cases, brokers of fresh produce to help food banks access more fresh produce, while occasionally assisting with the transportation. A recent study suggests that food banks are a reliable outlet for produce growers and that compensating farmers for the costs incurred in growing, harvesting, and packing produce is a "win-win" for both food banks and growers (Dunning, Bloom, and Brinkmeyer, 2020). The largest food bank distributor in California, the California Association of Food Banks (CAFB), has worked to establish a state tax credit for growers who donate produce (California Association of Food Banks, 2011). Originally, legislation for a 10% tax credit was successfully sponsored by CAFB in 2011 (California Association of Food Banks, 2011). However, CAFB found that the calculation based on the value of the inventory was difficult to estimate for many farmers. In 2017, the value of the tax credit was increased to 15%, and a new formula utilizing the wholesale value of the produce was instituted. This drastically simplified the calculations required to obtain the incentives and substantially increased the value of the credit for farmers (California Association of Food Banks, n.d).

To date, most research on food recovery for emergency food services has focused on one level or a limited portion of the food bank supply chain. Our study encompasses the entire supply chain, starting with the growers who produce the food, to the food bank distributors that aggregate donated produce, to the food banks that distribute food to food pantries, and, finally, to food pantries that distribute the produce to their clients. We conducted detailed interviews with managers from farms to food pantries to understand the situation as well as challenges to and opportunities for improving the donation and utilization of surplus fresh produce in the emergency food system. This research was conducted in California, the most populous state in the country and home to production of approximately half of the country's fruits and vegetables. We focused largely on the fresh produce supply chain in northern and central California, including growers in Monterey County and the Central Valley. Together these regions produce a substantial portion of many of the produce items in the U.S., and Monterey County produces more than half of the U.S. production of leaf lettuce. The food bank distributors, food banks, and pantries represented both large, urban areas as well as smaller, rural areas. Despite the narrow geographical focus of the study, we believe that many of the results and lessons learned will be applicable to participants in the food bank system throughout the U.S.

Methods

We conducted semi-structured interviews with participants at all levels of the California emergency food system supply chain, including grower/packer/shippers, food bank distributors, food banks, and food pantries. The grower/packer/shippers we interviewed performed all three functions (i.e., growing, packing, and shipping), and we will typically refer to them as simply growers. All seven growers we interviewed had previously cooperated with us on earlier research and were known donors of produce to the food bank system. We used the snowball sampling technique to identify interview candidates for food bank distributors, food banks, and food pantries. We started with our network of contacts and identified two food bank distributors, four food banks, and six food pantries, in addition to the seven growers. We aimed to have diversity in our sample, including growers from several growing regions, the two largest food bank distributors in California, food banks in both large, urban settings as well as smaller, rural settings, and food pantries that were both large and small and located in both urban and rural settings.

The interviews were conducted with managers or directors who were engaged in activities related to our research. Growers included CEOs, CFOs, COOs, area/district managers, and harvest managers. The food bank distributors we interviewed included one Executive Director and one Director in charge of the donation program. At the food bank and food pantry levels, the interviewees were all sourcing representatives who managed incoming donations and directors or sourcing managers, respectively. The interviews were conducted both in person and by telephone from January through December 2019. The semi-structured interview process utilized predetermined questions, appropriate to each level of the supply chain, which addressed the key themes related to the research questions. Interviewers encouraged the interviewees to elaborate on their responses to the interview questions and provide more details on related topics. We took detailed notes during the interviews and immediately reviewed the notes after each interview for clarity and accuracy.

We employed semi-structured interview guides with open-ended questions that were modified to address the issues at each level of the supply chain. Interviewees were asked to describe their current fresh produce donation practices, to identify the challenges and opportunities that exist with fresh produce donation, and to talk about their capacity to handle current volumes as well as potential future volume increases.

We analyzed the data using thematic analysis (Braun and Clarke, 2006; Maguire and Delahunt, 2017). The six steps included:

1. Familiarizing yourself with your data;
2. Generating initial codes;
3. Searching for themes;
4. Reviewing themes;
5. Defining and naming themes; and
6. Producing the report.

After reading and rereading the interview reports, we developed initial codes related to salient topics raised in the interviews and categorized key information by code. We then reviewed the coded data and organized it into preliminary themes. This was followed by a review of the themes and coded extracts to ensure that they adequately represented the coded extracts and the entire dataset. Themes were then refined to identify the meaning of each theme, as well as their relationships to each other, and then assigned meaningful names before writing up the analysis. Both researchers collaborated on the process but independently reviewed the work at each stage to ensure ample opportunity to independently reflect on the codes, themes, and meanings.

Results

The coding of interview responses and several iterations of thematic development resulted in the five themes as shown in Figure 1. Arrows indicate the major relationships and principal direction of impact among the themes. For example, donor incentives have a large impact on the availability of fresh produce to food banks but not vice versa. On the other hand, coordination, when properly executed, results in positive impacts on availability through increased efficiency. Conversely, availability issues, such as too much poor-quality product that results in high waste, call for increased coordination. We organize the results around the five major themes. However, where issues relate to multiple themes, the issue will be presented and discussed primarily under the theme that is most closely related to the issue to avoid redundancies.

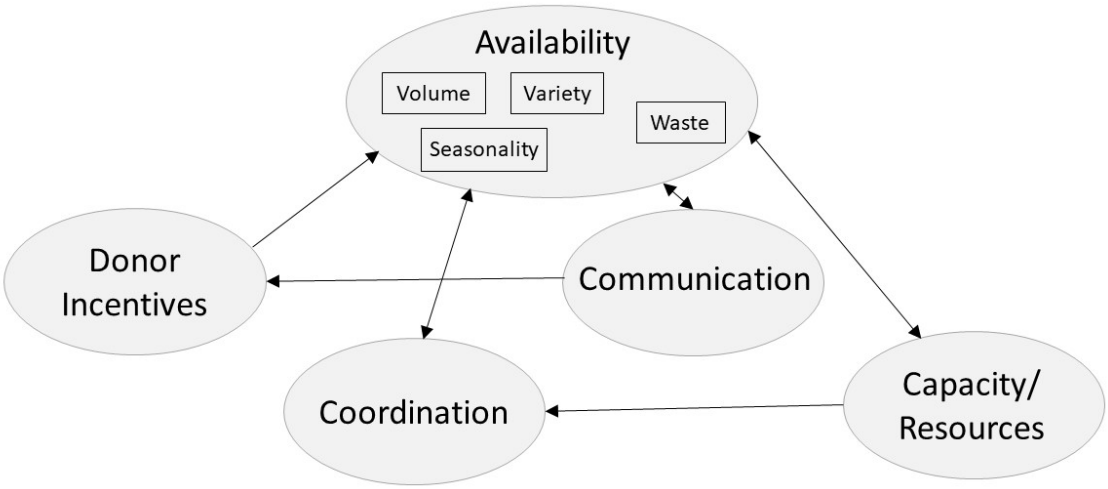

Figure 1. Graphical Representation of Thematic Analysis of the Fresh Produce/Food Bank Supply Chain

Availability. Availability is shown top and center and given greater prominence in our diagram of major themes as it was a central focus of all the conversations with interviewees at all levels of the supply chain. Moreover, it had strong ties to all other themes. Availability includes four sub-themes—volume, variety, seasonality, and waste. The first three sub-themes all relate to a primary objective of the food banking system, that is, to increase fresh produce availability to meet clients' needs for a healthy and nutritious diet. The variety and seasonality sub-themes are somewhat related as the seasonality of many products means that their availability is limited at times, thereby reducing variety. Waste impacts availability because it reduces the available produce and requires scarce resources to sort and dispose of poor-quality produce.

Among managers of the food bank supply chain, availability was the most commonly mentioned issue. It is the focus of the food bank distributors, food banks, and food pantries as they attempt to meet the demand for fresh produce by food bank clients and increase volume in concert with programs to encourage greater fresh produce consumption. While growers may not be directly focused on increasing the volume of donations, every grower we spoke to was unhappy that any product was "wasted" and was a proponent of donating more produce if it made financial sense. Donor incentives play a major role in encouraging donations and will be discussed under the donor incentives' theme.

The food bank distributors play the largest role in securing produce donations and it is a major focus of their efforts. One food bank distributor specifically noted that the lack of local supply during the winter was a major concern. The other food bank distributor indicated that they could use much more product and that seasonality of many items is a major issue as demand for products is year-round. This manager also raised a long-term concern that competitive pressures, including growth in the "ugly" produce market and increasing economic incentives for growers to switch from fresh produce to nut production, may lead to reduced fresh produce production and, therefore, less surplus product.

Food banks and food pantries are the best gauges of how well client demand for fresh produce is being met as they are closest to the clients. The food banks' needs varied by location, with the two rural food banks indicating that they generally had enough produce during the production season. However, they noted that they could use much more during the off-season, approximately one and two-thirds and 9 times more than current volume. By contrast, the two urban food banks could use somewhat more produce during the production season, but they were able to supplement the lower levels of donations during the off-season with cash purchases of produce. One of the rural food bank managers quipped that the urban food banks are "cash rich but farm poor." The food pantries echoed the concerns of the food banks. While they generally have sufficient volume, they noted a lack of variety, particularly during the off-season.

Waste was another issue that was raised by most food banks and food pantries and was a bigger problem than for the food bank distributors. This is not surprising as the distributors receive the product earlier in the products' life than do food banks and pantries. Both urban food banks noted that product that had to be thrown out was a concern with reported waste at approximately 3% and 5%. One of the rural food banks indicated that waste is as high as 30% to 40% for some produce

categories. Waste was an even greater issue for the food pantries. As with the food banks, they must sort through product and dispose of anything that is unsuitable. One pantry spends about $1,000 per month in disposal fees. Another pantry addressed the issue of high waste by physically inspecting product at the food bank before accepting shipment.

A contributing factor to waste is that growers will often hold on to a product until it nears the end of its shelf life in the hope that they may be able to sell it, contributing to donated product that has a very short shelf life. Such product must move through the food bank system quickly and may end up in a recipient's home with little shelf life remaining.

Donor Incentives. One of the clearest challenges to improving the fresh produce donation system is awareness and utilization of tax incentives. In addition to the federal tax deduction, there is a state tax credit available to growers in California. Of the seven grower/packer/shippers that we interviewed, only one was fully aware of and believed that his firm had a good understanding of both tax incentives. Growers generally had much greater familiarity with the federal tax deduction as compared to the state tax credit. One food bank distributor actively promoted the use of tax incentives while the other was not very familiar with them. The former food bank distributor indicated that the lack of awareness of the current state tax credit is likely because the credit was updated in 2017, after the previous version was met with poor reception from growers and shippers. However, he went on to emphasize that one grower donates 10 to 12 million pounds of fresh produce annually, due largely to the substantial tax benefits.

A key reason for the confusion over incentives may be that donors can benefit from produce donations in several different ways and that the financial benefits of each mechanism are not easily compared. For example, some donors prefer to simply write off the product as a loss, whereas others prefer to receive a PPO fee for the donation. Still others may utilize one or both tax incentives. Understanding which option or combination of options is most beneficial is not a straightforward calculation. Furthermore, many growers find the record-keeping requirements onerous and distracting from the operation of their business.

Complicating matters further is the difficulty faced by grower/packer/shippers that receive product from multiple growers. The shipper/aggregators seemingly provide a great target for produce donation because they are a large source of culled and surplus product that does not require much additional labor and expense for harvesting, cleaning, and packing. However, these shipper/aggregators are unable to take advantage of the tax incentives for the donated product themselves because they do not have ownership of the product sourced from other owners. This serves as a major disincentive to produce donations. Product that has been comingled among several growers makes assignment of the tax benefits difficult. One grower/packer/shipper addressed this issue through an improved records system to ensure that each grower received the proper tax benefit. Another grower/packer/shipper simply apportioned the donation of comingled product to each grower.

One manager underscored the importance of increasing awareness of the tax incentives by emphasizing that their current operation has two potential destinations for culled and surplus

product—donation and processing. Without full awareness of the tax incentives for donation, culled or surplus produce will often be sold for processing even though the best financial decision may be to donate the produce and receive the tax credits or deductions and/or PPO fees.

Communication. Tax incentives stand out as an area where communication could be greatly improved based on responses from both growers and the lone food bank distributor that promoted the use of the incentives. Promotion is certainly needed to increase awareness of the tax incentives. However, clear and user-friendly information that explains the tax incentives and assists growers with the financial calculus they must make in order to determine whether to donate surplus produce is also needed, as evidenced by the confusion expressed by many growers.

Most growers were not aware of Good Samaritan laws that protect them when donating produce in good faith. However, this apparently was not a substantial hindrance to produce donation, as some growers indicated that their food safety protocols for donated produce were equal to those of produce that entered the market and therefore liability was not a major concern for them. Nonetheless, better promotion of the liability protections along with the tax incentives might attract more grower donations.

Communication between food banks and food pantries and by food pantries with their clientele was reported as being very good. Pantry managers indicated that they focused on educating their clients by promoting good nutrition, explaining product expiration dates, and providing recipes. Recipes are especially helpful in promoting the use of unfamiliar foods that clients have never seen prepared or consumed. Pantry managers also indicated that they work closely with other agencies, such as shelters and churches, to share surplus produce.

Coordination. Several areas could benefit from closer coordination among organizations. A common complaint among growers was that food bank agencies were slow to respond to their offers of donations, alienating growers and reducing the already short shelf lives of perishable products. It is not clear whether this is primarily a coordination or capacity issue. Nonetheless, growers and recipients may be able to work together to provide earlier notification and shorter response times through better planning.

Another issue is that competitive relationships among organizations may lead to suboptimal allocations of fresh produce donations within the system and to food bank clients. As an example, two of the major food bank distributors have essentially locked down regions within the state and have agreed to not source product in each other's regions. A more collaborative relationship among the food bank distributors could address some of the system's current shortcomings regarding variety and seasonal availability. Food banks also sometimes establish direct relationships with growers to improve access to produce donations. To complicate matters, a well-intentioned group will sometimes try to rescue produce and engage organizations already working with emergency food agencies. A case in point was a new organization, founded by university students, that started a new recovery effort to link growers with surplus product directly with food banks. One of the food bank distributors lamented that this was creating confusion among growers as the new

organization was essentially duplicating and competing with the established system, which had the scale and knowledge to determine where surplus product was most needed.

At the food pantry level, managers shared with us how they handle surplus product. Some pantries have developed systems designed to be compatible with their clients' shopping preferences, such as distributing produce similar to what you would see at a farmers' market instead of in prepackaged bags/boxes. Another pantry sets up a table where clients can pick up surplus produce that must be moved quickly. All but one pantry shared their excess produce with other agencies, including shelters, churches, or other food pantries. The pantry that did not share excess produce noted that they are prohibited by their food bank distributor from doing so, possibly leading to increased waste. It was clear that the short shelf life of the produce resulted in the need for a high level of coordination to move product quickly to food bank clients.

Capacity/Resources. Capacity issues were raised at every level of the supply chain. For growers, the largest issue was labor availability and the cost of providing donated product (harvesting and packing). Another issue was limited storage space as saleable product took priority over product destined for donation. Food bank distributors, food banks, and food pantries all indicated that they had capacity and resource constraints that prohibited them from making more product available to downstream clients.

Food bank distributors noted that the high cost of transportation, maintaining the cold chain, and access to more growers were barriers to increasing volume. One distributor indicated that they would need to increase capacity across the board, including more refrigerated trucks, cold storage, and staff if they were to substantially increase the amount of produce that they supply to food banks. Funding, which would address the above-mentioned needs, was also needed.

The two urban food banks indicated that they currently have the resources and capacity required to handle the produce they receive and to meet most of the needs of their clients. One of the food banks indicated that they would like to handle more fresh produce but that their cooler is not large enough. They are looking to lower the ambient temperature in their warehouse to accommodate more produce. Both rural food banks indicated that they lack the funds to fully accomplish their mission.

As with the food banks, the capacity and resource needs of the food pantries were mixed. Most food pantries had sufficient capacity for their current volume, including cold storage, whereas others indicated that they occasionally run out or would need additional cold storage were they to expand. One manager explained that they lack sufficient space in their warehouse and sometimes must leave pallets of produce outside. Other issues included access to transportation for fresh produce, running out of fresh produce, especially at the end of the month when demand is at is greatest, and insufficient funds to purchase fresh produce or for other needs.

Discussion

The thematic analysis results of the interviews of participants in the fresh produce emergency food supply chain yielded several key themes. The theme raised by almost every organization was produce availability, a key research objective of the study. Increasing overall volume, improving variety, and reducing the impact of seasonal production, along with waste reduction were central aspects impacting the availability of fresh produce that reaches food bank clients. Four supporting themes were identified, including improved coordination within the system, better communication among supply chain participants, increased capacity at each tier of the supply chain, and improving the utilization and communication of donor incentives, particularly tax incentives. All four themes supported the primary goal of increasing the availability of fresh produce to food insecure families.

Three themes emerged as being critical to efforts to improving the utilization of surplus fresh produce to reduce food insecurity. Participants at every level of the supply chain, from growers to food bank distributors, to food banks, and finally food pantries, believed that it was important to increase the availability of produce for emergency food distribution. We found that donor incentives, especially tax incentives, are important to incent growers' produce donations, but that growers often lack awareness of the benefits, find the record-keeping requirements complicated and onerous, and frequently either underutilize or fail to utilize the tax incentives. A third theme that plagues the system from beginning to end is capacity limitations and underinvestment in the resources needed to better meet the needs of organizations within the food bank system.

Many of the challenges that we identified are symptomatic of a system where the individual actors act largely to pursue their own objectives. For example, it appeared that some produce that was of inferior quality or which had insufficient shelf life was delivered to food bank distributors, food banks, and food pantries, necessitating costly sorting and disposal. There was also evidence of a lack of coordination among the different levels of the distribution system as well as among organizations operating at the same level. As an example, one food pantry was prohibited from sharing surplus produce with other pantries that could have used this produce to distribute to their clients.

Effectively coordinating a distributed network of organizations with differing objectives represents a substantial challenge. None of the individual organizations have the size, funding, or influence to restructure the supply chain or to coordinate activities. One such organization that might have the resources and capability to take on such a task is Feeding America, the largest hunger relief agency in the U.S., with a network of more than 200 food banks. Such an effort would be a good fit with the objectives of Feeding America, food banks, and other organizations in the supply chain, which focus on providing healthy and nutritious foods to food-insecure people.

The goal of reducing food insecurity and improving nutrition is also a worthy social policy goal and one that would result in improvements in emergency food recipients' health. While such policies can be costly to develop and implement, the long-term benefits of a healthier population are sizable, including children who are better able to focus and succeed in school, a more productive workforce, and a healthier population that is more productive with reduced health care

needs and expenses. Funding for produce donations and development of a coordinated system for the produce donation supply chain would fit well with the USDA, which already spends the great majority of its budget on food and nutrition programs.

Concluding Remarks

The large amount of edible produce that is left in California farmers' fields or which goes unsold in packing houses presents an opportunity to reduce food insecurity, improve the nutrition and health of families receiving food assistance, and increase the sustainability of the food system. Through semi-structured interviews at all levels of the food bank distribution system, including growers, food bank distributors, food banks, and food pantries, we assessed the perceived need for additional produce donations and identified opportunities for increasing such donations to people in need of food assistance. We found that participants in our study mostly believed that the emergency food system in California worked well. The people closest to the clients, the food pantry managers, largely felt that they had sufficient produce to meet current client demand. However, there was a widespread belief that increased volume and variety, as well as greater seasonal availability, are needed to meet expected future growth as well as nutritional goals for food-insecure food bank clients. We suggest two potential strategies for increasing produce availability, including increasing the utilization and awareness of grower tax incentives and investing in building the capacity of the food bank system.

It is important to note that our interviews were conducted in 2019, before the COVID-19 pandemic disrupted the economy and drastically increased the incidence of food insecurity. The heightened need provides an increased sense of urgency to add capacity to the emergency food system.

A major limitation of this research is the geographical scope of the study, which focused largely on northern and central California. While this may limit the study's applicability, given the concentrated nature of crop production in the U.S., many of the study's findings may be applicable to other crop production regions. Another limitation is the relatively small sample size of the groups in the supply chain and the identification of organizations based largely on targeted sampling and referrals. While this might introduce some biases into our results, this strategy was necessitated by the difficulty in gaining access to people willing to be interviewed, particularly at the farm level. Interviewees were chosen to represent growers in several growing regions, two food bank distributors in different growing regions, urban and rural food banks, and food pantries that were geographically diverse. The purposeful sampling strategy was well suited to the qualitative analytical technique we employed to identify major issues.

Future research might focus on other regions of the country with different characteristics than those in the current study. This focus could provide a broader perspective of the produce donation system across the country as well as the challenges and opportunities faced by organizations in those regions. Moreover, a study with a larger sample size and more representative sampling would be useful to either confirm the results of this research or provide additional insights. Finally, research that investigates policies that address the potential feasibility of mechanisms to address the challenges and opportunities identified in this study, such as donor tax credits, could provide

insights into growing and improving the fresh produce donation system as well as the impact on food security and nutrition for food-insecure households.

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Understanding Shareholder Satisfaction and Retention in CSA Incentive Programs

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Abstract

Innovations in Community Supported Agriculture (CSA) have intensified during the COVID-19 pandemic, including the use of employer voucher programs. With many first-time shareholders trying the CSA model, evaluating shareholder satisfaction may help improve retention rates. We evaluate a dataset of new and experienced shareholders enrolled in a pilot CSA voucher program to determine what variables impact their decisions to join or recommend CSA. We find that increased levels of shareholder engagement during the CSA season and certain shareholder motivations for initially joining a CSA are associated with increased satisfaction and likelihood of joining a CSA in the future.

Keywords: Community Supported Agriculture; CSA incentive programs; CSA innovations; shareholder retention

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Introduction

Community Supported Agriculture (CSA) in the United States has seen a surge in innovation in recent years. CSAs are attempting to expand markets by reaching nontraditional shareholders and adapting to consumer demand for healthy, convenient food options. Among these innovations is the expansion of workplace benefits programs that subsidize CSA shares. As models that increase the accessibility of CSA, workplace incentive programs can provide insights into how CSA is perceived by an expanded shareholder base.

Understanding the first-time shareholder experience has become more important now that COVID-19 is driving consumer interest in CSA. During the initial wave of the pandemic in the United States, many consumers turned to more direct and local forms of food acquisition (Ricker and Kardas-Nelson, 2020; Urgenci, 2020). CSA provided consumers a sense of security during the food purchasing experience in an environment where they could avoid large crowds and that eliminated steps in the supply chain. Many CSAs reported demand beyond what could be satisfied in their preseason planning.[1] Consequently, many farms sold out their shares or redirected would-be wholesale production for institutions or restaurants into share expansion. Additionally, many farms that had not previously offered CSA pivoted to this production-distribution option. Finally, non-farm organizations, such as restaurants, food hubs, and even the federal government, adopted food box strategies to meet the needs of newly unemployed consumers and take advantage of consumer shifts in food purchasing (Helmer, 2020; USDA, 2020; Woods, 2020). These shifts point to a rapidly evolving food acquisition landscape in which CSA may play a larger role.

Yet there are risks inherent to the entrance of inexperienced CSA shareholders and producers. New CSA producers must learn different marketing, packaging, and logistic techniques. While COVID-19 required many changes for farm-product handling regardless of market orientation, producers new to CSA generally need a few seasons to make the model work well for themselves and for their shareholders. A rapid influx of new farmers might lead to CSAs that fall below the standard expected by shareholders, thereby damaging the perception of the model. While shareholders who value the "community" aspect of CSA with respect to sharing production risk might give more latitude to inexperienced CSA producers, new shareholders and those who expect a certain standard of quality might avoid CSA in future seasons if they have a negative experience.[2] Given the expansion of the shareholder base in 2020, farms are under pressure to ensure their CSAs operate correctly to maintain an acceptable year-to-year shareholder retention level.

Our manuscript focuses primarily on consumer behavior and perception of CSA in the context of workplace programs designed to attract and hopefully retain new employees in corresponding wellness benefit programs. Specifically, we use survey data gathered during the establishment of a workplace CSA incentive program in central Kentucky from 2015-2018 to understand the aspects of the shareholder experience that are associated with an increased likelihood to buy or recommend

[1] COVID-19 response data are gathered from communication with CSA technical assistance organizations at local, regional and national levels. We are part of the CSA Innovation Network (www.csainnovationnetwork.org) and have been updated on CSA demand dynamics throughout the pandemic.
[2] Personal communication with the CSA Innovation Network.

a CSA in the following year. While our manuscript involves work done prior to the pandemic, it offers insights into how CSA models can be adapted to a new consumer audience. Understanding specific shareholder values and attributes associated with satisfaction can help farmers and employers, who together provide CSA incentive programs, focus recruitment and messaging to improve retention of new subscribers.

These insights are important because many first-time shareholders may not be able to fully take advantage of the traditional CSA model. It requires creative meal preparation skills, time to attend box pickups, and usually a high upfront payment. Additionally, the seasonality and diversity of produce inherent to CSA require new shareholders to learn how to plan meals rapidly around a shifting mosaic of foods. Finally, many farms give little lead time to their shareholders on what to expect in their box each week. While experienced shareholders can adapt to the requirements of the CSA model, newer shareholders may encounter significant challenges in their experience. By understanding where farms might target their marketing, communication, and engagement activities, we identify how they might make their CSAs more attractive to a larger audience.

Program Background

The authors worked with various employers in central Kentucky to develop a CSA incentive program. In this program, each employer would fund a voucher for their workers to participate in CSA. The method and amount of that incentive varied by workplace, but generally involved a $100 to $200 voucher applied to the price of a full season CSA produce share. Most farms offered installment plans to further reduce the financial burden inherent in a large upfront payment. As such, the incentive programs generated interest and participation from individuals who had never experienced a CSA before. Consequently, we are able to use pre- and post-season surveys of program participants to evaluate how both first-time and experienced shareholders perceived the program. While participating farms had their own marketing strategies (e.g., meat/egg add-ons, digital versus paper newsletters, etc.), the vouchers were limited to funding vegetable shares. These farms agreed to have similar-sized and priced options available for the voucher program in the first few years to avoid undercutting one another. Finally, all farms had active websites, email communication, and newsletters. The engagement areas are important for our analysis since we evaluated the association between the use of these resources and shareholder satisfaction as well as willingness to join/recommend a CSA.

The CSA incentive program started in 2015 with a small pilot of employees at the University of Kentucky. The University's Health and Wellness program, part of the benefits office, initially contacted employees to assess interest in receiving a $200 voucher in exchange for participating in a CSA program. After receiving a list of interested individuals, we randomly selected 95 participants to receive a voucher offer. Employees could view four different farm CSA options and decide whether to sign up and pay the remaining cost of the CSA (typically an additional $350–$450). After two weeks, we offered a few more vouchers to fill the remaining spots after we determined who accepted and who declined the offer.

We collected data on shareholder behavior change via a survey (see Rossi, Woods, and Allen, 2017) and presented the data to the University of Kentucky benefits office as well as a few employers around central Kentucky. The University and four other employers agreed to fund vouchers for a larger pilot program for 2016. In 2017 and 2018, the University of Kentucky and a few regional employers established the CSA voucher program as a general employee benefit. Vouchers ranged between $100 and $200. CSA shareholders were given the option to complete standardized pre- and post-CSA surveys, which is how we collected data for this manuscript.

Currently, 15 employers in Kentucky offer approximately 1,300 CSA (Brooke Gentile, Executive Director of the Kentucky Farm Share Coalition, personal communication), of which nearly 1,000 were claimed this year in a time of widespread economic uncertainty. Considering the shareholder base (regardless of incentive structure) in central Kentucky was around 800 in 2014, it appears that the voucher project has had a significant impact on expanding the CSA shareholder base beyond the traditional locavore demographic. In 2020, incentive expansion provided many individuals with an easy alternative option for food acquisition.

Literature Review

Shareholder retention is one of the most challenging issues for CSA farms (Woods and Tropp, 2015; Woods, Ernst, and Tropp, 2017; Galt et al., 2019). High upfront payments, novelty of food preparation requirements, and lack of consumer choice can act as a disincentive to participate. However, after a shareholder participates in the model, their experiences of the program are critical to their likelihood of joining a CSA in the future (Durrenberger, 2002; Pole and Kumar, 2015). Similarly, many CSAs rely on testimonials from shareholders to peers as an effective recruitment tool. As such, understanding shareholder recruitment and retention is a pressing challenge to CSA researchers and practitioners.

Farms have explored various innovations and modifications to their share structure to respond to shareholder feedback and make the model more accessible (Woods, Ernst, and Tropp, 2017). Customization has become a popular resource for shareholders as it allows for some degree of consumer choice (Woods Ernst, and Tropp, 2017; Galt et al., 2019). Technology has evolved to assist farmers in the logistics of ordering, packing, and delivering fully or partially customized shares. The adoption of customization may increase after the pandemic because many CSA farms, especially those operating in other sectors such as farmers markets, expanded their e-commerce. Alongside expanded electronic ordering systems, CSAs have invested in making their websites more accessible and visible, especially in situations where a state department of agriculture or farmer support organization compiled and organized consumer-facing directories.

Other farms and organizations have focused on making CSA more economical. Cost-offset programs, such as our CSA voucher program, reduce the price of entry (Rossi, Woods, and Allen, 2017; Woods, Ernst, and Tropp, 2017). Combined with innovations like payroll deduction, CSA is more attractive to income-limited households. Additionally, sliding scale and fully subsidized models through vegetable RX programs reach households that do not have access to an employer-funded CSA. Finally, the pandemic is helping to speed up the use of online SNAP redemption

systems for CSA programs—a critical movement that will help technical assistance providers and farms process SNAP benefits within a CSA context (members of the CSA Innovation Network, personal communication).

Regarding logistics, some farms are experimenting with more targeted delivery options while folding the extra costs into the share payment structure. Others are developing multifarm aggregation models to provide market access to newer or under-resourced farmers. These models allow each farmer to produce fewer varieties of produce as well as delegating some marketing and logistic responsibilities to a designated organization (Flora and Bregendahl, 2012; Woods, Ernst, and Tropp, 2017; Si et al., 2020). Finally, some farmers are developing hybrid models of CSA that incorporate CSA box drops at farmers' markets and the ability to augment the base share with other items from the market stand. All of these innovations are aimed toward meeting the changing demands of a shifting consumer base in order to create a satisfactory experience.

Many advocates worry that these changes move CSA away from its foundational ideals of engaging the community to share risk. By attempting to increase shareholder satisfaction, farmers may overextend themselves and undermine their personal and financial well-being (Galt, 2013). Additionally, by reshaping CSA toward customization and consumer choice, the CSA box may start looking like other box products offered by food delivery services or large retailers (Galt et al., 2019). This risk has intensified due to the proliferation of CSA-like box products and online shopping/curbside pickup at grocery stores during the COVID-19 pandemic.

At the same time, the movement toward technologically mediated programs, consumer choice, and distribution innovations may have become more permanent fixtures in CSA because of the pandemic experience. The digital realm provides a different avenue for shareholder engagement—and engagement is an important variable in developing long-term participation. To counter the potential dilution of CSA's distinctiveness, farms must further emphasize what makes their product unique, and newly developed or refined digital platforms provide many possibilities for CSAs (Woods and Tropp, 2015).

Despite concerns with CSA's mission drifting away from foundational ideas of risk sharing, it should be noted that CSA's traditional prepayment structure is already exclusionary (even with payment plans) to many individuals. Participants in CSA are predominantly white and middle/upper class (Durrenberger, 2002; Perez, Allen, and Brown, 2003; Ostrom, 2007). Additionally, CSA requires consumers to (1) have or develop food preparation skills to eat seasonally and vegetable-centrically, (2) time to attend regular pickups, develop food preparation skills, and augment box contents with retail purchases, and (3) a household size or social network that is appropriately-sized to the size of the CSA share. Regarding this latter point, the standard share size can be far too large for a single-person or small household. Understanding how to choose a CSA size and share type poses challenges for new shareholders.

Because of these structural challenges, as well as the rapid emergence of a broader shareholder base during the pandemic, CSA innovations are likely to continue. The innovation that characterizes our particular dataset—the incentivized workplace CSA—was originally aimed at

broadening access to and knowledge about CSA. Our primary mode of promotion has been to work with benefits and wellness organizations. This aim was shaped by the observation that CSA has transformative potential, not just in terms of farmer income and sustainable farming practice, but also on the health and food consumption habits of shareholders (Durrenberger, 2002; Perez, Allen, and Brown, 2003; Brown and Miller, 2008; Russell and Zepeda, 2008; Landis et al., 2010; Cohen, Gearheart, and Garland, 2012; Wilkins, Farrell, and Rangarajan, 2015; Vasquez et al., 2016; Allen IV et al., 2017; Hanson et al., 2017; Vasquez et al., 2017).

Using a smaller portion of this current data set that only included new shareholders, we found that participants in a CSA incentive program gained cooking skills, consumed more vegetables, and perceived changes in their health along with a number of indicators (Rossi, Woods, and Allen, 2017). The repetitive and iterative structure of the CSA (weekly deliveries, constantly changing produce box, inundation with certain items during peak harvest) requires the shareholder to continuously learn, adapt, and innovate with respect to vegetable-centric meal planning (Rossi et al., 2017). Given that increased vegetable consumption is associated with a number of positive health outcomes (Dauchet et al., 2006; Boeing et al., 2012; Bellavia et al., 2013; Bechthold et al., 2019), CSA incentive programs within diverse organizations could have broader public health implications (Berkowitz et al., 2019). This point is reinforced by studies that show wellness programs, most of which focus on exercise and not diet, generally lead to positive returns on investment for employers, which is a proxy of positive health outcomes (Parks and Steelman, 2008; Baicker, Cutler, and Song, 2010; Berry, Mirabito, and Baun, 2010; Chapman, 2012).

The challenge of a CSA incentive program (and pandemic-induced expansions of the shareholder base) is that many new shareholders are completely unfamiliar with the CSA concept. The traditional shareholder base is defined by a few core values, such as interest in supporting local farmers, sustainability, and developing community (Ostrom, 2007; Hvitsand, 2016). In practice, however, the rationale for joining a program is more complex and balances these ideals with more individualistic concerns (Ostrom, 2007; Pole and Gray, 2013). In an incentivized model, different motivations for joining emerge, such as seeing the program as a good opportunity to get access to high-quality food at a discount. Additionally, since we have been working through wellness programs, participants might be more attracted to CSA's potential health benefits.[3]

The learning curve associated with CSA may lead to an unsatisfactory experience, and therefore, lower retention rates, if supplementary support is not given to the shareholder to keep them engaged and learning. The contribution of this paper, then, is to provide some context about how different shareholder attitudes and characteristics contribute to shareholder satisfaction and likelihood of joining or recommending the program in future years. As our shareholder base has been diversified beyond traditional, early-adopter CSA members through the incentive structure, we provide insights into what characteristics of new shareholders are potentially associated with program satisfaction. Additionally, since the wellness programs we worked with offered cooking classes, recipe cards, and other share usage strategies, we can measure how shareholders'

[3] It should be noted here that health improvement was not a significant motivator of CSA participation among longtime shareholders in a separate study we conducted (see Allen et al., 2017).

participation in these programs impacts their perception of and experience with the CSA. These programs were exclusive to shareholders and provided tips for using CSA produce

Methods

Survey and Data

Beginning with our pilot program in 2015, we offered pre- and post-CSA surveys to all participants. Both surveys asked questions about shareholder food consumption behaviors, perceptions of shareholder well-being, and basic demographics. The post-season survey also asked retrospective questions about satisfaction with the CSA experience as well as their willingness to recommend or buy a CSA with and without a voucher. The post-season questions are the focus of our analysis for this manuscript.

Participants received a small incentive to complete each survey. All surveys were distributed through SurveyMonkey, an online survey platform. CSA voucher participants were contacted multiple times via email with the survey opportunity. Pre-season surveys were administered in April or May. Post-season surveys were given in October or November. The timing of the surveys depended on when participating farms began and ended their seasons.

In 2015, 95 individuals joined a CSA with a voucher from the University of Kentucky. All participants except two completed both the pre- and post-CSA survey. In 2016, 150 out of the 180 total shareholders from three different organizations completed both surveys. In 2017, 227 out of a possible 320 shareholders completed both surveys from three different employers. In 2018, the final year that we offered a survey incentive, 276 participants completed both surveys out of 457 possible respondents from five employers. We received a total of 746 usable responses, which is a 70% response rate from all voucher participants in these employer programs.

The pre- and post-CSA surveys all contained a core set of 27 questions that asked shareholders to measure their (1) frequency of participation in 17 different food lifestyle behaviors, such as daily consumption of fruits and vegetables, and (2) perception of their own health and well-being along 11 different indicators. Behavior and perception changes are the subject of previous publications (Allen et al., 2017; Rossi, Woods, and Allen, 2017; Rossi et al., 2017;) and are not critical to this analysis.

More relevant to this manuscript are questions that were unique to the pre- and post-CSA surveys. In particular, our analysis revolves around five specific questions asked in the post-CSA survey. The first two questions are about the likelihood of joining a CSA in the following year. These questions were phrased in the following way: (1) After your experience with a CSA, how likely are you to join again next year with a subsidy from your employer? and (2) After your experience with a CSA, how likely are you to join again next year without a subsidy from your employer?

The second two questions are about the likelihood of recommending a CSA. They are phrased in the following way: (3) How likely are you to recommend a CSA subscription to a coworker with

a subsidy from your employer? and (4) How likely are you to recommend a CSA subscription to a coworker without a subsidy from your employer? Each participant was asked to rate these questions using a 5-point Likert scale with the following options: 1 = Extremely Unlikely, 3 = Unsure, and 5 = Extremely Likely.

Finally, we evaluate responses to the question, "Rate your overall satisfaction with the CSA experience." Participants indicated their satisfaction with the CSA program using a 7-point Likert scale with the following options: 1 = Did not meet expectations, 4 = Met Expectations, and 7 = Exceeded Expectations.

In addition to these questions, we gathered information about shareholder demographics, household characteristics, experience with CSA, motivations for joining the CSA program, and CSA resources used while participating in the CSA program.

Probit Regressions

Probit regressions were used to explore potential determinants of four shareholder decisions: (1) "Join with a Voucher," (2) "Join without a Voucher," (3) "Recommend with a Voucher," and (4) "Recommend without a Voucher." Behind shareholder i decision (i.e., *j*) to recommend and join the CSA program is the expected utility associated with participating in the CSA program (y_{ij}^*). We assume the latent variable y_{ij}^* is a function of observed and unobserved variables behind the decisions to join and recommend the CSA, and can be described as:

$$y_{ij}^* = \boldsymbol{x}_i'\boldsymbol{\beta} + \varepsilon_{ij} \quad (1)$$

where $\boldsymbol{x}_i$ is a vector of observable variables that could be correlated with shareholders' decisions to join a CSA in the future or recommend the CSA program, such as shareholder demographics, and household characteristics, experience with CSA, motivations for joining the CSA program, and CSA resources used while participating in the CSA program; $\boldsymbol{\beta}$ is a vector of coefficients capturing the correlation between the various observable variables and the shareholder decisions; and is the random disturbance term.

We do not observe y_{ij}^*, but we only observe whether the shareholder is likely or extremely likely to join or recommend the CSA program such that,

$$y_{ij} = \begin{cases} 1 & \text{,if } y_{ij}^* \geq 0 \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

where y_{ij}^* is the dependent variable to be used in the probit regressions evaluating the factors influencing shareholder likelihood of joining the CSA program in the future, or recommending the CSA program to others. This variable takes the value of 1 if shareholders are "likely" or "extremely likely" to join the CSA program in the future or recommend the CSA program to others, and 0 otherwise. Since dependent variables were originally on a 5-point Likert scale, we recoded responses that were "likely" and "extremely likely" (to recommend or join) as the positive record

of selection (i.e., 1). All other responses were coded 0. Table 1 describes the recoded variables for each question, which serve as dependent variables in each probit model.

Table 1. Descriptive Statistics of Probit Regressions' Dependent Variables

	No (0)		Yes (1)	
	N	**%**	***N***	**%**
Join with voucher	87	11.8%	648	88.2%
Join without voucher	443	60.2%	293	39.8%
Recommend with voucher	56	7.6%	680	92.4%
Recommend without voucher	285	38.7%	451	61.3%

The probability of shareholder *i* recommending or joining the CSA program (i.e., decision *j*) is defined as (Greene, 2008),

$$\begin{aligned} P(y_{ij} = 1 \mid \boldsymbol{x}_i) = P(y_{ij}^* \geq 0 \mid \boldsymbol{x}_i) &= P(\boldsymbol{x}_i'\boldsymbol{\beta} + \varepsilon_{ij} \geq 0 \mid \boldsymbol{x}_i) \\ &= P(\varepsilon_{ij} \geq -\boldsymbol{x}_i'\boldsymbol{\beta} \mid \boldsymbol{x}_i) = P(\varepsilon_{ij} \leq \boldsymbol{x}_i'\boldsymbol{\beta} \mid \boldsymbol{x}_i) \\ &= F(\boldsymbol{x}_i'\boldsymbol{\beta}) = \Phi(\boldsymbol{x}_i'\boldsymbol{\beta}), \end{aligned} \tag{3}$$

where $F(.)$ is the cumulative distribution function for the random variable ε_{ij}. We assume ε_{ij} is normally distributed, therefore Φ(.) is the cumulative normal distribution. Hence, the binary choice model described in equation (3) is estimated using a probit regression (Greene, 2012). Following Greene (2008), the average marginal effects for the variables included in were calculated following Greene (2008).

Ordered Logistic Regressions

An ordered logistic regression (Greene, 2008) was used to evaluate the factors influencing shareholder satisfaction with the CSA experience. Results from the ordered logistic regression provide insights into the factors influencing shareholder level of satisfaction with the CSA experience. Three ordered logistic regressions were estimated, one for the sample of all shareholders, one for the sample of shareholders with previous experience with CSAs, and one for the sample of shareholders with no previous experience with CSAs.

Independent Variables in Probit and Ordered Logistic Regressions

The variables included in the probit and ordered logit regressions are described in Table 2. The variables included in the estimated regressions include shareholder demographic characteristics; household characteristics; and variables capturing shareholder interest in local foods, CSA experience, food choice, and CSA program engagement. CSA experience allows us to see whether previous experience with a CSA program is associated with different evaluations of the CSA incentive program. Household size was included to control for any effects on program satisfaction and willingness to buy/recommend CSA caused by a mismatch between household and share size.

Table 2. Variable Descriptions for Probit and Ordered Logistic Regressions

Variable	Description	Values	Probit	Ord. Logit
Dependent Variables				
Join with a voucher	How likely are you to join again next year with a subsidy from your employer?	1 = Extremely Unlikely 3 = Unsure 5 = Extremely Likely	x	
Join without voucher	How likely are you to join again next year with a subsidy from your employer?		x	
Recommend with voucher	How likely are you to recommend a CSA subscription to a coworker with a subsidy from your employer?	Recoded to binary 0 (not join/not rec) = 1 to 3 1 (join/rec) = 4 to 5	x	
Recommend without voucher	How likely are you to recommend a CSA subscription to a coworker without a subsidy from your employer?		x	
Program satisfaction	Rate your overall satisfaction with the CSA experience.	1=Not meet expectations 4=Met Expectations 7=Exceeded Expectations		x
Independent Variables				
Demographic Variables				
Age	Please indicate your year of birth.	Recoded as age: continuous	x	x
Sex	Please indicate your sex.	binary: 0=male / 1=female	x	x
Household income	What range describes your total yearly household income before taxes?	$25k intervals up to $250k recoded as continuous from range midpoint	x	x
Household size	How many people live in your household (including yourself)?	Continuous	x	x
CSA experience	Mark any previous year in which you participated in a CSA at any location: Before 2010, 2010, 2011, 2012, 2013, … 2017	0 = No previous year marked 1 = Any previous year marked	x	

Table 2 (continued).

Variable	Description	Values	Probit	Ord. Logit
Food Choice Variables: Pre-CSA Survey Questions				
Wanting to lose weight	Which of the following factors caused you to join your CSA initially?	1 = Less of a factor 4 = Somewhat of a factor 7 = A significant factor	x	x
Wanting to support local farms and farmers			x	x
Wanting access to better quality food			x	x
Helping my family eat better			x	x
Wanting knowledge about how my food is produced			x	x
The voucher			x	x
Engagement Variables: Post-CSA Survey Questions				
CSA newsletter	How many times during the season did you use the following resources to use your CSA?	0 = Never 1.5 = 1 to 2 times 3.5 = 3 to 4 times 5.5 = 5 to 6 times 7.5 = 7 to 8 times 9.5 = 9 to 10 times 11.5 = more than 10 times	x	x
CSA website			x	x
Conversations with CSA staff			x	x
Conversation with family and friends			x	x
Cooking classes			x	x
Interactions with other shareholders			x	x

Notes: Program satisfaction is also used as an independent variable in the probit regressions of the "recommend" and "join" dependent variables. CSA Experience is used to segment ordered logistic regression models by experience.

We can further segment participants based on personal values they ascribe to different food choices. The six food choice variables from the pre-survey control for the values participants bring to the CSA experience. Here we include diverse aspects, such as concern with family, safety of food, health concerns, and the impact of the voucher itself. The six specific food choice questions used to construct the variables included in the regressions are listed in Table 2.

Similarly, we included six program engagement variables in all the regression models (see Table 2). These variables measured participants' use of different resources to consume their weekly produce box. These variables allow us to identify how different avenues of engagement with their experience contribute to shareholders' willingness to buy/recommend CSA and satisfaction with the CSA.

Diagnostic Tests

We tested for collinear relationships among the independent variables included in the various estimated regressions using a variance inflation factor (VIF). We also conducted specification tests for the probit models. Following each probit model, we evaluated the percent of actual responses that the model correctly predicted based on the demographic and other independent variables with a cutoff of 0.5 using the "estat classification" command in Stata. We also plotted the true positives (i.e., sensitivity) versus false positives (i.e., specificity) of the model and then measured the area under the curve (i.e., receiver operating characteristic) using the "lroc" command in Stata. The higher the area under the curve, the better the model is at classifying choices in a binary response model. Finally, we validated our models using the Hosmer-Lemeshow Goodness-of-Fit test. This test groups individuals by their probability of a particular response. It then tests whether these groups have different proportions of observed versus expected responses. Low p scores indicate that these proportions differ and that the model is incorrectly specified. Results from this test are presented in Table 5. For ordered logistic regressions, we conducted the Brant tests to ensure that the parallel regression assumption holds true.

Results and Discussion

Survey sample descriptive statistics of the demographic variables included in the probit and ordered logit regressions are presented in Table 3. CSA program participants are, on average, 42 years old, with a household income of around $110,000. Approximately half of the survey respondents were first-time shareholders. On average, households held between two and three individuals.

Table 3. Independent Variable Means in Aggregate and by Experience Level

Variable	All Shareholders	New Shareholders	Experienced Shareholders
Number of participants	736	353	383
Age	42.6 (10.8)	42.2 (11.0)	43.3 (10.5)
Household income	$110K ($57K)	$104K ($57K)	$118K ($57K)
Household size	2.4 (1.2)	2.5 (1.1)	2.3 (1.1)

Note: Standard deviations for age, income, and household size are included in parentheses.

In Table 4, we present descriptive statistics of the dependent and the independent variables, other than shareholder and household characteristics, included in all regressions. Overall satisfaction with the CSA program was high. On average, participants scored their experiences 5.6 out of 7, while shareholders with 1 year (or more) of experience with CSAs gave the program a higher score. This trend continued through all the dependent variables. Experienced shareholders averaged a higher score for recommending and joining a CSA with or without a voucher compared to first-time shareholders. *t*-tests suggest that all differences between experienced and first-time shareholders are significant (see the last column of Table 4).

Table 4. Means for All Variables Used in Regression Models

	All Shareholders *N* = 736		New Shareholders *N* = 353		Experienced Shareholders *N* = 383		*t*-test
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Dependent Variables (post-CSA survey responses)							
Satisfaction with CSA program (1-7 Likert)	5.6	1.4	5.3	1.6	5.8	1.2	***
Join with a voucher (1-5 Likert)	4.3	1.0	4.1	1.1	4.5	1.0	**
Join without a voucher (1-5 Likert)	2.7	1.3	2.6	1.2	2.9	1.3	***
Recommend with a voucher (1-5 Likert)	4.5	0.8	4.4	0.9	4.7	0.8	***
Recommend without a voucher (1-5 Likert)	3.4	1.2	3.2	1.2	3.5	1.2	***
Independent Variables							
Food Choice Variables (pre-CSA survey responses) –7 point scale							
Wanting to lose weight	4.1	2.1	4.1	2.1	4.0	2.1	
Wanting to support local farms and farmers	6.1	1.2	6.1	1.2	6.2	1.2	
Wanting access to better quality food	6.4	1.0	6.3	1.1	6.5	1.0	*
Helping my family eat better	5.9	1.5	5.9	1.5	5.8	1.5	
Wanting knowledge about how my food is produced	4.8	1.8	4.8	1.9	4.8	1.7	
The voucher	6.0	1.6	6.0	1.6	6.0	1.6	

Table 4 (continued).

	All Shareholders $N = 736$		New Shareholders $N = 353$		Experienced Shareholders $N = 383$		*t*-test
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Engagement Variables (post-CSA survey) – times per CSA season							
CSA newsletter	7.2	4.2	6.5	4.3	8.0	4.0	***
CSA website	5.0	4.3	4.4	4.4	5.6	4.6	***
Conversations with CSA staff	2.1	3.0	1.5	2.4	2.9	3.5	***
Family and friends	4.4	3.7	4.3	3.6	4.6	3.9	
Cooking classes	0.4	1.3	0.3	1.2	0.5	1.5	*
Interactions with other shareholders	3.8	4.1	3.7	4.1	3.9	4.2	

Note: Two-tailed *t*-tests were conducted on means comparing experienced and first-time shareholders. Significance: ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

On average, all shareholders rated their likelihood of joining CSA 4.3 out of 5 with a voucher and 2.7 without (see Table 4). Similarly, participants are likely to recommend the CSA with a voucher (4.5 out of 5) though are a bit closer to "unsure" without a voucher (3.4 out of 5). The same relationship holds true when we examine the means for these same questions by CSA experience level. Differences between the with/without voucher conditions are significant at a 1% level in *t*-tests for all segments and in each recommend/join condition. Again, the voucher is critical to inducing participation in a certain segment of consumers. It is possible, then, that once a shareholder experiences the incentive, their future willingness to join CSA will depend on the existence of the incentive.

Food choice variables, the motivation shareholders give for joining a CSA, are very similar among new and experienced shareholders. The highest scores are related to accessing better quality food, helping families eat better, supporting farmers, and the voucher incentive itself. The only factor with a significant difference by CSA experience level is shareholders joining CSA to acquire better-quality food.

The engagement variables provide a bit more contrast, with the experienced shareholders having a higher frequency of interacting with CSA resources throughout the season. Farm websites and newsletters were among the most-used resources, whereas discussions with family, friends, and other shareholder peers were also important to participants. Experienced shareholders were more engaged overall, probably because they already had figured out that CSA success requires external resources.

Probit Regression for Joining a CSA Next Year

In this section, we examine the impact of different variables on shareholders' personal decisions about whether or not to join a CSA in the future. We present probit regression results for the "joining a CSA in the future" dependent variable in Table 5. Regression results suggest program satisfaction is highly correlated with shareholder likelihood of joining a CSA next year with or

without a voucher. As expected, if someone enjoys their experience with the CSA voucher program, one would expect that they would consider doing it again. Beyond satisfaction, previous experience with a CSA is not associated with a higher likelihood of joining next year, regardless of whether the voucher incentive is offered again.

Results from the probit regressions suggest that satisfaction with the CSA voucher program is associated with an 11.4% increase in the probability of shareholders joining a CSA program without a voucher in the future (see Table 5). The percentage increase for each variable is represented by the marginal effect's values in Table 5. We only present marginal effects for variables that are significant in the probit regression.

Only one food choice variable is associated with the likelihood of joining a CSA without a voucher. Individuals who had a higher initial rating for 'helping my family eat better' as a reason for joining the CSA seemed to have more of a commitment to joining a non-incentivized CSA program in the future. The marginal effect of 0.045 represents a 4.5% increase in the probability of recommending a program. Here, individuals have the motivation to acquire what they perceive to be better food than what they might find in other venues. As all of the farms in our employer program are USDA Organic Certified, a subset of shareholders may see CSAs as a valuable option for acquiring quality produce at a lower price than they might find at a specialty market or retail locale. It may also be simply that these shareholders perceive farm-fresh food as important for their household's everyday experience. The supporting farms variable does not seem to be associated with individuals' decisions to join a CSA in the future. This observation may support previous research that suggests that shareholders ultimately make choices that benefit themselves and not necessarily their communities (Pole and Gray, 2013).

One engagement variable (i.e., measured by the use of different resources during the CSA experience) is positively correlated with the likelihood of joining a CSA without a voucher—the number of times participating in cooking classes during the CSA season. This result suggests that parallel programming such as cooking classes is likely to increase shareholder engagement with the CSA and willingness to participate in a CSA program in the future.

Finally, individuals who placed a higher emphasis on the voucher as a reason for joining have a 5% decrease in the probability that they will join a CSA without the incentive. This result may suggest that a subgroup of program participants views CSA as an interesting idea, but only attractive at a reduced price. Previous experience was not a significant variable in explaining the likelihood of joining a CSA in the future. If someone participated in a CSA in previous years, and then received an incentive for the first time, they might be expected to join again regardless of whether they are offered a voucher. But we do not see this relationship. Instead, a voucher incentive and satisfaction with the CSA program are far more important. As such, CSA incentive programs may not lead to long-term shareholder based expansion unless great care is given to (1) developing long-term financial sustainability for incentive funding and/or (2) pairing incentive programs with farms and programming options that lead to a better shareholder experience.

Table 5. Results for Probit Regressions for Likelihood to Join/Recommend CSA

	Join without Voucher		Join with Voucher		Rec without Voucher		Rec with Voucher	
	Coef	**ME**	**Coef**	**ME**	**Coef**	**ME**	**Coef**	**ME**
Demographic Variables								
Age	-0.004		-0.004		0.011*	0.003	-0.005	
Sex–female	-0.010		-0.129		0.217		0.353	
Income	0.002		0.002		0.001		0.000	
Household size	0.057		0.067		0.010		0.035	
Program satisfaction	0.412***	0.114	0.396***	0.061	0.334***	0.107	0.597***	0.050
CSA experience	0.136		0.232		0.079		0.113	
Food Choice Variables								
Wanting to lose weight	-0.031		0.053		-0.036		-0.127**	-0.010
Wanting to support local farms	0.101		0.093		0.105*	0.034	0.244**	0.020
Wanting access to better quality food	-0.014		0.094		0.006		-0.116	
Helping my family eat better	0.164***	0.045	0.038		0.082		0.087	
Knowledge about how food is produced	-0.050		-0.057		0.046		0.021	
The voucher	-0.192***	-0.053	-0.046		-0.094**	-0.030	-0.048	
CSA Engagement Variables								
CSA newsletter	-0.017		-0.001		-0.019		0.009	
CSA website	0.008		-0.026		0.020		0.005	
Conversations with CSA Staff	0.032		0.011		0.067**	0.021	0.078	
Conversations with family and friends	-0.031		0.028		-0.007		0.057	
Cooking classes	0.111**	0.030	-0.071		-0.037		-0.216***	-0.018
Interactions with other shareholders	-0.008		0.004		-0.013		0.002	
Additional Statistics								
N	396		396		396		396	
Pseudo R2	0.209		0.221		0.176		0.432	
Wald Test	74.78***		59.81***		82.61***		88.64***	
% Predicted correctly	74.0%		89.7%		69.7%		94.2%	
Hosmer-Lemeshow Goodness of fit	6.00		5.93		8.43		7.31	

Notes: Coef = Probit Coefficient. ME = Marginal Effects. Marginal effects only shown if the variable is significant in the model. Level of significance for marginal effects is the same for all coefficients.
Significance: ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$. Additional statistics include results for specification tests.

Likelihood of Recommending a CSA

The two questions about recommending a CSA reveal a bit more about how participants value CSA beyond their immediate experience. Participants' recommendations to others acknowledge implicitly that other individuals use their best judgment in deciding whether to join a CSA. It costs little to the shareholder to make a recommendation to someone else, but it does indicate whether they feel the CSA model has value.

Yet, there are still differences when a voucher is involved. As indicated in Table 4, participants are more likely to recommend CSA with a voucher. The voucher matters in these recommendations, because shareholder scores without a voucher are closer to "unsure" regarding promotion to others. Given that peer-to-peer marketing can be an effective strategy for building CSA's community aspect, these questions provide an understanding of who might be effective peer marketers.

As we have observed in workplace-based CSA programs, success depends on having an active and engaged "champion" of the model who presents the voucher idea to participants or funders in their workplace. Similarly, workplace champions can help organize workplace drops, pre- and post-season program evaluations, and communications with farms or farm support organizations. What characteristics of an effective champion can we glean from these questions? We turn to the probit regression results to answer this question.

First, when observing the "recommend with voucher" condition, a few variables are significantly associated with a choice to recommend. Program satisfaction is associated with a 5 percent increase in the probability of recommending the CSA program (see Table 5). In contrast, previous experience seems not to be associated with the shareholder decision to recommend.

There is a statistically significant association between shareholder interest in supporting local farms and farmers, and the decision to recommend the CSA program, although this variable only accounts for a 2% increase in the probability of recommending the program. Nevertheless, these shareholders appear to value the program because it provides small and medium-sized farms with a market for diversified produce. Participants who joined because they wanted to lose weight and those who participated in cooking classes were less likely to recommend the CSA voucher program. Perhaps their experience did not meet their expectations in terms of the health benefits received or the quality of supplementary programming.

Shifting to the "recommend without" a voucher regression results, we see various associations between the dependent and independent variables emerge. The evaluation of this shareholder decision provides insights into the CSA model in general. Was the performance of the model in the subsidized year satisfying enough that shareholders would promote it without the subsidy?

Probit regression results suggest those who initially joined a CSA because of the voucher are again less likely to recommend a CSA without an economic incentive. This 3% decrease in probability to recommend indicates that for many participants, the voucher itself is a factor for encouraging participation and recommendation. While this subset likely has other motivations beyond the voucher for participation, the absence of a voucher might push these individuals toward other

market channels for produce acquisition. Further exploration of this subset of participants should be considered as CSA incentive programs evolve.

On the other hand, shareholders who joined because they wanted to support local farms have a 3% increase in the probability that they will recommend the program, even without a voucher. Supporters of local agriculture would likely be candidates to promote CSA within and outside of their workplace. Another indicator associated with willingness to recommend the program is having conversations with the CSA staff. Shareholders who actively engage with resources provided by the farms and with the farmers themselves are more active promoters of the CSA model in general. In short, when searching for a workplace or organizational champion for workplace CSA promotion, it makes sense to find someone who is already invested in the model, wants to support local agriculture, and regularly engages with CSA staff and other external resources that help them navigate their CSA experience.

While there are differences in the variables associated with the likelihood of recommending the CSA program with and without a voucher, the one variable that is highly associated with recommending the CSA program is program satisfaction. Increased satisfaction is associated with a 10% increase in the probability that a shareholder will recommend the program without an incentive (and a 5% increase with the voucher). As such, we further examine which variables are associated with higher levels of satisfaction for the full shareholder sample as well as for first-time and experienced shareholder segments.

Results from Diagnostic Tests

As we conclude our discussion of our probit models, it is worth noting that the specification tests provide validation to our models. In terms of collinear relationships among variables, we calculated a mean variance inflation factor of 1.2. No individual VIF above 1.5, so multicollinearity appears not to be a significant concern. Following each probit regression, we evaluated each model for its ability to predict actual responses based on the variables included in the regression models (see percent predicted correctly in Table 5). The recommend/join without voucher models are at 70% and 74% correctly predicted responses, respectively. The recommend/join with voucher models are at 94% and 90% correctly predicted responses, respectively. While the recommend and join without voucher models perform better than random chance, they are rather average. However, when plotting true and false positives, the area under the curve is above 0.80 for all models, which is considered a good fit. Finally, each model has a Hosmer-Lemeshow Goodness of Fit test statistic that is nowhere near significant (see Table 5). These results indicate that the proportion of observed versus expected choices is proportionate across respondent groups when segmented by their original probability of choosing the positive condition. The latter two test results suggest that our regression models fit the data well.

CSA Satisfaction

Shareholder satisfaction is generally related to higher retention rates (Durrenberger, 2002; Pole and Kumar, 2015; Galt et al., 2019). We included the same independent variables from the probit

regressions in the ordered logit regressions aiming to evaluate the factors associated with shareholder satisfaction. Results from the ordered logit regressions are presented in Table 6. It should be noted that following each ordered logit regression, we conducted the Brant Test and found no evidence that the parallel regression assumption was violated.

First, we examined shareholder satisfaction with the CSA program using all respondents who completed the surveys regardless of experience. The logit regression results suggest that a few of the engagement variables were correlated with the likelihood of a participant giving the CSA program a higher overall rating. Both variables related to CSA communication (newsletter and website) are positively correlated with the level of satisfaction with the CSA program. As such, an individual who used these resources more often was more likely to have a better experience overall. Additionally, individuals who had interactions with their family and friends around how to use the CSA were more likely to be satisfied with the experience.

Here, it seems that individuals drew from the expertise of others to use produce from their CSA box. During follow-up focus groups from this project, many shareholders discussed how they shared their produce and swapped tips for preparation with others. It is, however, difficult to disentangle the causality and directionality of engagement and satisfaction; an individual who is more satisfied initially may seek out these resources and engage in discussion.

It is here where the food choice variables can provide some clarity. In this case, only the variable "wanting to know about how my food is produced" had a significant positive impact on satisfaction. Those who are more interested in food production processes may be predisposed to be more engaged with the CSA experience. As CSAs require active learning to vary meal planning with seasonal produce, it may be that CSAs are most effective for a specific personality type.

Income is positively associated with the likelihood of satisfaction. Those with more income may be less limited in their ability to acquire supplementary food items (spices, meats, cheeses, other vegetables) to diversify meal experiences. Another possibility is that individuals to whom a CSA is a smaller portion of their income will put less pressure on the CSA to provide a superior experience than that of a grocery store or farmers' market.

Next, we examine how different variables are associated with satisfaction when considering first-time and experienced shareholders as separate groups. When we observed simple means by experience group in Table 4, experienced shareholders had mean satisfaction ratings that were statistically higher than the first-time shareholder group. This result is not surprising. Someone who enjoyed their first time in a CSA would probably enjoy it subsequent times. Otherwise, they would not have joined again. Consequently, we evaluate each group to see if different variables are correlated with higher satisfaction ratings.

Table 6. Ordered Logistic Regression Results of Voucher Satisfaction

	All Shareholders		First-Time Shareholders		Experienced Shareholders	
	Coef	**SE**	**Coef**	**SE**	**Coef**	**SE**
Demographic Variables						
Age	0.000	0.009	-0.006	0.011	0.018	0.016
Sex–female	-0.109	0.216	-0.216	0.265	0.327	0.401
Income	0.004**	0.002	0.003	0.002	0.008**	0.004
Household size	0.003	0.091	0.053	0.106	0.000	0.198
Food Choice Variables						
Wanting to lose weight	0.056	0.050	0.085	0.062	-0.076	0.098
Wanting to support local farms	0.035	0.084	0.019	0.114	0.073	0.147
Wanting access to better quality food	0.159	0.101	0.019	0.123	0.490***	0.195
Helping my family eat better	-0.045	0.077	-0.046	0.093	-0.034	0.155
Knowledge about how food is produced	0.119**	0.062	0.138*	0.076	0.176	0.117
The Voucher	-0.011	0.059	-0.015	0.086	0.072	0.096
Engagement Variables						
CSA newsletter	0.098***	0.027	0.110***	0.035	0.080*	0.047
CSA website	0.068***	0.022	0.066**	0.028	0.076**	0.038
Conversations with CSA staff	0.052	0.036	0.059	0.052	0.035	0.059
Conversations with family and friends	0.052*	0.028	0.042	0.038	0.070	0.047
Cooking classes	0.095	0.084	0.212*	0.127	-0.116	0.127
Interactions with other shareholders	0.009	0.023	-0.017	0.030	0.072*	0.042
Additional Statistics						
N	396		254		141	
LR Chi^2	86.81***		55.01***		40.76***	
Pseudo R^2	0.069		0.064		0.109	

Notes: Coef = Variable coefficient in ordered logit. SE = Standard Error. Significance levels: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$.

First-time shareholders are more likely to score satisfaction higher if they engaged with resources provided by farms (newsletter and website) to use their produce (see Table 6). Additionally, there is a positive association between satisfaction and participation in cooking classes offered by their employer or support organization. Most of the employer organizations representing this shareholder sample had cooking classes, demos, webinars, and/or recipe cards centered on specific items received in the CSA at different points during the season. As the seasonality of the produce box is one of the main challenges noted in open-response questions in our survey (and follow-up focus groups), supplementary programming and resources provide learning opportunities for those new to the CSA concept. Given that the only other variable statistically associated with a higher level of satisfaction is "wanting knowledge about how food is produced" prior to the CSA program, different engagement opportunities are important for helping a first-time shareholder navigate the CSA experience in a satisfactory manner. Income is not significant among this group of shareholders, nor is the voucher as an important motivating factor for originally joining the CSA.

The ordered logit regression used to evaluate factors associated with experienced shareholders' satisfaction with the CSA program have a few weakly significant coefficients. "Wanting access to better quality food" has the strongest significance. It may be that those who have participated in CSA before feel that the quality of produce received directly from a farm is better than what they might get elsewhere. Income and "wanting knowledge about how food is produced" also play roles in experienced shareholder satisfaction with the CSA program. Individuals in this shareholder segment who are more satisfied appear to be the typical CSA consumer (i.e., a higher-income foodie). Where this segment and the first-time shareholder segment overlap, however, are in the resources provided by the farms themselves. If farms and employer organizations can push participants toward different CSA resources and programs, shareholders in both segments are more likely to be satisfied with their experience. In short, offering a CSA incentive is not enough to guarantee satisfaction. Farms and employer organizations must think carefully about how to provide shareholders with supplementary learning and support opportunities.

Conclusion

Incentive programs are novel innovations in the CSA world which predate COVID-19, but which may offer similar insights into how new subscribers evaluate their experience. Based on our analysis, the key to retaining these new subscribers is to provide supplemental resources, programs, and avenues for engagement with their peers, family, and CSA farmers. Farmers might consider focusing on both their newsletters and websites to provide an interactive space for shareholders, especially in situations where social distancing is emphasized. In conversations with many technical assistance providers during COVID-19, CSA farmers have made this pivot quickly as e-commerce platforms became a necessity for reaching customers within and outside their CSA businesses. In employer-based programs, special consideration should be given to employee outreach and engagement. These communications are likely to be effective if both the farms and a liaison within the employer organizations are communicating with shareholders. New shareholders need particular assistance in accessing resource options and strategies for using their seasonal produce box.

It is critical to note here that while employer programs were growing before the pandemic, the nature of work and employer-based programming may be altered significantly in the coming years. Whether workplace incentive programs survive is an open question, and the funding for such endeavors may evaporate if the economy takes a protracted and significant hit. However, the workplace CSA model can be extended to diverse programs and organizations, and maybe incorporated with modifications, into food assistance programs.

In these cases, it is important to consider the impact of vouchers and incentives on the long-term market opportunities of farmers. Vouchers help capture initial participation. But the value of a voucher must be weighed over and against the goals of an organization, as well as financial and wellness outcomes of employees and communities for an employer, to justify the expense. If a balance cannot be struck, we may see a yearly fluctuation in enrollment, which would create new difficulties for farmer decision making. Additionally, inexperienced shareholders increase the workload for farmers regarding their outreach and shareholder engagement. Farmers could

alleviate these by focusing on their communications via newsletter, website, and social media strategies. Additionally, technical assistance providers and farmer coalitions might fill consumer education and shareholder facilitation roles. To conclude, while CSA is experiencing a dramatic shift in demand in 2020, farmers and support personnel must continue to develop innovative strategies to provide all shareholders useful resources, communications, and venues for engagement.

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Factors Influencing Consumers' Expected Food Waste

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Abstract

This study analyzes the factors influencing consumers' self-reported expected food waste when preparing a meal at home versus buying the meal already prepared. Results show that far-off expiration dates are expected to generate less food waste—particularly for fresh produce used in larger quantities and chicken. The Ready to Heat meal generated the lowest expected food waste. Convenient meal alternatives have the potential to reduce organic food waste, aside from any potential packaging waste, by facilitating the handling of products in transit, improving logistics, and reducing organic food waste.

Keywords: fresh produce, RTH meals, shelf life, food waste

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Introduction

While waste is inevitable at any stage of the food supply chain, the amount of waste at the consumer level is large. At earlier points of the supply chain, much of the pre- and post-harvest food that a farmer or distributor cannot sell can be repurposed in many ways, such as animal feed, compost, and biomaterials (Ellison, Muth, and Golan, 2019). However, at the consumer level, there is little opportunity for repurposing and recycling; instead, most of it goes to waste (Parfitt, Barthel, and Macnaughton, 2010; Buzby, Wells, and Hyman, 2014). The U.S. Environmental Protection Agency (EPA) reported that in 2018, 63 million tons of food waste originated from commercial, institutional, and residential sectors in the United States. Also, the EPA reported that in 2017, 41 million tons of food waste were generated, constituting 22% of discarded municipal solid waste (U.S. Environmental Protection Agency, 2020). The problem is not exclusive to the United States; Gustavsson et al. (2011) argue that approximately one-third of the food produced for human consumption along the global supply chain is lost or wasted.

The negative impacts of food waste include the loss of valuable resources, both the food itself and the water and energy that went into the production of that food (Hall et al., 2009; Cuellar and Webber, 2010; Kummu et al., 2012; Birney et al., 2017). Moreover, food waste that ends up in landfills generates harmful greenhouse emissions, such as CO2 and methane, that have been linked to global warming and other environmental costs (Venkat, 2011; United Nations, Food and Agriculture Organization, 2013; Heller and Keoleian, 2015; Moult et al., 2018).

Based on economic theory, the optimal level of food waste is the quantity at which the marginal benefit of reducing food waste is equal to its marginal cost. Lusk and Ellison (2017) found that the optimal level of household-level food waste is a function of prices, wages, time constraints, and marginal productivities of raw food and time in producing meals. They note that an individual's characteristics will affect these marginal productivities. In addition to traditional economic theory arguments, consumers might experience disutility from the regret of being wasteful when throwing out food, or disutility from the lack of variety when eating leftover foods. In practice, there are multiple challenges to achieving the optimal level of food waste on an aggregate or national level. First, there is no consensus on the definition of food waste, and there are no standard procedures to measure food waste (Buzby, Wells, and Hyman, 2014; Ostergren et al., 2014; Ellison, Muth, and Golan, 2019). As a result, the socially optimal amount of food waste is unknown, making it difficult to set goals for the level of food waste reduction that would generate a positive impact on society (Katare et al., 2017). Ellison, Muth, and Golan (2019) suggest that reducing food waste and food loss at earlier stages of the production cycle is likely costly, and the reduction methods may impose environmental costs. The earlier stages of the production cycle refer to all stages of the agri-food supply chain before reaching the consumer (i.e., production at the field, processing, shipping, transportation, and retail). Other researchers claim that a more impactful measure is to target consumers because much of their waste stems from improper grocery planning, lack of understanding of date labels and expiration dates, general indifference toward waste, or the opinion that food waste reduction is someone else's responsibility (Gustavsson et al., 2011; Stefan et al., 2013; Graham-Rowe, Jessop, and Sparks, 2014).

In light of the problem that food waste represents to society, in this study, we aim to investigate whether ready-to-heat (RTH) meals, besides convenience, offer an opportunity to reduce household food waste. This aim is based on the finding by Wilson et al. (2017), who found that consumers perceive that convenient meals, such as fresh salads with a longer shelf-life, can reduce food waste. Convenient prepared meals offer an interesting case to measure preference for meal options with reduced food waste. In general, convenient foods are categorized into four groups: (1) Ready-to-eat (RTE) meals that are consumed as purchased (e.g., sandwiches, salads, etc.), (2) Ready-to-heat (RTH) meals that require no more than 15 minutes of heating before consumption (e.g., refrigerated, frozen, dehydrated, and canned meals), (3) Ready-to-end-cook (RTEC) meals that require more than 15 minutes of heating before consumption, and (4) Ready-to-cook (RTC) meals that are minimally prepared and require full cooking (Costa et al., 2001).

The objective of this study is to estimate the factors influencing consumers' self-reported expected food waste for selected food products. The selected foods include a meal purchased already prepared and RTH, and a bundle of raw ingredients used to prepare that same meal at home. The factors considered in this analysis are: (1) three different expiration-dates for the raw ingredients and the RTH meal: close, medium, and far-off; (2) sociodemographic characteristics, and (3) grocery purchase habits of survey respondents.

The inclusion of the bundle of raw ingredients and a RTH meal is further aligned by the literature analyzing the food sustainability paradox, raised by Cavaliere and Ventura (2018). These authors claim that food products with an enhanced shelf-life and convenient meal alternatives increase the sustainability of the food supply chain by facilitating the handling of products in transit, improving logistics, and reducing food waste. However, consumers relate an enhanced food shelf-life and convenience with a lack of naturalness or freshness. Our study further explores the food sustainability paradox by comparing consumers' expected food waste of two products, one bundle perceived as natural and fresh versus a food product that is not. It is worth noting that RTH meals may lower food waste at the consumer level, yet may generate more food waste at earlier stages of the supply chain. We underscore the importance of reducing waste at the consumer level, as literature has demonstrated that at earlier stages of the supply chain, farmers and distributors can repurpose products that are imperfect for the fresh market; however, at the consumer level there are limited options for repurposing or recycling (Parfitt, Barthel, and Macnaughton, 2010; Buzby, Wells, and Hyman, 2014; Ellison, Muth, and Golan, 2019).

Literature Review

A branch of the literature on food waste focuses on food waste mitigation strategies. Reutter et al. (2017) and Ellison, Muth, and Golan (2019) suggest that there are tradeoffs along the supply chain where reducing food waste in earlier stages (in the field or processing facility) may be more beneficial or less costly from an environmental standpoint, compared to reducing it at the retail or consumer stage. Rutten (2013) analyzes whether food waste mitigation strategies would have a positive impact on societal welfare and food security and finds that the demand and supply of food play a role in estimating such impact. For example, in the presence of perfectly inelastic supply and demand curves, if loss reductions in the supply level involve cost increases (resulting in a

decrease in quantity supplied), then the welfare impacts will be lower, as the effect will be that prices will increase and quantities supplied will decrease. Aligned with such findings, Ellison, Muth, and Golan (2019) stress the importance of cost-benefit analyses when assessing food waste mitigation strategies. They suggest these costs include those faced by businesses, the government, and consumers, as well as the opportunity cost of the time needed to reduce food waste.

Understanding consumers' motives to waste food can improve mitigation strategies. For example, Visschers, Wickli, and Siegrist (2016) found that consumers are motivated to waste food when they have a "good-provider" identity, a general term that describes a type of person who enjoys having ample amounts of food even if it generates more waste. Delley and Brunner (2017) classified a sample of consumers based on their attitudes toward food waste using parameters such as whether they review what they have in stock at home, their thriftiness, usage of leftovers, perceived environmental impact, general awareness of food waste behavior, and good provider identity, and their likelihood to engage in planned shopping and be price- and discount-driven.

Neff, Spiker, and Truant (2015) suggested that consumers' main motivations to reduce food waste involve saving money and setting an example. They argued the main reasons for wasting food stem from avoidance of foodborne illness and preference for freshness. Qi and Roe (2016) found that 70% of the respondents in their study agreed that discarding food when the expiration date passes reduces the chance of foodborne illness, whereas 60% of respondents agreed that in order to eat fresh meals some food waste is needed.

Date labels on food products are believed to be a major cause of food waste. In fact, the lack of standard regulations for expiration dates leads to inconsistent labeling practices across states and to the discretion of industries. Consumers are often misled by the labels "use by," "best before," and "sell by" labels; these labels are perceived as indicators of safety, when they are meant to indicate when food will be at its peak taste. This leads food processors, retailers, and consumers to discard food that is perfectly safe to sell or eat (Broad Leib et al., 2013). Researchers have measured the impact of these different labels on food waste. Wilson et al. (2017) measured the impact of date labels, such as "use by," "sell by," "fresh by," and "best by," on food waste through auctions for products of diverse sizes and types. They found that, overall, the label "use by" had the lowest mean expected waste. Wilson, Miao, and Weis (2019) analyzed the effect of quality ("best if used by") versus safety labelling ("use by") and found that the likelihood of consuming a product based on the type of label varies by product.

In general, studies agree that consumers' previous negative experiences and perceived risk affect their interpretation of date labels, making them more likely to discard a product before it expires and increasing food waste (Broad Leib et al., 2013; Miles and Frewer, 2001; Tsiros and Heilman, 2005; Wilson et al., 2017). To our knowledge, this is the first study to estimate expected percentages of food waste comparing a bundle of raw ingredients and a prepared RTH meal made with the same bundle of raw ingredients.

Methodology

Data Collection and Survey Design

Data were collected through an online survey using the Qualtrics platform and the Qualtrics market research consumer panel. Qualtrics randomly selected and recruited a representative sample of U.S. consumers, following Census sociodemographics in terms of age, income, education, ethnicity, and rural/urban place of living. In addition, the selection criteria included individuals who were 18 years old or older, in charge of the grocery shopping in the household, and had consumed a convenient prepared meal within the 3 months prior to taking the survey. The survey was distributed from September 13 to October 1, 2017. In total, 377 complete responses were obtained.

Respondents were asked to report what percentage, ranging from 0% to 100%, of the product their household was likely to consume before each of a set of three different expiration dates—a close, a middle, and a far-off date. The products included selected raw ingredients, including chicken, broccoli, tomatoes, garlic, and basil; also included was a refrigerated RTH meal, chicken piccata and penne rigate with broccoli. The latter was selected because this is a product that exhibited a balanced combination of protein (chicken), carbohydrate (pasta), and vegetable (broccoli) in the meal. These raw ingredients were chosen because they are ingredients found in the RTH meal. In this way, it is possible to compare side by side how much food is wasted when preparing the meal at home versus when buying the already prepared meal. An example of the question used to elicit expected food waste is included in Figure 1. To analyze the expected food waste, the data were tabulated as the difference between 100% minus the percentage they indicated they are likely to consume.

Suppose you are grocery shopping today and purchase the product below. What percentage of the following product are you (or your household) likely to consume before it expires, based on your recent consumption habits? For example, purchased 7/13/17.

		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100 %
Q14a. Chicken breast (stored in your refrigerator) 	Use by (next day) Ex. 7/14/17											
	Use by (three days after) Ex. 7/16/17											
	Use by (5 days after) Ex. 7/18/17											

		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100 %
Q14b. Broccoli (stored in your refrigerator) 	Use by (next day) Ex. 7/14/17											
	Use by (3 days after) Ex. 7/16/17											
	Use by (5 days after) Ex. 7/18/17											

		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100 %
Q14c. Garlic (stored in your pantry) 	Use by (3 days after) Ex. 7/16/17											
	Use by (2 weeks after) Ex. 7/27/17											
	Use by (a month later) Ex. 8/13/17											

		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Q14d. Tomatoes (stored in your pantry) 	Use by (next day) Ex. 7/14/17											
	Use by (3 days later) Ex. 7/16/17											
	Use by (a week later) Ex. 7/20/17											

		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Q14e. Fresh Basil (stored in your refrigerator) 	Use by (next day) Ex. 7/14/17											
	Use by (a week later) Ex. 7/20/17											
	Use by (10 days later) Ex. 7/24/17											

		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Q14f. Ready-to-eat meal (stored in your refrigerator) 	Use by (next day) Ex. 7/14/17											
	Use by (four days later) Ex. 7/17/17											
	Use by (two weeks later) Ex. 7/27/17											

Figure 1. Example of the Question Eliciting Expected Percentages of Food Consumed/Wasted

The expiration dates vary to match each product's typical shelf-life. These are obtained from the FoodKeeper App (U.S. Department of Health and Human Services, 2019). For example, raw chicken typically has a shelf-life of 3 to 5 days, so the survey specifies that the chicken expires within 1, 3, and 5 days from the date of purchase. Broccoli is presented with similar expiration dates: 1, 3, and 5 days. Tomatoes are presented with expiration dates of 1 day, 3 days, and 1 week. Basil is presented with expiration dates of 1 day, 1 week, and 10 days. Garlic had 3 days, 2 weeks, and 1 month. Finally, the refrigerated RTH meal chicken piccata and penne rigate with broccoli exhibited the expiration dates of 1 day, 4 days, and 2 weeks. This was based on the shelf-life of vacuum-packed-in-store refrigerated RTH meals (4 days) and commercially sealed RTH meals with USDA label (up to 2 weeks). The online survey was programmed in a way that the date of purchase coincided with the day the respondent took the survey. In addition, the survey included questions about food shopping habits, food consumption habits in general, consumption of RTH meals, and sociodemographic questions.

Data Analyses

Summary statistics of sociodemographic profiles include the estimation of frequency distributions and weighted averages. Summary statistics of expected food waste include the means and Tukey difference test estimation. A double-bounded Tobit model is used to estimate the parameter estimates of sociodemographic and purchase habit factors affecting the percentage of expected food waste. This model allows censoring in both tails of the probability distribution of the dependent variable. In our case, the dependent variable is the stated percent of expected food waste, whose reported values are in the interval [0–100]. Figure 2 presents the histogram showing the distribution of the dependent variable, expected food waste percentage.

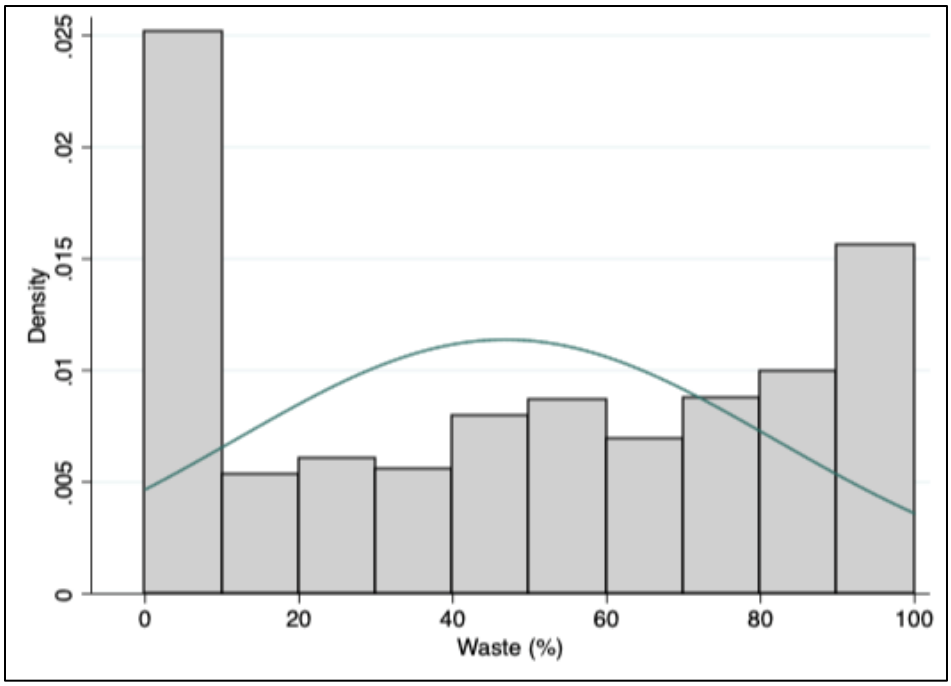

Figure 2. Histogram Showing the Distribution of the Dependent Variable, Waste Percentage

The Tobit model follows:

$$Y = \begin{cases} 0 & if\ Y^* \leq 0 \\ y^* & if\ 0 < Y^* < 100 \\ 100 & if\ Y^* \geq 100 \end{cases} \quad (1)$$

$$Y_i^* = X_i\beta + \epsilon_i \quad (2)$$

where $Y^*$is a latent variable that is observed for values within the range [0–100] and censored otherwise. X_i is the vector of explanatory variables, which include: expiration dates (close, medium, and far, which was excluded to omit the dummy variable trap); product category (garlic, basil, tomato, broccoli, chicken, and RTH meal [excluded option]); and sociodemographic characteristics of the respondent, which encompasses if female, if millennial (born after 1985); if income is above the U.S. median ($61.372 per year; U.S. Census, 2018c); if attained a 4-year college degree; if white ethnicity; if lives in a large city; if lives in the West, South, Midwest, and Northeast, which was omitted to avoid the dummy variable trap; if more than two individuals in the household; if children are present in the household; and if employed. Other respondents' characteristics of if consider themselves healthy, active, or if pay attention to food labels, and places they grocery shop (limited assorted establishments, online, farmers' markets, drugstore, convenience store, supermarkets, ethnic food stores, supercenter, warehouse, organic specialty stores, and discount stores), were also collected. Among these, farmers' markets was omitted to avoid the dummy variable trap. β is the vector of parameters to be estimated, and ϵ_i represents the error term that captures possibly unobservable factors affecting the expected percent of food waste and is assumed to follow a normal distribution.

The sociodemographic characteristics of the respondent were chosen based on previous findings on sociodemographic predictors of food waste behavior. Grasso et al. (2019) found that being older, unemployed, and working part-time were associated with less food waste in Europe (Spain and Denmark). In Denmark, being male was associated with more waste, but being part of a larger household implied less waste. Dusoroth and Peterson (2020) conducted a survey in Minnesota, U.S., and found that consumers who have established a pre-shopping and in-store behavior were less prone to waste fresh spinach and ground beef products. Pre-shopping routine includes making grocery shopping lists and checking food inventories at home before grocery shopping. The in-store behavior refers to buying impulses in the store or how prone shoppers are to stick to the shopping list. The place for grocery shopping could be an indicator of the level of pre-shopping and in-store behavior and, therefore, may impact one's proneness to waste food. Finally, we include self-perceptions of health and physical activity since these variables have been found to influence consumption of RTH meals (Cavaliere and Ventura, 2018). A Variance Inflation Factor (VIF) was conducted to infer whether independent variables included in the model exhibited collinearity. Test results prove no evidence of collinearity.

Results and Discussion

Respondents' Sociodemographic Profile

The sociodemographic characteristics of the sample of respondents to this survey are compared to the U.S. Census 2018 in Table 1 (U.S. Census Bureau, 2016a–b, 2018a–c). The data in this study represent more women, more educated, wealthier, more of white ethnicity individuals, and somewhat similar age compared to the general U.S. population. This profile is aligned with the selection criteria for the sample of respondents: should be in charge of the grocery shopping in the household and had consumed a convenient prepared meal within the 3 months prior to taking the survey. The requirement of being in charge of the grocery shopping explains the higher proportion of women in the sample of respondents (Dusoruth and Peterson, 2020). Besides the sociodemographic profile of respondents to this survey (e.g., more women, more educated, wealthier, more of white ethnicity individuals) follows the profile of individuals who tend to be more responsive to surveys (Curtin, Presser, and Singer, 2000). Urban/rural residency, employment, and regional distribution of respondents of our survey are comparable to those estimated for the general population using the U.S. Census data (2016a-b). In relation to shopping habits, 53% of the respondents reported shopping for two people, and around 82% said they do not shop for someone under the age of 18. Concerning self-reported health, 37% of the respondents reported being somewhat healthy, and 31% reported being healthy. Thirty-one percent of respondents reported being somewhat active, and 38% of respondents reported being active.

Table 1. Sociodemographic Variables by Frequency for Selected Characteristics

		Frequency (%)	
Variable	**Description**	**Survey Sample**	**U.S. Census 2018**
Gender	Male	28.12	49.20
	Female	71.88	50.80
Education	Some school	0.80	12.40
	High school graduate	9.55	27.10
	Community college	16.98	29.00
	4-year college or university	37.93	19.40
	Advanced or professional degree	34.75	12.10

Table 1 (continued).

		Frequency (%)	
Variable	**Description**	**Survey Sample**	**U.S. Census 2018**
Community	Rural area	19.89	19.30[a]
	Small town	19.89	
	Small city	22.55	80.70
	Large city	37.67	80.70
Occupation	Manual labor	8.49	–
	Services and hospitality	8.22	–
	Education, business, and information	36.34	–
	Miscellaneous	2.65	–
	Retired	12.73	–
	Not employed	31.56	–
Age	18–24 years	4.77	9.54
	25–34 years	11.67	13.80
	35–44 years	13.00	12.60
	45–54 years	10.88	13.20
	55–64 years	22.55	12.80
	65+ years	37.14	15.20
Income	Less than $25,000/year	7.96	20.20
	$25,000–$34,999/year	6.10	9.30
	$35,000–$49,999/year	10.34	12.60
	$50,000–$74,999/year	19.36	17.50
	$75,000–$99,999/year	19.63	12.50
	$100,000/year or more	36.60	27.90
Number of people you shop for	One person	20.69	–
	Two people	53.32	–
	Three people	13.00	–
	Four or more people	13.00	–
Number of people you shop for who are under 18	None	81.70	–
	One person	7.69	–
	Two people	7.16	–
	Three people	1.86	–
	Four or more people	1.59	–

Table 1 (continued).

Variable	Description	Frequency (%)	
		Survey Sample	U.S. Census 2018
Race	American Indian or Alaskan Native	0.80	0.70
	Asian	2.12	5.40
	Black	2.65	12.30
	Hispanic	3.45	17.80
	Middle Eastern	–[b]	–
	Pacific Islander	0.27	0.20
	White	86.47	61.10
	Mixed race	1.59	2.60
	Prefer not to respond	2.65	–
Region	New England	7.16	4.56[c]
	Middle Atlantic	10.88	12.86
	East North Central	13.26	14.47
	West North Central	7.16	6.55
	South Atlantic	16.71	19.79
	East South Central	1.33	5.85
	West South Central	4.77	12.21
	Mountain	9.55	7.36
	Pacific	28.91	16.34
	Other	0.27	–
Health status	Not healthy	0.80	–
	Somewhat healthy	6.90	–
	Neither healthy nor unhealthy	9.28	–
	Somewhat healthy	36.87	–
	Healthy	46.15	–
Activity level	Not active, never exercise	5.57	–
	Somewhat active, occasionally exercise	30.50	–
	Active, exercise 1–3 times per week	38.46	–
	Very active, exercise > 4 times per week	25.46	–

[a] Based on 2015 estimates.

[b] There was no direct group Middle Eastern nor respondents who selected this category in the survey.

[c] Based on 2016 estimates.

Summary Statistics for Expected Food Waste

The means and differences of the waste percentage for the three expiration date categories, close, medium, and far, are presented in Table 2. Respondents stated they would waste a larger percentage of food with a close expiration date (57%), followed by a medium (47%), and finally by a far-off date (36%), with respect to the time the survey was taken. The pairwise differences

among expiration date categories are all statistically significant. The food waste reduction between a far and close expiration date is at 22%, and the reduction between a far and medium expiration date is at 11.7%. These results suggest that post-harvest technologies that could enhance the shelf-life of fresh produce may reduce expected food waste. Also, these results support that enhancements to shelf-life shall be applied to all products included in this study, that is, fresh produce, protein source, and even prepared meals.

The mean percent of food waste across food products included in this study are also presented in Table 2. Consistently, one can observe four groups of foods in terms of food waste, across all expiration date categories. The largest expected waste percentage is for garlic (57%) and basil (56%). The second largest expected food waste percentage is for tomato (45%) and broccoli (44%). The third largest expected waste is for chicken (42%), and the smallest food waste percentage is for the refrigerated RTH meal (37%). These results suggest that perishable produce, such as garlic, basil, tomato, and broccoli, is contingent to more food waste compared to protein sources, such as chicken. This could be attributable to the relatively higher unit prices of chicken, and the type of food preparation used for these products (often served raw versus cooked or reheated). Also, garlic and basil are subject to higher waste percentages compared to tomatoes and broccoli. This may be because the former are usually sold in bunches and are used in small quantities in meals prepared at home. These results imply that selling fresh produce, such as garlic or basil, in smaller quantities is a possible food waste mitigation strategy.

Table 2. Expected Percentage of Food Waste by Expiration Date and Food Product—Means and Tukey Differences

	Expected Food Waste Percentage		
Variables	**Means**	**Difference**	***p*-value**
Food waste percentage by expiration date			
Close expiration date	57.29	–	–
Medium expiration date	47.42	–	–
Far expiration date	35.72	–	–
Food waste percentage comparison across expiration dates			
Far–close	–	-21.57	0.00
Medium–close	–	-9.87	0.00
Medium–far	–	11.70	0.00
Food waste percentage by food product			
Garlic	56.81	–	–
Basil	55.99	–	–
Tomato	45.24	–	–
Broccoli	44.39	–	–
Chicken	41.81	–	–
RTH meal chicken piccata	36.62	–	–

Table 2 (continued).

	Expected Food Waste Percentage		
Variables	**Means**	**Difference**	***p*-value**
Food waste percentage comparison across food products			
Garlic-chicken	–	15.01	0.00
Garlic-broccoli	–	12.43	0.00
Tomato-RTH meal	–	8.62	0.00
Tomato-chicken	–	3.43	0.14
Tomato-broccoli	–	0.85	0.99
Garlic-basil	–	0.83	0.99
Chicken-broccoli	–	-2.58	0.43
RTH meal-chicken	–	-5.19	0.003
RTH meal-broccoli	–	-7.77	0.00
Tomato-basil	–	-10.75	0.00
Tomato-garlic	–	-11.58	0.00
Broccoli-basil	–	-11.60	0.00
Chicken-basil	–	-14.18	0.00
RTH meal-basil	–	-19.37	0.00
RTH meal-garlic	–	-20.19	0.00

Note: Expiration date varies by product.

Results from the Tukey difference test indicate that there are no statistically significant differences between garlic and basil waste, but differences are observed between garlic and tomatoes, garlic and broccoli, basil and tomatoes, and basil and broccoli waste. Meanwhile, there are no statistically significant differences between tomatoes and broccoli. However, there are statistically significant differences between the waste of chicken and garlic, chicken and basil, chicken and tomatoes, and chicken and broccoli. Finally, the differences in food waste between the refrigerated RTH meal and each of the raw ingredients included are statistically significant.

The average food waste percentages by product and expiration date category are presented in Table 3. These results are consistent—closer expiration dates imply higher food waste percentages for all products included in this study. Also, across expiration date categories, the product exhibiting the highest food waste percentage is garlic, followed by basil, tomatoes, broccoli, chicken, and the refrigerated RTH meal. The differences in the average food waste by product and by expiration date category are also presented in Table 3. The results are not consistent with those in Table 2. These differences highlight the importance of the different expiration dates on the propensity to waste food. Mixed evidence is found when food waste percentage is analyzed by each expiration date category. For example, no differences are found between food waste percentages of garlic and basil across three expiration date categories. When comparing garlic with chicken and tomato, statistically significant differences are observed across three expiration dates. However, statistically significant differences are observed between food waste for garlic and broccoli for a close and medium, but not for a far expiration date.

Table 3. Expected Food Waste Percentage by Expiration Date and Food Product—Means and Tukey Difference Test

	Means		
Food Product	**Close**	**Medium**	**Far**
Garlic	71.78	58.54	40.12
Basil	65.59	56.28	46.10
Tomato	58.43	46.21	31.07
Broccoli	55.47	45.36	32.33
Chicken	50.89	42.91	31.62
RTH meal	41.56	35.21	33.08

	Comparisons					
Food Product	**Difference**	***p*-value**	**Difference**	***p*-value**	**Difference**	***p*-value**
Broccoli-basil	-10.114	0.004	-10.918	0.001	-13.769	0.000
Chicken-basil	-14.695	0.000	-13.369	0.000	-14.480	0.000
Chicken-broccoli	-4.581	0.911	-2.451	1.000	-0.711	1.000
Garlic-basil	6.191	0.474	2.265	1.000	-5.979	0.542
Garlic-broccoli	16.305	0.000	13.183	0.000	7.790	0.107
Garlic-chicken	20.886	0.000	15.634	0.000	8.501	0.043
RTH meal-basil	-24.021	0.000	-21.069	0.000	-13.013	0.000
RTH meal-broccoli	-13.907	0.000	-10.151	0.003	0.756	1.000
RTH meal-chicken	-9.326	0.013	-7.700	0.119	1.467	1.000
RTH meal-garlic	-30.212	0.000	-23.334	0.000	-7.034	0.239
Tomato-basil	-7.159	0.212	-10.069	0.004	-15.024	0.000
Tomato-broccoli	2.955	0.999	0.849	1.000	-1.255	1.000
Tomato-chicken	7.536	0.143	3.300	0.997	-0.544	1.000
Tomato-garlic	-13.350	0.000	-12.334	0.000	-9.045	0.020
Tomato-RTH meal	16.862	0.000	11.000	0.001	-2.011	1.000

The differences in food waste percentages are not consistent for basil and other foods. For example, considering a close expiration date, there are no statistically significant differences in food waste between basil and tomato, but differences are observed between basil and tomato for medium and far expiration dates. Meanwhile, consistently across all three expiration dates, higher food waste percentages are stated for basil compared to broccoli and chicken.

Similarly, across all three expiration date categories, statistically significant differences in food waste percentages are observed between broccoli and basil, but not for broccoli and tomato, or broccoli and chicken. These results highlight the importance of the time-until-expiration dates when considering food waste. For example, the consumer will be indifferent between wasting chicken, broccoli, or garlic with an enhanced shelf life (far expiration date) or buying a refrigerated RTH meal.

Factors Affecting Food Waste

Parameter estimates from the double censored Tobit model are presented in Table 4. Marginal effects of each of the variables are also presented in Table 4, and are discussed in the following paragraphs. Results are consistent with the summary statistics in that a closer expiration date implies higher waste percentages compared to longer expiration dates. The expected waste for foods with a close and medium expiration date is 18% and 10% larger, respectively, than the expected waste for foods with a far-off expiration date. These results are consistent with findings in Qi and Roe (2016), who found that consumers discarded food when the expiration date had passed to reduce the risk for foodborne illness. The results are also consistent with findings in Tsiros and Heilman (2005) and Miles and Frewer (2001) in that consumers are more likely to discard a product before it expires, increasing food waste.

Table 4. Parameter Estimates and Marginal Effects for the Double Censored Tobit Model Depicting Factors Affecting Expected Food Waste Percentage

Variables	Parameter Estimate	Standard Error	Marginal Effects	Standard Error
Intercept	34.087***	3.701		
Close expiration date	27.081***	1.259	18.225	0.889
Medium expiration date	16.118***	1.261	10.644	0.857
Garlic	26.855***	1.783	18.906	1.362
Basil	25.457***	1.784	17.843	1.353
Tomato	12.643***	1.790	8.488	1.255
Broccoli	11.848***	1.791	7.932	1.249
Chicken	7.816***	1.798	5.158	1.220
Female	5.726***	1.189	3.620	0.741
Millennial	2.398	1.610	1.551	1.051
Income above U.S. median	1.016	1.376	0.650	0.877
4-year college	-2.336*	1.287	-1.507	0.835
White	-8.756***	1.625	-5.815	1.117
Lives in large city	3.890***	1.141	2.508	0.739
Lives in the West	3.726**	1.611	2.400	1.043
Lives in the South	1.384	1.684	0.891	1.089
Lives in the Midwest	-4.005**	1.701	-2.533	1.062
More than two in household	-4.878***	0.736	-3.128	0.472
Presence of children	1.559	1.687	1.005	1.094
Healthy	-4.034***	1.498	-2.625	0.989
Active	3.139***	1.194	2.003	0.758
Employed	-4.385***	1.118	-2.819	0.721
Attention to labels	-2.235	1.605	-1.446	1.047
Limited assortment stores	6.000***	1.635	3.943	1.101

Table 4 (continued).

Variables	Parameter Estimate	Standard Error	Marginal Effects	Standard Error
Online	5.677**	2.499	3.744	1.694
Drugstore	1.449	1.366	0.933	0.883
Convenience stores	1.200	1.659	0.773	1.073
Supermarket	-0.485	1.383	-0.312	0.890
Ethnic food stores	-0.428	2.536	-0.274	1.619
Supercenter	-1.385	1.290	-0.886	0.822
Warehouse	-2.373	1.542	-1.508	0.972
Organic specialty stores	-5.537***	1.228	-3.518	0.773
Discount stores	-13.205***	2.519	-7.910	1.404
Log likelihood	-20,169.602	No. obs.	6,786	

Notes: *, **, *** means the parameter estimates are statistically significant at the 10%, 5%, and 1% level. There are 6,786 observations as the study; this includes six products, each with three expiration dates, and 377 respondents (6 x 3 x 377 = 6,786).

Four groups can be observed in terms of food waste when comparing ingredients to RTH meals. The largest expected food waste percentage is for fresh produce that is used in small quantities in recipes. The expected food waste percentage for garlic is 19%, and basil is 18% larger than the expected waste of RTH meals. The second group is fresh produce that is used in larger amounts in prepared at-home meals. The expected waste of tomato and broccoli is 8% larger than the expected food waste percentage of RTH meals. The third group is chicken, the protein source, with an expected food waste percentage that is 5% larger than the expected food waste percentage of RTH meals. This result is consistent with Qi and Roe (2016), who found that consumers expect to waste food in order to eat fresh meals, however, from a different perspective. Qi and Roe (2016) center their findings on the fact that consumers tend to waste leftovers or ingredients with limited remaining shelf-life.

With respect to sociodemographic characteristics of the sample, females stated they would waste 4% more, compared to males. This finding contrasts with Dusoruth and Peterson (2020), who found that male respondents to a survey conducted in Minnesota, U.S., exhibited a higher tendency to waste fresh spinach. Parameter estimates for being a millennial and having an income higher than the U.S. median are not statistically significantly different from 0. This finding is different from Dusoruth and Peterson (2020), who found that younger and higher income individuals in their study showed a lower tendency to waste fresh spinach. Estimates for completion of a 4-year college degree and for white ethnicity are statistically significant and negative for the food waste percentage. Consumers with a 4-year college degree stated they would waste 2% less food than those without a 4-year college degree. This finding coincides with Dusoruth and Peterson (2000), who found that individuals with higher educational attainment had a lower tendency to waste ground beef products. White-ethnic respondents stated they would waste 6% less food than non-white respondents. Similarly, this finding coincides with Dusoruth and Peterson (2000), who found that white respondents had, on average, a lower tendency to discard ground beef.

Estimates for living in large cities and the U.S. West region are positive and statistically significant. Results indicated that survey respondents living in large cities exhibited a higher expected waste by 3% more compared to respondents living in non-large cities. Similarly, survey respondents living in the U.S. West region, exhibited a higher expected waste by 2%, compared to respondents living in the Northeast. In contrast, individuals living in the Midwest exhibited a lower expected food waste by 3% less compared to those in the Northeast. These results signal regional differences in expected food waste percentage; however, we cannot identify the specific lifestyle factors, including ability and access to compost, that would explain such differences.

Respondents in households with more than two individuals stated that they would waste 3% less food, compared to households with less than two individuals. This is consistent with Grasso et al. (2019) in that consumers in Denmark with larger households wasted less food. The parameter estimate for presence of children is not statistically significantly different from 0. Individuals who consider themselves healthy stated they would waste 3% less food, compared to those who considered themselves not healthy. Also, those who consider themselves as active stated that they would waste 2% more food, compared to those who consider themselves as not active. Individuals who are employed full-time would waste 3% less food compared to those who are retired or unemployed. This finding is different from Grasso et al. (2019), who found that unemployed and employed part-time respondents were associated with less food waste. Interestingly, the parameter estimate for attention to labels was not statistically significantly different from 0. The different findings on the effects of sociodemographics on expected food waste between this study and Grasso et al. (2019) may be explained by the specific contextual circumstances faced by consumers in each country being surveyed. Grasso et al. (2019) surveyed consumers in Spain and Denmark, and the present study surveyed consumers in the U.S. The effect of the specific context of each country is further supported by the differences in food waste behavior between the two countries surveyed by Grasso et al. (2019).

With respect to places where respondents shop for groceries, findings show that those buying food at limited assortment stores (e.g., Grocery Outlet, Aldi's, Save-A-Lot) and online (e.g., Amazon Fresh) stated they would waste 4% more compared to respondents who buy at farmers' markets. Those buying food at organic specialty stores (e.g., Whole Foods, Trader Joe's) and discount stores (e.g., WinCo, Fareway) stated they would waste less food, 4% and 8%, respectively, compared to respondents who buy from farmers' markets. These latter results are aligned with Delley and Brunner (2017), who found that consumers who are price- and discount-driven are more likely to waste less food. Dusoroth and Peterson (2020) found that consumers who have established a pre-shopping and in-store behavior were less prone to waste spinach. These results emphasize that food retailer format (e.g., online and "brick and morter") could indicate the level of pre-shopping and in-store behavior and, therefore, the proneness to waste.

Conclusions

Food waste is a sizable problem for society. Valuable resources are wasted, and pollution is generated. Researchers studying food waste concur that food waste at the consumer level is the most problematic and that mitigation strategies should be directed to consumers. This study

estimates the factors influencing consumers' self-reported expected food waste for a bundle of raw ingredients used to prepare a meal at home compared to the same meal bought already prepared and RTH.

Findings in this study indicate that expiration dates further away leave respondents less food waste across all food products included in this study. Also, fresh produce used in smaller quantities in meals prepared at home, such as garlic and basil, are expected to generate more food waste compared to fresh produce used in larger quantities, such as broccoli and tomatoes. Among the bundle of raw ingredients, the lowest expected food waste percentage was for the protein source, chicken. Comparing the bundle of raw ingredients with the RTH meal, the latter implied the lowest expected food waste percentage.

Results from this study support the idea that fresh produce with enhanced shelf-life could mitigate food waste. Since the taste, quality, and safety of food deteriorate over time, and consumers are risk averse, they waste more of a food product that is closer to the expiration date. Hence, part of a mitigation strategy could rest on advancing post-harvest technologies that improve fresh produce shelf-life, provided consumers accept these novel post-harvest technologies. These results also suggest that a potential food waste mitigation strategy at the grocery store retail level could include selling some types of fresh produce in smaller quantities.

Further, findings from this study imply that refrigerated RTH meals can reduce food waste compared to a bundle of raw ingredients, adding to the food sustainability paradox raised by Cavaliere and Ventura (2018). Convenient meal alternatives have the potential to reduce organic food waste, aside from packaging waste, by facilitating the handling of products in transit, improving logistics, and reducing organic waste. Even considering that food waste could be generated at an earlier stage of the supply chain, past research demonstrates that there are more alternatives to mitigate or repurpose waste at earlier stages of the supply chain compared to the consumer stage. This research highlights the need to improve policies and other efforts to increase consumer knowledge and awareness of the trade-offs of preparing foods at home, that is, natural and fresh foods; with perceptions of environmental consciousness, that is, options to reduce food waste, to aid in the decision-making process of choosing a food product.

Limitations of the study include that the survey tool was administered to subjects who are in charge of grocery shopping and who have consumed a RTH meal in the last 3 months. While it was important for the study to gather subjects in charge of deciding what food items to purchase and were knowledgeable of RTH meals, this could have affected the generalizability of the findings. Further research warrants a more ample selection of consumers, not screening for subjects in charge of grocery shopping or who have consumed a RTH meal. Suggestions for further research warrant the collection of information on respondents' perceptions and level of knowledge on how food waste affects the environment, accessibility and availability to large food storage appliances, and to compost options.

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Tennessee Fruit and Vegetable Farmer Preferences and Willingness to Pay for Plastic Biodegradable Mulch

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Abstract

Regardless of the potential economic and environmental benefits associated with plastic biodegradable mulch (BDM) use in fruit and vegetable production, BDM adoption among U.S. farmers remains relatively low. One of the factors influencing low BDM adoption is its cost. Using a 2019 Tennessee fruit and vegetable farmer survey, the contingent valuation method, and a probit regression, this study evaluates farmers' preferences and willingness to pay (WTP) for BDM. Results suggest price, on-farm income, and familiarity with BDM are factors influencing farmer adoption of BDM. However, results suggest producer WTP for BDM is below current BDM market prices.

Keywords: contingent valuation, plastic biodegradable mulch, farmer willingness to pay
JEL Codes: Q16 Q13

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Introduction

Traditionally polyethylene (PE) mulch is used in fruit and vegetable production because of the benefits it provides, including soil moisture and temperature conservation, weed control, higher yields, and better crop quality (Emmert, 1957; Kasirajan and Ngouajio, 2012). Regardless of the benefits of PE mulch, there are concerns regarding the environmental sustainability associated with its use (Velandia et al., 2020b). At the end of the cropping season, PE mulch is removed and farmers use various methods to dispose of it, including disposing of it in landfills, burying it on-farm, or burning it (Kasirajan and Ngouajio, 2012; Velandia et al., 2020a). The choice of disposal method likely varies by location, depending on environmental regulations, regulation enforcement, costs, and producer preferences. However, each of the above disposal methods negatively impact the environment and directly or indirectly contribute to soil plastic pollution (Valavanidis et al., 2008; Velandia et al., 2020a; Velandia et al., 2020b). Furthermore, when removing PE mulch, fragments may remain in the soil. The accumulation of these mulch fragments over time generates plastic pollution that could negatively impact soil health, yield, and, therefore, the profitability of farm businesses (Liu, He, and Yan, 2014; Touchaleaume et al., 2016).

Plastic biodegradable mulch (BDM) is a more sustainable alternative to PE mulch. It provides the same benefits of PE mulch (e.g., soil moisture and temperature conservation, weed control, higher yields, and better crop quality), but does not have to be removed at the end of the cropping season, rather it is tilled into the soil, as it is designed to decompose into water and carbon dioxide (Waterer, 2010; Goldberger et al., 2013; Cowan et al., 2014; Ghimire et al., 2018; Sintim et al., 2019). It is important to acknowledge that the performance of both PE mulch and BDM in terms of weed control could be affected by the specific weed community and weed pressure at each farm (Moore and Wszelaki, 2019). Additionally, the benefits provided by BDM, like higher yield and better crop quality, are affected by the crops grown and environmental conditions, which vary by location and from one year to another (Ghimire et al., 2018). The long-term impact of tilling BDM into the soil needs to be investigated further (Sintim and Flury, 2017; Sintim et al., 2019), but for now, BDM seems to be a viable option to reduce plastic pollution associated with the use of PE mulch. Furthermore, Chen et al. (2019) suggest consumers are willing to pay a price premium for products grown on BDM. Specifically, they suggest that U.S. consumers, on average, are willing to pay a 10.3% premium above the market price for a 1-pound box of strawberries grown on BDM. Their results imply that BDM not only offers end-of-the-season cost savings because it reduces activities related to the removal and disposal of PE mulch, but it may also provide revenue opportunities for farmers.

While BDM is more environmentally friendly than PE mulch and there are potential cost savings and revenue opportunities associated with its use, the level of BDM adoption among fruit and vegetable farmers is relatively low. A 2020 survey of Tennessee fruit and vegetable farmers, the same survey data used in this study, revealed that only 15% of the 181 respondents had ever used BDM in their fields (Velandia et al., 2020a). Furthermore, results from a survey of strawberry farmers in California, the Pacific Northwest, and the Mid-Atlantic region of the United States showed that only about 19% and 9% of the respondents in California and the Mid-Atlantic region, respectively, had used BDM in their strawberry fields. None of the survey respondents in the

Pacific Northwest indicated BDM use in their strawberry fields (Goldberger, DeVetter, and Dentzman, 2019). Additionally, a 2012 survey of Tennessee, Washington, and Texas fruit and vegetable farmers found that only 29% of 34 respondents indicated they had used BDM in the past (Goldberger et al., 2013).

Potential explanations for the low adoption rate of BDM among fruit and vegetable farmers include: lack of information about these mulch products; the high price of BDM compared to PE mulch; uncertainty about the performance of BDM compared to PE mulch; concerns about the impact tilling BDM would have on the soil in the long run; product availability; and previous poor experiences with mulch products that were incorrectly labeled as BDM but that were not actually designed to biodegrade, such as oxo-degradable mulches (Goldberger et al., 2013; Velandia et al., 2020a). Goldberger et al. (2013) and Velandia et al. (2020a) suggested that the price of BDM is the most common barrier to adoption listed by fruit and vegetable farmers.

As stated above, one of the most important considerations by farmers in evaluating the use of BDM is its cost relative to prices of other mulch options (e.g., PE mulch, straw, paper-based mulch, no mulch). In general, BDM is more expensive than PE mulch. Previous studies suggest BDM can be twice as expensive as PE mulch (Velandia, Galinato, and Wszelaki, 2019). Using information from various input suppliers' websites, we estimated that the price of BDM could be 75% to 200% higher than the price of PE mulch.

For those producers currently using PE mulch, the cost savings (i.e., reduced labor) associated with not having to remove and dispose of BDM is an additional consideration when evaluating the use of BDM (Velandia, Galinato, and Wszelaki, 2019). For example, using the same survey data from this study, Velandia et al. (2020a) suggested that producers could save between 0 and 80 hours per acre due to the elimination of removal and disposal activities. These savings vary greatly from farm to farm, depending on the crop grown, soil and environmental conditions, and removal and disposal methods (Velandia et al., 2018). Respondents who stated that there are no labor savings associated with the elimination of PE mulch removal and disposal activities likely perform these tasks themselves or with the help of unpaid family labor. As a result, they would not assign a dollar value to this labor. On the other hand, cost savings associated with PE mulch disposal vary greatly from farm to farm, depending on disposal method (e.g., burying, burning, dumping it in landfills) and location (i.e., county). In general, the cost of burning or burying PE mulch on farm is close to $0. However, there may be penalties associated with burning PE mulch because of the negative environmental impacts associated with this practice (Velandia et al., 2020a). The costs associated with disposing PE mulch in landfills include transportation, labor, and landfill disposal fees. In Tennessee, disposal fees vary by county from $0 to $50 per ton (Velandia et al., 2018; Velandia, Galinato, and Wszelaki, 2019). Using the same survey data from the analyses presented in this study, Velandia et al. (2020a) found that the majority of Tennessee fruit and vegetable farmers (75%) dispose of PE mulch in landfills.

BDM is already available in the marketplace. However, due to its relatively low market penetration, it may be important for manufacturers to not only understand the factors influencing farmers'

willingness to use BDM at various price levels but also to compare farmer willingness to pay (WTP) for BDM with market prices at which the product is currently being offered.

A few studies have evaluated the factors that could be correlated with the use of BDM (Goldberger, DeVetter, and Dentzman, 2019; Velandia et al., 2020b). Using the same Tennessee fruit and vegetable farmer survey data analyzed in this study, Velandia et al. (2020b) suggested that labor savings and environmental stewardship are two factors correlated with the use of BDM, specifically among farmers with previous experience using PE mulch. Goldberger, DeVetter, and Dentzman (2019) found that, on average, more than 50% of respondents to a survey of strawberry farmers in California, the Pacific Northwest, and the Mid-Atlantic region would be moderately to very likely to consider the use of BDM if the price drops, and university researchers indicate BDM does not harm the soil.

Only two studies have explored farmer willingness to adopt BDM at various price levels (Scaringelli et al., 2016; Velandia et al., 2020a). Using the same survey data analyzed in this study, Velandia et al. (2020a) suggested that, as expected, the percentage of Tennessee fruit and vegetable farmers willing to use BDM decreased as the price of BDM increased, but found that even at prices higher than the current average market price for BDM, some farmers preferred BDM over PE mulch. This preference was likely due to the potential labor savings and the reduced environmental impact associated with its use. However, Velandia et al. (2020a) did not estimate farmers' WTP for BDM or the factors influencing their WTP. Another study by Scaringelli et al. (2016) evaluated Italian farmers' WTP for BDM derived from organic waste. They found that farmers using conventional mulch products, such as PE mulch, were willing to pay a higher price for BDM derived from organic waste when compared to similar products already available on the market. A recent study by Chen et al. (2020) evaluated various U.S. agricultural stakeholders' (e.g., farmers, crops advisors, educators located in the Pacific Northwest) WTP for various BDM attributes. They found that less risk-averse stakeholders who were less sensitive to the cost of BDM were more likely to adopt BDM. They also found that a potential price premium for products grown on BDM and the percentage of BDM plastic residue left in the field after harvesting were desirable BDM attributes for farmers. No studies have evaluated the factors influencing U.S. farmers' willingness to purchase BDM when facing various price scenarios. Furthermore, to the authors' knowledge, no studies have compared U.S. farmers' WTP for BDM to actual BDM market prices.

Understanding the difference between farmers' WTP for BDM and actual BDM market prices could inform policy makers interested in reducing soil plastic pollution from the use of PE mulch. For instance, estimates of the differences between WTP and market prices could assist in developing policy instruments, such as subsidies, to motivate the use of BDMs among fruit and vegetable farmers. Using the same survey data from this study, Velandia et al. (2020a) estimated that the majority (about 60%) of the respondents to a survey of Tennessee fruit and vegetable farmers use PE mulch to produce fruits and vegetables. Therefore, there is plastic waste generated by these farmers, and incentivizing the transition from PE mulch to BDM could be beneficial to the environment due to the reduced plastic pollution resulting from BDM. The adoption of BDM could result in increased revenue due to increased yield and crop quality associated with

transitioning from no mulch or a natural mulch option (e.g., straw) to a synthetic mulch option (Lamont, 1996). Farmers using other mulches might be interested in the benefits of PE mulch, but may also have concerns about the negative environmental impacts associated with its use. Therefore, these farmers might consider BDM a better alternative to PE mulch but may not be able to afford it. Future policies could incentivize the use of BDM with the goal of averting future negative environmental impacts associated with the use of PE mulch.

The primary objective of this study is to develop a measure of WTP for BDM. This study also seeks to identify non-price factors, such as farmer demographics, farm characteristics, and farmer attitudes, that may influence the probability of choosing BDM. This information is useful in building market profiles of those more willing to purchase BDM to aid in the marketing of this type of mulch to farmers. The study also provides comparisons of the farmers' WTP for BDM with current BDM market prices. This information is helpful in the development of policy instruments, such as subsidies to incentivize the use of BDM.

Conceptual Framework

Following Lusk and Hudson (2004), in this study we assume farmers maximize their profits, subject to a given production function. We assume the farmer chooses the level of inputs to be used, and assume the mulch product use, *m*, is fixed. Given a vector of input prices, *w*, except the mulch input *m*, and a vector of output prices, *p* (e.g., assuming there is no price premium associated with crops grown on BDM), the farmers choose the optimal level of inputs and outputs, which yield to the indirect restricted profit function, $\pi(p,w,m)$.

We assume a farmer considers changing the mulch option currently being used to produce fruits and vegetables from m^0 (e.g., PE mulch, natural mulch such as straw) to BDM (m^{BDM}), where m^0 and m^{BDM} define the quantity of mulch currently being used (e.g., two rolls of PE mulch) and the quantity of BDM to be used, respectively. A farmer's WTP function, also called the variation function *d* (Zapata and Carpio, 2014), is defined as,

$$d = \pi_{BDM}(\boldsymbol{p}, \boldsymbol{w}, m^{BDM}) - \pi_0(\boldsymbol{p}, \boldsymbol{w}, m^0) \quad (1)$$

If transitioning from the current mulch option m^0 used by a farmer to BDM (m^{BDM}) results in an increase in profits, $d > 0$, then equation (1) represents the maximum amount a farmer will be willing to forgo to obtain the potential benefits of transitioning to BDM (e.g., reduced labor costs, reduced plastic pollution). Some farmers may not be willing to forgo any money to transition from m^0 to m^{BDM}, because they may perceive no cost savings and only potential environmental benefits, such as the reduction of plastic pollution associated with the use of BDM. Therefore, we also consider the scenario where $d = 0$. According to equation (1), the maximum amount a farmer is WTP for BDM is given by the difference between the *ex post* (after adopting BDM) and *ex ante* (before adopting BDM) farm business's profit levels (Zapata and Carpio, 2014).

We do not observe *d*, but we do observe whether a farmer, *i*, is willing to choose BDM at a specific price level,

$$y_{iBDM} = \begin{cases} 1 & \text{if } y^*_{iBDM} \geq 0 \\ 0 & \text{otherwise} \end{cases}, \quad (2)$$

where y^*_{iBDM} is a latent variable capturing the underlying differences in profits driving the decision to choose BDM, thus farmer i's propensity to purchase BDM. The variable y_{iBDM} is the dependent variable to be used in the regression model evaluating the factors correlated with farmer willingness to use BDM. This variable takes the value of 1 if the farmer selected BDM, and 0 if the farmer selected PE mulch or no plastic mulch (e.g., neither PE mulch nor BDM). Survey respondents who indicated they would choose neither BDM nor PE mulch were included in the analysis to better reflect the choices farmers face when deciding which mulch option they want to use on their farm operations. A farmer growing fruits and vegetables could use PE mulch, BDM, a natural mulch such as straw, or no mulch at all (Velandia et al., 2020b).

The latent variable y^*_{iBDM} is a function of observable and unobservable variables and can be described as,

$$y^*_{iBDM} = \boldsymbol{x}_i'\boldsymbol{\beta} + \varepsilon_i, \quad (3)$$

where $\boldsymbol{x}_i$ is a vector of observable variables that could be correlated with farmer i's decision to purchase BDM, such as price and familiarity with this mulch product, but also farmer and farm business characteristics, environmental stewardship, and risk attitudes; $\boldsymbol{\beta}$ is a vector of coefficients capturing the correlation between the observable variables and the decision to purchase BDM; and ε_i is the random disturbance term.

Data and Methods

Survey

The survey of Tennessee fruit and vegetable farmers was conducted between January and March 2019. Farmers were surveyed using both web-based and mail versions of the survey. Both versions of the survey instrument contained identical questions. We used a mixed-mode survey (i.e., web and mail [paper] versions) to improve response rates and reduce coverage and nonresponse error (Dillman, Smyth, and Christian, 2009). The web version of the survey was sent on January 29, 2019, to individuals with email addresses. We sent email reminders on February 5 and 12, 2019, to participants who had not completed the survey. The paper version of the survey was mailed to individuals who had mailing addresses but did not have or had invalid e-mail addresses, or did not respond to the web survey on March 20, 2019. Reminder postcards and follow-up surveys were sent on March 30 and April 5, 2019, respectively. The survey contained several sections, including a question that elicited Tennessee fruit and vegetable farmers' preferences for BDM, reasons for choosing and not choosing BDM, familiarity with BDM, risk attitudes, environmental stewardship, and farmers and farm business characteristics. Details of the overall survey instrument, including sections not used in this study, can be found in Velandia et al. (2020a). As stated in the introduction section, previous studies have used data from various sections of this survey (Velandia et al., 2020a; Velandia et al., 2020b). None of them have used data from the question that elicited

Tennessee fruit and vegetable farmers' preferences for BDM, or estimated WTP for BDM or the factors correlated with farmers' willingness to use BDM at alternative price levels.

Data

A comprehensive list of 990 Tennessee fruit and vegetable farmers was obtained from the Tennessee Department of Agriculture that included growers participating in a program that promotes and advertises food grown in Tennessee (Pick Tennessee Products), and in a program that provides cost sharing for long-term investments for Tennessee farms (Tennessee Agricultural Enhancement Program). The selection criteria for these two voluntary programs are very general. They include being 18 years of age or older, operating a farm in Tennessee, and growing products for sale, which provided a farmer contact list that minimized potential biases associated with farmer participation in these programs (Velandia et al., 2020a). After eliminating respondents who indicated they were not farming, not growing fruits and vegetables, were ill or retired, or had email or mailing addresses that were marked as undeliverable, we obtained a final list of 753 Tennessee fruit and vegetable farmers (Velandia et al., 2020a). From this list, we obtained 186 completed surveys; 49% of those surveys were completed online, and 51% were sent via mail. The overall survey response rate was 25%. After eliminating observations with missing values, 125 observations were used in estimating the probit regression.

Survey Sample Representativeness

As in Velandia et al. (2020a, 2020b), the representativeness of the sample used in the regression analysis was examined by comparing the distribution of this sample according to acres in fruit and vegetable production to the same distribution according to acres in vegetable production based on data from the 2017 Census of Agriculture (U.S. Department of Agriculture, 2020). As suggested by Velandia et al. (2020b), the criterion "acres in vegetable production" is a good basis of comparison, because most respondents reported either growing vegetables only or growing a combination of fruits and vegetables. Figure 1 shows the farm distribution comparison between the 2017 Census of Agriculture and the sample included in the probit regression. Overall, the sample included in the probit regression follows closely the distribution of farms based on farm size according to the 2017 census. As shown in Figure 1, according to the 2017 Census of Agriculture, a large percentage of the Tennessee farms have less than 5 acres in vegetable production (i.e., 80%). Similarly, more than half of the farms included in the survey sample (63%) have less than 5 acres in vegetable production. Nonetheless, it is important to note that the sample included in the probit regression tends to underrepresent farms in the 0.1- to 0.9-acre category and overrepresent farms in the 5- to 25-acre (medium-sized) categories. The overrepresentation of medium-sized farms in the regression sample could be explained by the fact that these farmers were more likely to respond to the survey, since as farm size increases, farms may be more interested in synthetic mulch products that provide benefits such as weed control (Velandia et al., 2020b). For larger farms, weed control without the use of a mulch option may not be economically feasible because it is a labor-intensive task.

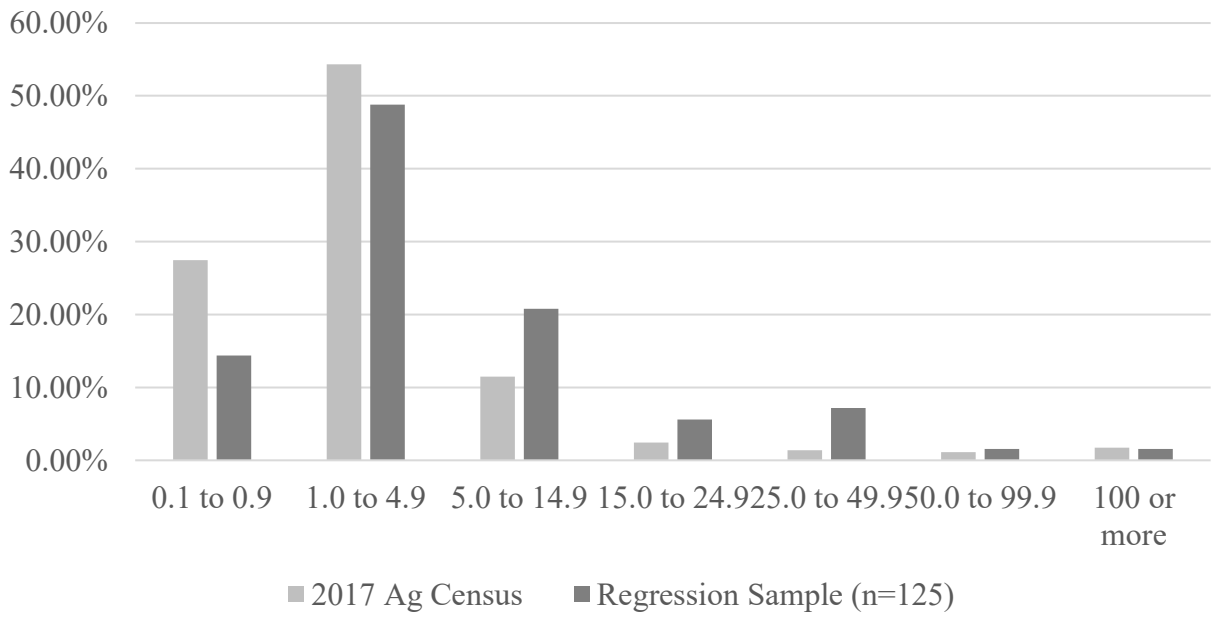

Figure 1. Percentage of Farms in Each Farm Size Category Based on Acres in Vegetable Production According to Data from the 2017 U.S. Census of Agriculture and the Sample Included in the Probit Regression

Contingent Valuation

The Contingent Valuation (CV) method was used to elicit Tennessee fruit and vegetable farmers' willingness to adopt BDM over PE mulch at various price points. This method has been used by several researchers to determine consumer and producer willingness to adopt various products (e.g., Dobbs et al., 2016; McKay et al., 2019a; McKay et al., 2019b; DeLong et al., 2020). The elicitation method used in this study is a single-bounded dichotomous choice framework, where the price of BDM is varied across surveys, and the average WTP is estimated by examining how willing the population is to purchase BDM at alternative price levels (Lusk and Hudson, 2004; Dobbs et al., 2016; McKay et al., 2019a; McKay et al., 2019b; DeLong et al., 2020). In contrast to Chen et al. (2020), the goal of this study was not to evaluate farmer WTP for BDM attributes but to assess farmer WTP for BDM, farmer willingness to adopt BDM, and the factors, including BDM price, farmer demographics, and farm characteristics, that contribute to their decision to adopt BDM.

Before eliciting Tennessee fruit and vegetable farmers' preferences for BDM, we provided the following details about BDM:

"BDMs are used in the same manner as PE mulches with the additional benefit of being 100% biodegradable. Below, you are presented with two 4' x 4,000' mulch rolls. Option A is a roll of black polyethylene (PE) mulch (plastic mulch). Option B is a roll of black plastic biodegradable mulch. Both products provide the same benefits (i.e., weed control, soil moistures conservation, and yield improvements); both products can be laid using a mechanical plastic layer. The only

difference is that BDMs do not have to be removed, but rather they are tilled into the soil or composted at the end of the season."

To examine Tennessee fruit and vegetable farmers' preferences for a 4' x 4,000' roll of BDM, farmers were next presented with a contingent valuation question involving two 4' x 4,000' rolls of mulch. The first roll was PE mulch, priced at $100 according to current market prices gathered from various input suppliers. The second roll of mulch provided similar benefits to PE mulch but was the 100% biodegradable BDM and was priced at one of four price points ($100, $200, $250, or $300). Each survey participant was randomly assigned to one of the price categories for the BDM. The survey respondent could select the PE mulch, the BDM, or neither product. The BDM price scenarios were not distributed symmetrically around the average BDM market price (i.e., $220). Although the average market price (i.e., $220) is a likely anchor for our analysis, the inclusion of a $100 BDM price option is important because it provides a BDM option at the same market price as PE mulch, which is the closest alternative to BDM. It is unlikely that a BDM would ever be sold at this low price, but this option allowed for gauging farmer interest in BDM at the same price point as PE mulch. The other price scenarios (i.e., $200, $250, and $300) were created based on the most common BDM prices found at various input suppliers' websites. An example CV question is shown in Figure 2. Following the CV question, respondents were asked the number of acres on which they were willing to use BDM to measure the potential intensity of BDM adoption, as well as the main reason associated with their choice of mulch product (i.e., PE mulch, BDM, neither PE mulch nor BDM).

	Option A	***Option B***	***Option C***
Product	**Polyethylene Mulch (plastic mulch)**	**Plastic Biodegradable Mulch**	I would not purchase either of the mulches
Laying	Can be laid with a mechanical plastic layer	Can be laid with a mechanical plastic layer	
End of season activities	Has to be removed and disposed of at the end of the growing season	Does not have to be removed, but rather it is tilled into the soil or composted at the end of the season	
Pictures of mulch used in bell peppers (both mulches can be used for growing fruits and vegetables)			
Mulch price (per 4' x 4,000' roll)	$100	$300	
Please select one (mark with an X)	☐ ⬇ **Please go to Q1**	☐ ⬇ **Please go to Q2**	☐ ⬇ **Please go to Q4**

Figure 2. Example Contingent Valuation Question for Mulch Options

Probit Regression

The probability of farmer i choosing BDM is defined as (Greene, 2012),

$$P(y_{iBDM} = 1 \mid \boldsymbol{x}_i) = P(y^*_{iBDM} \geq 0 \mid \boldsymbol{x}_i) = P(\boldsymbol{x}_i'\boldsymbol{\beta} + \varepsilon_i \geq 0 \mid \boldsymbol{x}_i) \quad (4)$$

$$= P(\varepsilon_i \geq -\boldsymbol{x}_i'\boldsymbol{\beta} \mid \boldsymbol{x}_i) = P(\varepsilon_i \leq \boldsymbol{x}_i'\boldsymbol{\beta} \mid \boldsymbol{x}_i)$$

$$= F(\boldsymbol{x}_i'\boldsymbol{\beta}) = \Phi(\boldsymbol{x}_i'\boldsymbol{\beta}),$$

where $F(.)$ is the cumulative distribution function for the random variable ε_i. We assume ε_i is normally distributed, therefore $\Phi(.)$ is the cumulative normal distribution. Hence, the binary choice model described in equation (4) is estimated using a probit regression model (Greene, 2012).

The average marginal effects for the discrete and continuous variables were calculated following Greene (2012). The statistical package Stata was used to estimate the probit regression using the probit command (StataCorp, 2017). The associated marginal effects were computed following the probit regression by using the Stata command margins.

Diagnostics Tests

The overall significance of the probit regression was tested using a Wald test distributed $\chi^2(k)$ (StataCorp, 2017). A condition index was used to detect collinear relationships among the independent variables included in the probit regression (Belsley, Kuh, and Welsch, 1980). A condition index below 30 suggests that multicollinearity is not a concern for the variance estimates, and, therefore, not a concern for the potential inferences drawn from the regression results (Belsley, 1991).

WTP Estimation

Results from the probit regression were used to estimate average farmer WTP for BDM with the formula:

$$\widehat{WTP}_{iBDM} = -\frac{\hat{\beta}_0 + \boldsymbol{z_{i'}}\widehat{\boldsymbol{\beta}}_{-p}}{\hat{\beta}_p}, \tag{5}$$

where $\hat{\beta}_0$ is the estimated intercept, $\widehat{\boldsymbol{\beta}}_{-p}$ is a vector of estimated parameters excluding the BDM price coefficient, z is the vector of independent variables excluding BDM price, and $\hat{\beta}_p$ is the estimated parameter for the price of BDM (Dobbs et al., 2016). The WTP for BDM was determined as the average WTP evaluated for each farmer.

Hypothesis for Explanatory Variables

In this section, we describe the criteria used for including the various independent variables in the analysis, specifically how previous studies support the inclusion of these variables. The independent variables hypothesized to be correlated with farmers' decisions to adopt BDM at various price levels are described in Table 1. It is assumed that as the price of BDM increases, farmers will be less likely to purchase BDM. This assumption is consistent with previous studies suggesting the cost of BDM has a negative impact on farmers' willingness to use BDM (Goldberger et al., 2013; Goldberger, DeVetter, and Dentzman, 2019; Velandia et al., 2020a).

Table 1. Probit Regression Variable Definitions, Means, and Standard Deviations (n = 125)

Variable	Description	Hypothesis Sign	Mean	Std. Deviation
BDM	= 1 if the respondent chose BDM over PE mulch		0.4320	0.4973
Price	BDM price levels (for a 4' x 4000' roll) of $100, $200, $250, and $300	−	210.80	72.5637
Farm revenue	= 1 if gross on-farm revenue is greater than $25,000	+/−	0.4960	0.5019
Age	Respondent's age in years		55.3920	14.7007
BS degree or higher	= 1 if farmer has a bachelor's degree or higher; 0 otherwise	+	0.6400	0.4819
Acres F&V	Acres in fruit and vegetable production	+/−	11.4979	37.3901
Risk attitudes	Average of the scores associated with the statements below	+	2.6770	0.9945
"I like taking financial risks with my farm business."	Likert-scale question[a] -		2.3440	1.1785
"I accept more risk in my farm than other farmers."	Likert-scale question[a] -		3.0080	1.0813
Environmental stewardship	Average of the scores associated with the statements below	+	3.0640	1.0219
"I only buy products in packages that can be recycled."	Likert-scale question[a]		2.728	1.1457
"I try to convince my family or friends not to buy environmentally harmful products."	Likert-scale question[a] 3		3.4000	1.2572
Familiarity with BDM	Likert scale, 1 = Not Familiar at all, 2 = Slightly Familiar, 3 = Moderately Familiar, 4 = Very Familiar	+/−	2.0800	0.8762
Percentage of respondents on each familiarity category	1 = Not Familiar		0.2960	
	2 = Slightly Familiar		0.3760	
	3 = Moderately Familiar		0.2800	
	4 = Very Familiar		0.0480	

Notes: [a]1 = Strongly Disagree, 2 = Somewhat Disagree, 3 = Neutral, 4 = Somewhat Agree, and 5 = Strongly Agree.

Given the relatively low adoption of BDM among U.S. farmers (Goldberger, DeVetter, and Dentzman, 2019; Goldberger et al., 2013; Velandia et al., 2020a), as well as farmer uncertainty about BDM performance and the potential impact on soil health (Goldberger, DeVetter, and Dentzman, 2019; Chen et al., 2020; Velandia et al., 2020a), we hypothesized that familiarity with BDM would be positively correlated with farmers' willingness to adopt BDM. Respondents' familiarity with BDM was captured by a 4-point Likert scale variable, where 1 indicated the respondent had no familiarity with BDM, and 4 indicated the respondent was very familiar with BDM (Table 1).

Previous studies evaluating farmer WTP for inputs with potential economic and environmental impacts suggest farm income has a positive impact on farmers' willingness to adopt inputs with these characteristics (Kenkel and Norris, 1995; Kuwornu et al., 2017). In this study, we hypothesized that gross on-farm revenue would have a positive impact on farmers' willingness to adopt BDM. We hypothesized that farmers with higher on-farm income are in a better financial position to invest in agricultural inputs that may result in positive economic and environmental impacts. In this study, gross on-farm income is captured by a dummy variable taking the value of 1 if reported annual gross on-farm income was higher than $25,000. This cut-off point was chosen based on the survey sample distribution, where 50% of the respondents indicated a gross on-farm income higher than $25,000 per year.

Similar to Kuwornu et al. (2017), we hypothesized that farm size has a positive impact on farmers' willingness to use BDM. Use of BDM has labor-saving implications that may be more important for larger farms using PE mulch than for smaller farms that either might not be using PE mulch or might be using PE mulch but use farm operator and family labor to complete end-of-season activities on their farms (Velandia et al., 2020b). Farm size was captured by a continuous variable estimating the number of acres in fruit and vegetable production (Table 1).

Previous studies have found that age and education positively influence farmers' willingness to purchase inputs that could have positive economic and/or environmental impacts (Kenkel and Norris, 1995; Adetonah et al., 2008; Garming and Waibel, 2009; Kuwornu et al., 2017). For example, Kenkel and Norris (1995) suggest that older farmers with more farming experience may be more aware of farming risks that could have economic and environmental implications, and, therefore, more likely to be willing to pay for inputs that have the potential to reduce those risks. Additionally, they contend that more educated farmers are more likely to understand the new input benefits; thus, they are more likely to be willing to pay for this input. Garming and Waibel (2009) and Kuwornu et al. (2017) suggest that age could have a positive effect on the WTP for inputs with environmental benefits, such as a low-toxic pesticides or excreta pellet fertilizer, as older farmers may have been exposed to negative environmental and/or health impacts of traditional inputs for a longer time. Therefore, they may be more aware of the negative impacts of less environmentally friendly inputs. On the other hand, they suggest older farmers may not be willing to pay for more environmentally friendly inputs because the potential long-term impacts associated with the use of these inputs may not be important to them. They also assert that more educated farmers have higher WTP for inputs with potential environmental benefits because they may better understand the potential benefits associated with the use of these inputs. Similar to Garming and Waibel (2009),

we hypothesized that age could have a positive or negative impact on farmer willingness to adopt BDM. Although older farmers might be more aware of or exposed to the potential risks associated with the plastic pollution generated by mulch products such as PE mulch, they might not be concerned about or understand the long-term impacts of soil plastic pollution. We also hypothesized that more educated farmers are more willing to adopt BDM at various price levels because they may be more likely to understand the potential benefits associated with the use of BDM (Velandia et al., 2020b).

Previous studies evaluating the use and adoption of BDM suggest that farmers who are risk-tolerant are more likely to use or adopt BDM (Chen et al., 2020; Velandia et al., 2020b). Chen et al. (2020) found that farmers who are more willing to take risks are more likely to choose BDM. Velandia et al. (2020b) suggest the adoption of a new mulch product creates uncertainty about the unknown performance of the product compared to other mulch products (e.g., PE mulch), especially for farmers located in a state such as Tennessee where the adoption of BDM is fairly low. Similar to Velandia et al. (2020b), we captured farmers' risk preferences using the simple average of two scores for statements associated with farmers' risk preferences, which are presented in Table 1. Respondents were asked to express their level of agreement with the presented statements using a 5-point Likert scale, where 1 represents strong disagreement and 5 represents strong agreement. One of the statements captured farmer preferences for taking financial risks with the farm business, whereas the other captured farmer acceptance of risks compared to other farmers. In this study, we hypothesized that farmers with a higher risk preference score or farmers who are more risk tolerant are more likely to purchase BDM.

Similar to Velandia et al. (2020b), we hypothesized that farmers' environmental stewardship or concerns for the impact their actions and their close network of individuals' actions could have on the environment would have a positive impact on farmers' willingness to use BDM. Therefore, we hypothesized that farmers' environmental stewardship would also have a positive effect on their willingness to adopt a mulch product exhibiting potential environmental benefits associated with the reduction of soil plastic pollution. Similar to Velandia et al. (2020b), we captured farmer environmental stewardship using the simple average of two scores for statements associated with farmers' use of products that have the potential to reduce plastic pollution and farmers' influence on others regarding the purchase of products that can be harmful to the environment. Respondents were asked to express their level of agreement with the statements using a 5-point Likert scale, where 1 represents strong disagreement and 5 represents strong agreement. In this study, we hypothesized that farmers with a higher score of environmental stewardship would be more willing to use BDM at various price levels.

Results

Sample Descriptive Statistics

The means and standard deviations of the variables included in the probit regression are presented in Table 1. The respondents' average age was 55 years old. More than half of the respondents (64%) reported having a bachelor's degree or higher. The average number of acres in fruit and

vegetable production reported by respondents was 11.5, and 50% of the respondents reported gross on-farm revenue greater than $25,000 per year. On average, farmers were slightly familiar with BDM (i.e., 2 on the 4-point Likert scale, where 1 is not familiar at all and 4 is very familiar). More than half of the respondents (67%) indicated they were slightly to not at all familiar with BDM.

Figure 3 shows the percentage of respondents willing to purchase BDM at various price levels. As expected, as the price of BDM increased, the percentage of respondents willing to purchase BDM decreased (Velandia et al., 2020a). The percentage of respondents willing to purchase BDM at the $200 per roll and $300 per roll price levels and at the $250 per roll and $300 per roll price levels was not statistically significantly different at the 5% significance level. However, a significantly lower percentage of respondents (30%) were willing to purchase BDM at the $250 per roll price point compared to the percentage of respondents willing to purchase BDM at $200 per roll (45%), which was the closest price option to the current average BDM market price point (i.e., $220 per roll).

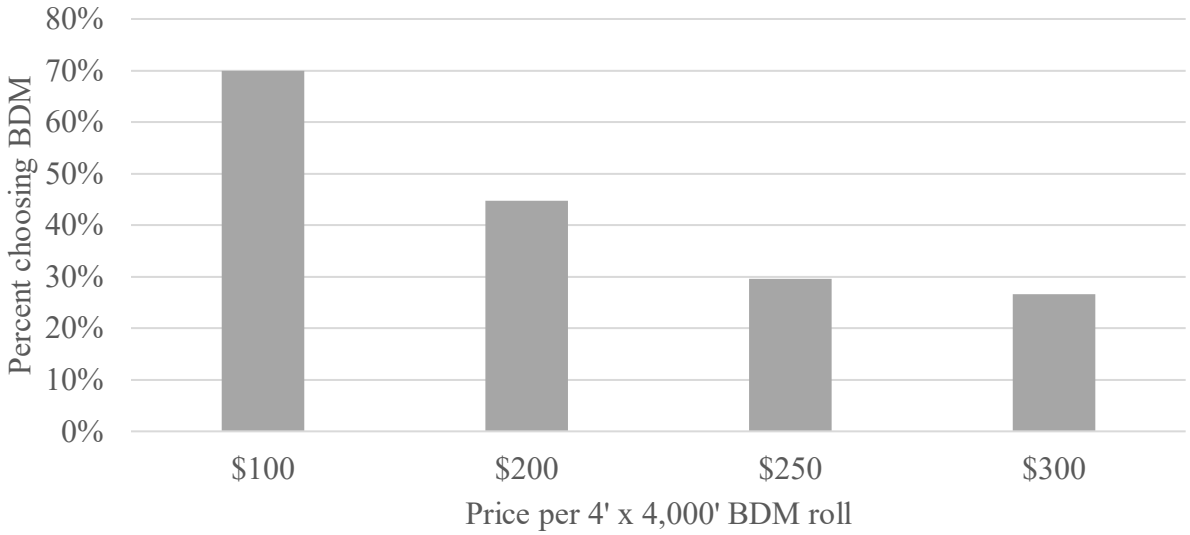

Figure 3. Percentage of Respondents Choosing BDM Instead Of a 4’ x 4,000’ PE Mulch Roll Priced at $100

Notes: Using a *t*-test, the percentage of respondents who chose BDM versus PE mulch was not significantly different at the 5% level of significance among the following price ranges: $200 and $300; $250 and $300.

Probit Regression Results

Estimated probit regression coefficients and the associated marginal effects are presented in Table 2. The estimated conditional index number associated with all independent variables included in the probit regression is 22.85, which suggests no significant concerns with multicollinearity in the estimated regression (Belsley, Kuh, and Welsch, 1980).

Table 2. Probit Regression Results and Marginal Effects for BDM Preferences (n = 125)

Variable	Coefficient	Marginal Effect on the Probability of Adopting BDM
Price	−0.0068***	−0.0023***
	(0.0018)	(0.0005)
Farm revenue	−0.5104**	−0.1717**
	(0.2612)	(0.0845)
Age	0.0029	0.0009
	(0.0094)	(0.0032)
BS degree or higher	−0.2288	−0.0769
	(0.2598)	(0.0864)
Acres F&V	0.0009	0.0003
	(0.0026)	(0.0009)
Risk attitudes	−0.0576	−0.0194
	(0.1351)	(0.0455)
Environmental stewardship	−0.1035	−0.0348
	(0.1384)	(0.0463)
Familiarity with BDM	0.2867**	0.0965**
	(0.1466)	(0.0471)
Wald statistic $\chi^2(8)$	19.8500**	
Log-pseudolikelihood	−73.9141	

Notes: Standard errors in parentheses; * $p < 0.1$, ** $p < 0.01$, *** $p < 0.001$

As expected, the price of BDM had a negative impact on the farmers' choice of BDM. With a dollar increase on the price of BDM, a farmer is 0.2% less likely to indicate they would purchase BDM, or a $10 increase in the price of BDM decreased the likelihood of the farmer responding they would purchase BDM by 2%. Farmers with yearly gross farm revenue above $25,000 were 17% less likely to choose BDM. This result is the opposite of what was expected and suggests that farmers with higher gross farm revenue, and perhaps a higher dependence on on-farm income, are less likely to purchase BDM. Although farmers with higher gross on-farm revenues might be willing to purchase a mulch that is more expensive than options such as PE mulch, they may also be unwilling to risk using a mulch that might be ineffective in controlling weeds and maintaining soil temperature and humidity. Finally, a 1-point increase in farmer familiarity with BDM on a 4-point Likert scale increased the likelihood of farmers choosing BDM by 10%. Like Velandia et al. (2020b), the regression results suggest the choice of BDM among Tennessee fruit and vegetable farmers is not influenced by farmers' demographic characteristics, such as age and education. Although Velandia et al. (2020b) argue that the number of acres in fruit and vegetable production has a positive impact on the likelihood of Tennessee fruit and vegetable farmers using BDM, the results of this study indicate acres in fruit and vegetable production do not impact farmers' willingness to purchase BDM after controlling for BDM price and gross on-farm revenue.

WTP Estimates

Using the estimated coefficients from Table 2, equation (6) and the respondent data, the WTP estimates were calculated. On average, survey respondents were willing to pay $182.59 per 4' x 4,000' roll of BDM (Table 3), with a lower bound (95% confidence level) of $127.52 per roll and an upper bound (95% confidence level) of $216.75 per roll. Given that we assumed the price for a 4' x 4,000' roll of PE mulch was $100, this finding represents an average WTP premium of $82.24 per roll for BDM, or an 82% price premium over the PE mulch price. The average WTP was about $40 below the average BDM market price (Velandia, Galinato, and Wszelaki, 2019), excluding shipping costs. This result implies that the current average BDM market price point (i.e., $220 per roll) is still above the average price point that Tennessee fruit and vegetable farmers are willing to pay for this type of mulch. The estimated average WTP is influenced by the inclusion of a relatively low price point of $100, which is slightly below the BDM average market price ($200), and two price points that are greater than the average market price of $220 (i.e., $250 and $300). Specifically, our WTP is biased toward prices lower than the average market price because of the inclusion of a price point that is $100 below the average BDM market price. As stated in the Data and Methods section, the inclusion of the $100 price point is important to evaluate farmer WTP relative to the price of a mulch option that is used by a large percentage of Tennessee farmers (i.e., PE mulch) and that offers the same benefits as BDM.

Table 3. Average WTP and WTP by Market Segment for a 4' x 4,000' Roll of BDM

Market Segment	WTP for 4' x 4,000' BDM roll***
Mean	$182.59
Gross on-farm revenue < $25,000, Not Familiar with BDM	$174.68
Gross on-farm revenue > $25,000, Not Familiar with BDM	$99.11
Gross on-farm revenue < $25,000, Very Familiar with BDM	$300.86
Gross on-farm revenue > $25,000, Very Familiar with BDM	$225.71

***All possible combinations of WTP are statistically significantly different at $p < 0.001$.

We also estimated WTP among various market segments (i.e., gross farm revenue > $25,000 versus gross farm revenue < $25,000, Not Familiar with BDM versus Very Familiar with BDM). As shown in Table 3, respondents who indicated having an annual gross on-farm revenue above $25,000 had a lower WTP than those reporting an on-farm gross revenue below $25,000. Those farms reporting gross on-farm revenue above $25,000 may be more dependent on farm income and more cautious about the increased costs associated with the adoption of new inputs or production practices. Also, the results presented in Table 3 suggest that respondents who are very familiar with BDM have a higher WTP than those who are not familiar at all with BDM, regardless of on-farm gross revenue. This result suggests that farmer familiarity with BDM, specifically increased familiarity with the benefits associated with the use of BDM (e.g., labor savings, reduced plastic pollution), could have a significant impact on the price farmers are willing to pay for BDM. Respondents were also asked, "If you were to adopt BDMs at the price offered, on how many acres do you believe you would use it?" On average, Tennessee fruit and vegetable farmers were willing to use BDM on 6.64 acres ($n = 46$). On average, those respondents expecting to pay BDM prices higher than $100 per 4' x 4,000' roll were willing to use BDM on 8.33 acres. As can be seen in

Figure 4, farmers expecting to pay BDM prices higher than $100 per roll were willing to use BDM on more acres than those facing a BDM price of $100 per roll. At $200 per roll, which is close to the current average BDM market price point, respondents were willing to commit the largest number of acres to BDM, although this acreage was not significantly different from the number of acres on which respondents were willing to use BDM at the $250 per roll and $300 per roll price points (Figure 4).

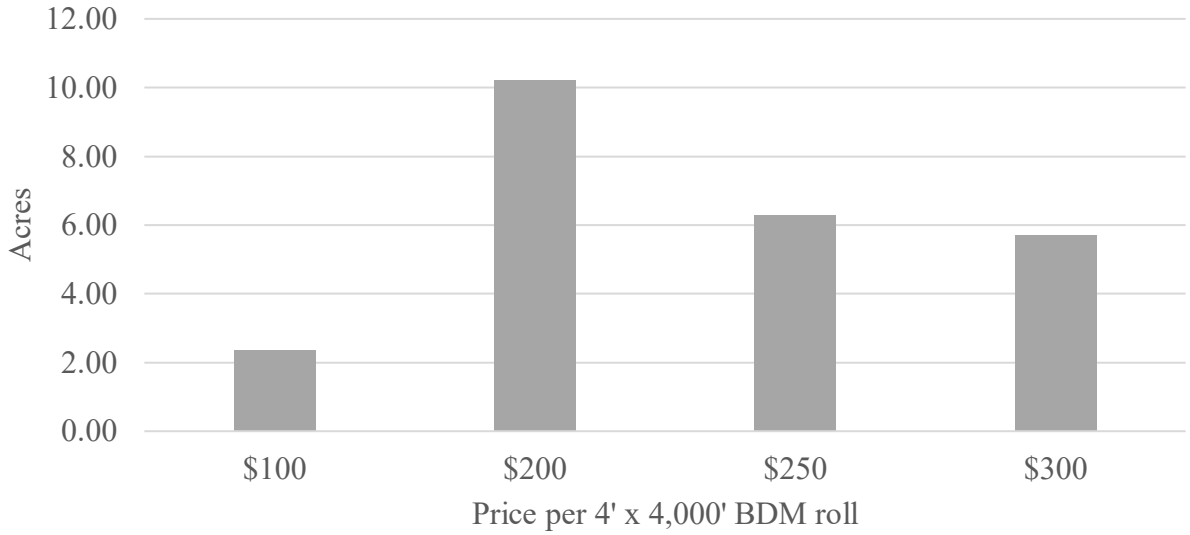

Figure 4. Acres Respondents Would Use BDM
Notes: Using a *t*-test, the acreage on which respondents would use BDM was not significantly different at the 5% level of significance among the following price ranges: $200 and $250; $250 and $300; and $200 and $300.

Reasons Associated with WTP for BDM

The most important reasons listed by respondents for explaining their WTP a higher price for BDM were related to potential cost savings and reduction of plastic pollution associated with the use of BDM (Table 4).

Table 4. Reason for Willingness to Pay a Higher Price for BDM Than for PE Mulch

	Price				
	$100 (*n* = 21)	**$200 (*n* = 17)**	**$250 (*n* = 8)**	**$300 (*n* = 8)**	**All prices (*n* = 54)**
I believe there are production cost savings associated with the use of BDMs.	47.62%	76.47%	75.00%	37.50%	59.26%
I believe using BDMs reduces plastic pollution.	57.14%	70.59%	25.00%	62.50%	57.41%
I believe BDMs would allow my plants to grow or produce better than PE mulches.	0.00%	5.88%	0.00%	0.00%	1.85%
I believe the use of BDMs would improve the health of my soil.	23.81%	23.53%	0.00%	12.50%	18.52%
Other	4.76%	29.41%	12.50%	0.00%	12.96%

In contrast, the most important reason respondents listed for choosing PE mulch instead of BDM at the various price levels was the uncertainty about the performance of BDM, specifically, the perception that BDM would break down too fast, and, therefore, would not control weeds (Table 5). The percentage of respondents indicating cost savings as one of the main reasons for paying a higher price for BDM was statistically significant across price level categories. A higher percentage of respondents who paid the $200 per roll and $250 per roll price levels listed this as one of their main reasons compared to the percentage of respondents who listed this reason among those respondents facing the $100 per roll and the $300 per roll price level categories.

Table 5. Reason for Choosing PE Mulch Over BDM

	Price				
	$100 (*n* = 9)	**$200 (*n* = 21)**	**$250 (*n* = 19)**	**$300 (*n* = 21)**	**All prices (*n* = 70)**
I think BDMs will break down too fast and will not control for weeds.	11.11%	19.05%	26.32%	28.57%	22.86%
I don't think I have enough information about BDMs.	0.00%	23.81%	21.05%	19.05%	18.57%
I'm concerned about the effect tilling BDMs would have on my soil.	0.00%	9.52%	5.26%	19.05%	10.00%
I have used a mulch that was labeled as biodegradable mulch, and I did not like it.	0.00%	4.76%	15.79%	4.76%	5.71%
Cost	0.00%	0.00%	5.26%	28.57%	10.00%
Certified organic unable to use BDM	11.11%	4.76%	0.00%	4.76%	4.29%
Other	0.00%	9.52%	31.58%	9.52%	14.29%

Discussion

Alternatives to PE mulch, such as BDM, offer options with the same benefits as PE mulch while reducing potential plastic pollution associated with the use of PE mulch, as well as potential labor savings and revenue opportunities. Nevertheless, the use of BDM among Tennessee farmers remains relatively low. Previous studies have reported the cost of BDM as one of the significant barriers to adoption, as BDM tends to be more expensive than other mulch options such as PE mulch. In this study, we evaluated Tennessee fruit and vegetable farmers' WTP for BDM and the factors correlated with farmer willingness to use this mulch product. We found that while the price of BDM and gross on-farm revenue were negatively correlated with farmers' willingness to use BDM, increased familiarity with BDM was positively correlated with their willingness to use it.

The negative correlation between gross on-farm revenue and farmer willingness to use BDM, and the positive correlation between farmer familiarity with BDM and farmer willingness to use BDM could have similar implications or could be related. Although farmers reporting higher gross on-farm revenue might be in a better position to invest in an input that could result in labor savings and reduced negative environmental impacts associated with the use of other mulch products such

as PE mulch, they also have more to lose if the performance of BDM is not comparable to other mulch products. Previous studies suggest that farmer beliefs associated with how fast BDM will start breaking down, and therefore, the uncertainty of potential losses associated with the use of BDM, affects their willingness to adopt this mulch product. The uncertainty about the performance of BDM compared to other mulch products could be reduced by making more information about BDM available to farmers. More information about BDM in the hands of farmers will increase farmers' familiarity with BDM, which as suggested by this study, could increase farmers' willingness to adopt BDM. Nonetheless, it is important to acknowledge that more information in the hands of growers would help them make more informed decisions about the adoption of BDM, which could be to adopt or not adopt BDM. Each grower should carefully weigh the crops they intend to grow, their weed pressure and community, the seasonal environmental conditions of their location, and the labor costs associated with their current mulch practices when determining whether to adopt BDM. As indicated by Velandia et al. (2020b), BDM manufacturers and extension personnel have a critical role in providing information about BDM to farmers to reduce uncertainty about the use of and increased familiarity with BDM.

Regarding the demand for BDM at the various price levels, we found a significant difference between the percentage of farmers willing to purchase BDM at the $200 and $250 price levels. This difference has important implications for BDM manufacturers and input suppliers. Although not considered in this study, shipping costs could be high depending on the farm location, supplier, mode of shipping, and size of the order (Velandia et al., 2018). High shipping costs could increase the base price of BDM, which is estimated at about $220 per roll (Velandia, Galinato, and Wszelaki, 2019), resulting in a negative impact on the number of farmers willing to purchase BDM. These costs could be reduced if local input suppliers decide to carry BDM based on the market potential for this type of mulch.

Estimates from this study can be used in a “back-of-the-envelope” analysis of the potential size of the market. The numbers of mulch rolls used per acre were determined by the space between bed centers. Space between bed centers varies by crop, possibly between 5 and 8 feet (Velandia et al., 2018). For this analysis, we assumed an average of 6’ spacing between bed centers, which requires two mulch rolls per acre (Chen et al., 2018). With an average of 6.64 acres per farm covered in BDM and an average of 2 rolls per acre, an average of 13 rolls would be used per farm. Because the majority of survey respondents reported growing either vegetables only or a combination of fruit and vegetables, we used the number of vegetable farms reported in the 2017 U.S. Census of Agriculture to estimate the total number of rolls of and total expenditures on BDM at the state level. Assuming there are 1,961 vegetable farms in Tennessee (U.S. Department of Agriculture, 2020), and 34% of these farms adopt BDM at $182.24 per roll, based on the percentage of survey respondents indicating they would use BDM at prices above $100 per roll, the total number of rolls used by Tennessee vegetable farmers would be 8,668. This amount represents about $1.5 million in total expenditures on BDM per year.

As noted earlier, market prices are around $220 per roll, which is higher than the estimated average WTP for BDM of $182.24 per roll. Therefore, for example, if a 34% participation rate is desired, a subsidy of $37.76 per roll would be needed. If a total of 8,668 rolls were subsidized, the total

program cost would be $327,304 per year. The estimated cost of this program assumes no labor savings associated with the use of BDM, or no dollar value associated with labor savings, which is a possible scenario for farm operators who perform the end-of-season activities of removal and disposal of PE mulch by themselves or with the help of unpaid family labor. When assuming potential average labor savings of 17.25 hours per acre due to the elimination of PE mulch removal and disposal activities (Velandia et al., 2020a), valued at $12.40 per hour (the Tennessee 2020 adverse effect wage rate), we estimated labor savings of $1,420 per farm. These savings are higher than the estimated subsidy of $491 per farm for those farms transitioning from PE mulch to BDM. Labor savings associated with transiting from mulches other than PE mulch (e.g., straw, no mulch) are uncertain and are not considered in this analysis. Therefore, production costs would need to be weighed against potential labor savings, which vary greatly depending on the type of mulch used (e.g., PE mulch, straw, no mulch), removal and disposal methods, and farm size, among other factors (Velandia et al., 2018).

Additionally, program costs would need to be weighed against potential environmental benefits (e.g., reduced plastic pollution), which are not only beyond the scope of this study but have not been evaluated by previous studies. However, additional research should examine the cost/benefit trade-off when both agronomic and environmental benefits from BDM are considered. Furthermore, the study region should be expanded across several states that capture a variety of fruit and vegetable growing conditions. Future studies should evaluate the impact of disposal costs and mulch practices used by farmers on their willingness to adopt BDM, factors that were not considered in this study because of the lack of data (i.e., number of missing observations, no data available from the survey).

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Trouble at Old River: The Impact of a Mississippi River Avulsion on U.S. Soybean Exports

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Abstract

The Mississippi River transportation system provides relatively low transportation costs for bulk commodities, enhancing U.S. competitiveness in the world soybean market. The Mississippi River's urgency to change course and disrupt barge travel to the New Orleans Gulf Port Region puts this advantage in jeopardy. Using transportation costs of specific modes and routes to port of import destinations, we determine that a change in the river's course would lead to an overall 27.27% increase in total costs of shipping soybeans to Shanghai, Rotterdam, and Veracruz.

Keywords: avulsion, exports, intermodal transportation, Mississippi River, network optimization model, soybeans, transportation costs, transportation system, United States

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Introduction

Barge travel along the Mississippi River provides a competitive advantage for U.S. agricultural exports. The possibility of an avulsion—the natural displacement of an established river channel (Latrubesse, 2015; Smith and Rogers, 1999)—at the Old River Control Structure (ORCS) is gradually increasing as a result of several factors related to the deposition of alluvial sediments and severe weather.

The ORCS maintains water discharge capacity for the Atchafalaya and Mississippi Rivers at approximately 30% and 70%, respectively. Should severe flooding cause the structure to fail, the distribution of water for each river would interchange, causing the abandonment of the existing Mississippi River channel and the creation of a new course to the Gulf of Mexico via the Atchafalaya River. Should this avulsion occur, the disruption of U.S. shipping channels would create an immediate need to identify alternative routes and modes for moving U.S. goods, particularly bulk agricultural commodities such as soybeans. Longer-term issues include whether or how quickly the Mississippi River could be recaptured. If the avulsion were permanent, the form and speed at which transportation infrastructure along the "new" Mississippi River would be developed is not certain. Regardless of the outcome of these issues, the possibility of an avulsion threatens the U.S. competitive advantage in soybean trade.

This research determines the immediate impact of a Mississippi River avulsion on U.S. soybean trade and examines options for transporting soybeans via alternative transportation modes and routes. The specific objectives are to identify alternative soybean export routes based on the total transportation cost from U.S. supply points to foreign destinations, compare the least-cost alternatives of shipping soybeans to port of export destinations and final demand destinations before and after an avulsion, and provide implications for future policy and industry decisions.

Background

Brazil currently leads the world in soybean production and export market share, followed by the United States and Argentina. Although competition from other countries in the global market has increased, low transportation costs of soybeans, grain, and other oilseed crops allow the United States to retain a competitive advantage. The shipment of soybeans by barge to Mississippi Gulf ports relies on the accessibility of the Mississippi River to maintain a cost-efficient transportation system. An efficient transportation infrastructure—consisting of effective railroad, highway, and waterway systems—connects United States soybean producers to global markets (U.S. Soybean Export Council, 2015).

Before reaching markets, soybeans produced in the Midwest pass through a complex supply chain involving several options including local elevators, crushing facilities, and rail and barge terminals (Informa Economics, 2016). Typically, when harvested, soybeans not placed in on-farm storage are transported by truck to port of export facilities or shipped to nearby intermodal facilities (Informa Economics, 2016), including barge terminals and shuttle elevators. Soybeans destined for export are loaded onto barges and railcars and shipped to port of export facilities. Between

2007 and 2017, on average nearly 50% of soybeans produced in the United States was exported in bulk or containerized shipping through Mississippi Gulf and Pacific Northwest (PNW) ports.

The Mississippi River is responsible for most U.S. soybean exports. As shown by U.S. customs district data (Table 1), Gulf and West Coast ports accounted for over 90% of U.S. soybean exports, with the Gulf region accounting for over 65%. It is not surprising that the Gulf and West Coast regions are the dominant ports of export for product shipped to Asia, but the Gulf is also dominant in shipping product to Europe, the Middle East, and Africa. Although it would be logical for the Great Lakes and East Coast ports to capture more of these markets, the infrastructure and low transportation costs of shipping soybeans through the Gulf via the Mississippi River have contributed to the dominance of the Gulf region with respect to U.S. soybean exports.

Table 1. U.S. Soybean Export Quantities by Customs District, 2015–2019 Average (metric tons)

	East Coast	Great Lakes	Gulf	West Coast	Other	Total
Caribbean	62,655.9	0.0	38,857.9	350.6	4.4	101,868.7
Central America	365.3	13.6	345,086.2	1,227.2	0.0	346,692.3
East Asia	1,039,344.1	257,525.7	16,630,287.9	12,005,213.7	0.9	29,932,372.2
EU27+UK	185,132.3	269,320.8	5,248,220.4	12,010.8	0.0	5,714,684.3
Former Soviet Union-12	56,413.2	9,781.6	69,217.4	0.0	0.0	135,412.2
Middle East	62,682.2	85,701.9	698,034.8	50,938.0	0.0	897,356.9
North Africa	201,430.6	13,752.0	1,659,369.6	0.0	0.0	1,874,552.2
North America	1,663.1	430,817.9	4,209,332.5	7,878.7	49.0	4,649,741.2
Oceania	13.8	0.0	0.0	1,258.0	0.0	1,271.8
Other Europe	3.6	4,300.0	0.0	0.0	0.0	4,303.6
South America	52,267.0	20,695.4	1,212,385.2	6,133.3	0.0	1,291,480.9
South Asia	78,338.9	4,933.8	1,678,483.0	162,841.9	0.0	1,924,597.6
Southeast Asia	1,210,558.2	122,931.8	2,097,064.4	1,607,329.7	5.2	5,037,889.3
Sub-Saharan Africa	9.2	0.0	22,112.8	230.2	0.0	22,352.2
Total	2,950,877.4	1,219,774.5	33,908,452.2	13,855,412.1	59.5	51,934,575.6

Source: USDA/FAS Global Agricultural Trade System Database.

The Port of South Louisiana, a port region located between Convent and Westwago, Louisiana, typically services over 55,000 barge shipments and 4,000 ocean-going vessels annually. Over 60% of U.S. soybean exports are shipped through the New Orleans Port Region (U.S. Department of Agriculture, 2017). If an avulsion were to occur, the Mississippi River beyond Old River would become impassible due to draft limitations. This would impact the shipment of several agricultural commodities, including soybeans. Cargo vessels used for overseas bulk soybean shipments would not be able to reach ports as far north as Baton Rouge. Additionally, the possible disruption of river commerce beyond the ORCS would force producers to consider shipping soybeans using more costly alternative modes of transportation. Assuming the Mississippi River to be the most cost-efficient method of transporting soybeans, use of other modes of transportation to meet global demands would increase total transportation costs.

The Mississippi River has one of the largest drainage basins in the world, serving as an outlet for approximately 41% of the contiguous United States (U.S. Army Corps of Engineers, 2019). The ORCS maintains the distribution of water between the Mississippi and Atchafalaya Rivers (see Figure 1), where 1.2 million square miles of drainage narrow into an area approximately 40 miles wide (Barnett, 2017). The ORCS distributes roughly 70% of the flow down the Mississippi River and 30% down the Atchafalaya River (Kazmann and Johnson, 1980). Floods in 1927 and 1973 highlighted the need for the existing ORCS and its associated structures. However, while the Army Corps of Engineers has thus far controlled the flow of the river at a 70–30 split, some maintain that a shift in the course of the river is inevitable (Barnett, 2017).

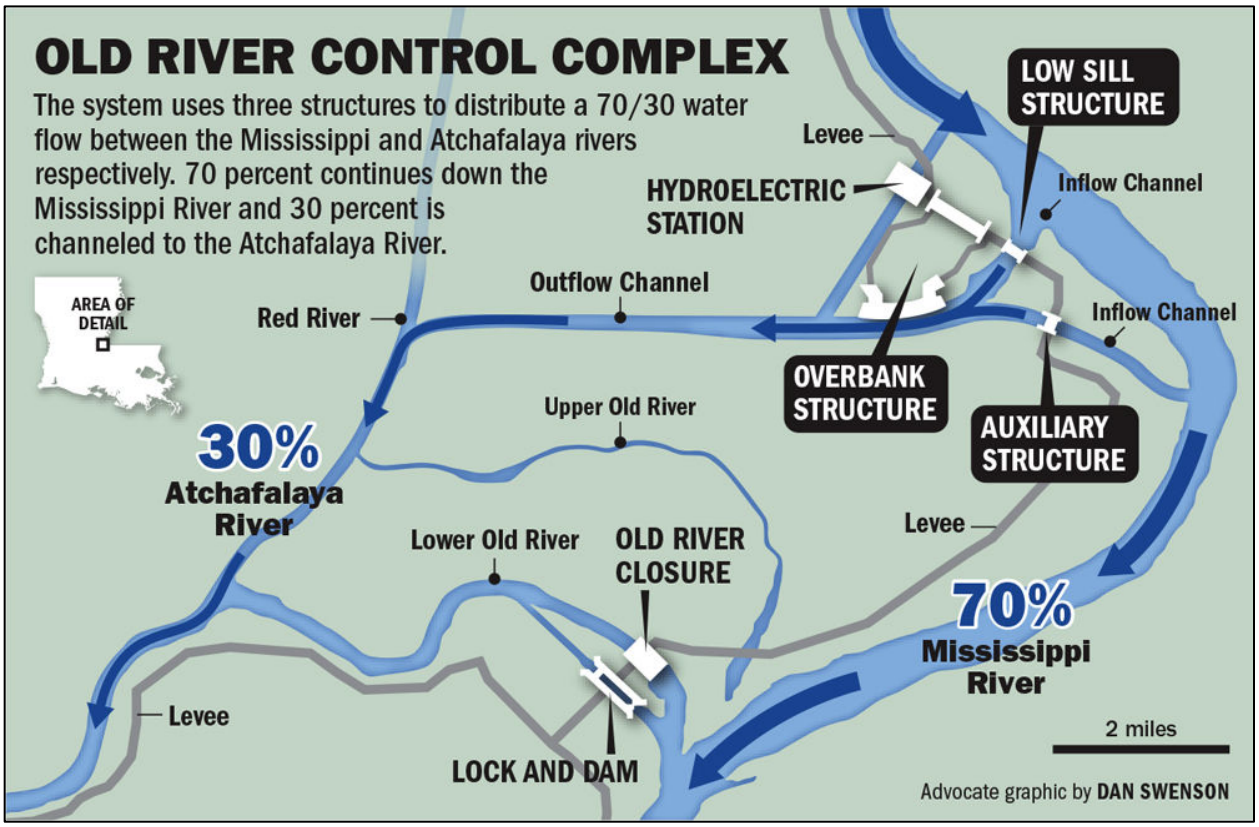

Figure 1. Map of Old River Control Complex
Source: Hardy (2018).

Theory suggests that the occurrence of a natural disaster will cause environmental, economic, and social impacts on the infrastructure of the affected area (Neal, 2014). The occurrence of a natural event—such as heavy rainfall, massive snowmelt in the Midwest region, or an intensive storm surge pushed up a flood-stage river—would increase the flow of water in the Mississippi River. This increase in flow would exceed the allotted discharge capacity of the ORCS, causing it to fail. As a result, river discharges of both the Mississippi and Atchafalaya Rivers would interchange, causing most of the water to enter the Atchafalaya River indefinitely. Flood damages, saltwater intrusion, the highway and transportation sector, and natural gas supply would be impacted. The disorder of the highway and transportation sector would directly affect soybean transportation infrastructure due to the Mississippi River becoming impassible below Old River.

A worst-case scenario assumes that substantially more water will be diverted to the new route to the Gulf. As a result, transport by barge to ports along the lower Mississippi would become increasingly difficult and eventually impossible due to lowered channel depths and vessel draft restrictions. Because the flow of water in the lower Mississippi channel would be minimal, the backflow of water from the Gulf of Mexico will be pushed up-river, allowing ocean-going vessels to access ports along the New Orleans Port Region. In the immediate aftermath of an avulsion, alternative transportation modes would be needed to meet the demands of foreign consumers. When transporting soybeans abroad, railroads occupy the second-highest modal shares after transport by barge (Denicoff, Prater, and Bahizi, 2014). Much uncertainty exists as to what the intermediate or long-term infrastructure would look like. Could the existing route be recaptured? Would the environmental lobby allow new ports and facilities on the "new" lower Mississippi River to be built? Could a slack-water estuary (system of lakes using locks and dams) be built between Baton Rouge and New Orleans to allow for barge travel along the current route?

The three alternative export regions in the United States that service soybean shipments (PNW, Atlantic, and Great Lakes) have limited capacities and specialize mainly in containerized rather than bulk shipping. Given that the ability to transport soybeans to the New Orleans Port Region—which is known for bulk shipping and exports approximately 60% of soybeans abroad—would be questionable after an avulsion, it is important to consider the shipping capacities of other ports of export and their ability to accommodate larger export quantities. The importance of and lack of research in this area encourage a closer look at the potential economic implications of an avulsion on U.S. soybean trade.

An avulsion of the Mississippi River due to the failure of the ORCS could have several economic and physical consequences. Based on previous research, a generalized hypothesis can be made regarding how U.S. soybean trade will be affected. Although this study seeks to examine the impact of an avulsion on soybean transport, the results have implications for the transportation and export of a variety of agricultural and nonagricultural commodities.

Review of Literature

Commodity disruptions as a result of compromised transportation infrastructure could occur as a result of a flood or any type of natural disaster; therefore, it is important to understand the economic

impact of these disruptions. Pant et al. (2011) modeled atypical activity at ports of export through simulations capable of quantifying the number of commodities at every operating point. They used a multi-regional inoperability input–output model and multiregional extensions along with a simulation model to provide estimates of incoming and outgoing commodities through the ports.

A similar study conducted by Pant, Barker, and Landers (2014) examined the economic losses from disruptions in imports and exports of commodities on ports of export and waterways. The increase in containerized freight transport allows for the investigation of disruptions in transporting containerized freight caused by extreme weather conditions or other circumstances. They used a risk-based extension to the economic input–output model that describes the interdependent relationship among industry and infrastructure sectors in meeting final demand as well as a multiregional, multi-industry interdependency model and a simple discrete-event simulation model for commodity arrivals and departures at several docks.

Of particular relevance to this analysis, various models have been utilized to determine the impact of waterway disruptions on the movement and export of U.S. grains and oilseeds. Fuller and Grant (1993) used a least-cost network flow model to examine the impact of lock delay on transportation efficiency. Fuller, Fellin, and Eriksen (2000) used a spatial equilibrium model to examine the importance of the Panama Canal to U.S. corn and soybean exports. Their analysis examined the impact of increased Panama Canal tolls on U.S. exports and the impact of a disruption via complete closure of the canal. Fellin et al. (2008) used a spatial model to examine the impact of a catastrophic event on Mississippi River Lock and Dam 27 for the movement of agricultural commodities. They determined the value of the upper Mississippi and Illinois Rivers for grain transport to be between $229 million and $806 million. Yu, English, and Menard (2016) also used a spatial equilibrium model to examine the impact of closures on the upper Mississippi and Illinois Rivers. However, their analysis considered disruptions due to lock closures at Mississippi River Lock 25 and Illinois River La Grange Lock. Yu, English, and Menard found that the closure of Lock 25 for the marketing year resulted in a $747 million loss of economic surplus to the U.S. corn and soybean sectors; the closure of the La Grange Lock for the marketing year resulted in a $549 million loss.

Güler, Johnson, and Cooper (2012) analyzed the impact of a partial or full disruption on the transportation system between coalmines and coal-dependent power plants located in the Ohio River Basin. Using a minimum cost flow model, the authors were able to minimize total system transportation cost of coal while meeting service and capability constraints.

Kruse et al. (2018) analyzed the economic impact of the Gulf Intercoastal Waterway (GIW) on Texas, Louisiana, Mississippi, Alabama, and Florida using the IMPLAN model, a modeling tool that enhances the general input–output model approach. The authors also examined the impact of an abrupt closure of the GIW, which would force shipments usually transported by barge to shift to rail and truck transport.

Oztanriseven and Nachtmann (2017) used a simulation-based approach to examine the economic impacts of a navigable inland waterway's disruption response, which includes responses based on commodity type. Their methodology measured the total economic loss during a disruption based

on shippers' decisions to wait for the inland waterways to reopen or transfer cargo to an alternative mode of transportation and considered short-, medium-, and long-term scenarios.

The demand for agriculture commodities has a significant influence on the economy; therefore, it is also important to look at supply chain logistics of those commodities. The rapid growth of soybean production and exports places a huge burden on the transportation sector to fulfill growing demands. Once the flow of shipment of commodities, such as soybeans, is disrupted, a producer must find ways to reroute their product for shipment and export. Bai et al. (2017) developed a modeling framework and detailed calculation procedure to analyze total transportation costs for containerized soybean exports. The methodology assessed the cost of containerized shipments from a specific point in the United States to a destination point to identify least-cost transportation options. Lopes, Lima, and Ferreira (2016) conducted a similar transportation cost study using a transportation network model to minimize costs among alternative soybean export routes in Brazil.

Reis and Leal (2015) proposed a mathematical model that allows an individual soybean shipper to plan the logistics for a soybean supply chain. Soybean supply in Brazil is much lower than demand, so suppliers must determine how much soy they will bring to the market. There is also a shortage of rail transport due to travel by roadway being a cheaper alternative. Models used to plan for the food supply chains were strategic, tactical, and operational. The mathematical model used for this study was a linear programming model set to maximize profit with continuous and nonnegative variables.

Gohari et al. (2018) used a theoretical intermodal network to identify the shortest path and other modes of transport for containers being shipped from an origin to destination point based on minimal time, distance, cost, and carbon dioxide emission objectives. Trade-offs associated with different transportation modes were also identified.

The literature examined provides insight on topics relevant to this study; however, essential questions remain unanswered. First, published studies that focus on waterway disruption through the closure of waterways or dams find that the absence of barge transport increases total transportation costs. However, after a thorough review, no literature was found to assess the economic implications of the potential impassibility of the Mississippi below Old River, an area that distributes over 60% of U.S. agricultural export volumes. In addition, soybean logistic studies examine the most cost-effective routes when all modes of transportation are available, but there is lack of research that measures cost-efficient routes from an origin to a destination port in a foreign country given the impassibility of the Mississippi River as well as how these costs change as a result of an avulsion. This research seeks to fill these gaps.

Estimation Methods

Based on the review of literature and the scope of this research, it was determined that a network optimization model would yield dependable estimates of the economic impact of U.S. soybean trade. The network optimization model used to conduct the analysis is the minimum cost flow model, a model that can combine and efficiently solve maximum flow, shortest path, and

transportation applications, all of which are needed when determining a plan for transporting commodities from their supplier to storage facilities and then to consumers (Hillier and Lieberman, 2015).

Using a minimum cost flow model requires supply, demand, transshipment, and constraints. Incorporating the transportation costs of truck, rail, and barge, production region supply and the demand of the destination country, as well as the capacities of port of export regions into the model, will allow us to determine the least-cost route combinations while minimizing total overall cost to transport product to a final destination.

Many soybean production sites exist at the county level. To simplify, it is assumed that the supply node will be represented best by a location that is equally distant from barge and rail transportation (Bai et al., 2017). Five production regions were included to represent annual soybean production. States that produced over 100,000,000 bushels annually were selected and divided into regions based on Bureau of Economic Analysis business areas.

The mathematical model used for this analysis is adapted from Lopes, Lima, and Ferreira (2016) and is presented below in equations (1)–(10). The objective function seeks to minimize the total transportation cost of shipping soybeans through current routes in a pre-avulsion scenario and alternative routes and modes in a post-avulsion scenario to meet foreign demand:

(1) $$\text{Minimize } Z = \Sigma_{i=1}^{n}\Sigma_{j=1}^{m}\Sigma_{k=1}^{o}\,(c_{ij} + c_{jk})x_{ijk}$$

subject to the following constraints and transportation costs:

(2) (a) production region supply: $\Sigma_{i=1}^{n} x_{ijk} \leq P_i \; for \; i = 1, \ldots, n$;

(3) (b) destination demand: $\Sigma_{k=1}^{o} x_{ijk} = D_k \; for \; k = 1, \ldots, m$;

(4) (c) transshipment constraints: $\Sigma_{j=1}^{m} x_{ij} - \Sigma_{j=1}^{m} x_{jk} = 0$;

(5) (d) port capacity: $\Sigma_{j=1}^{n} x_{ijk} \leq T_i \; for \; j = 1, \ldots, m$;

(6) (e) transportation costs: $c_{ij} = c_t + c_r + c_b + c_u$,

where c_t represents truck transportation cost in dollars per metric ton ($/MT); c_r represents rail transportation cost in $/MT; c_b represents barge transportation cost in $/MT; and c_u represents modal change unitary cost in $/MT when multiple modes are used.

Considering that for equation (6):

(7) $$u \geq 0$$

and

(8) $$c_u \geq u \cdot c_{uf},$$

where u represents the number of modal changes for x_{ij}; and c_{uf} represents modal change cost in \$/MT.

For c_{ij}:

(9) $$c_{jk} = c_s,$$

where c_s represents ocean transportation cost in \$/MT.

(10) (f) nonnegative conditions: $x_{ijk} \leq P_i \; for \; i = 1, \ldots, m; j = 1, \ldots, n; k = 1,$

where m indicates the number of exporting port regions; n indicates the number of soybean production regions; o indicates the number of importing ports; T_j represents port j's capacity to export soybeans; P_i represents the quantity of soybeans produced in metric tons in each region i; c_{ij} represents the transportation cost of shipping soybeans from production region i to exporting port region j; c_{jk} represents the transportation cost of shipping soybeans from exporting port j to importing port k; x_{ijk} represents the volume of soybeans shipped from production region i to exporting port j and exporting port j to importing port k; and Z represents the total transportation cost of soybean shipment.

The economic impact of an avulsion on soybean trade flows is estimated as follows: First, we identify the pre- and post-avulsion supply chains. This includes original and alternative routes, intermodal facility locations, and port of export regions. The next step is to obtain truck, rail, barge, and ocean transportation costs for domestic shipments from producer to final destination. The final step is to calculate total shipment costs for original shipment routes for a pre-avulsion scenario and total shipment costs using alternative routes and modes of transportation for a post-avulsion scenario.

In addition, based on revealed preferences, it is assumed that transporting soybeans downstream via barge along the Mississippi River for export through New Orleans is the most cost-efficient mode of transportation for soybean producers. If there were a cheaper alternative for shipping soybeans, this alternative would already be used. Therefore, we assume that the costs associated with alternative modes of transportation would increase transportation costs of soybean exports. This would result in a negative trade-off due to the costs associated with increasing infrastructure in competing port regions (PNW, Atlantic, and Great Lakes), exceeding costs that would be saved if the Mississippi remained accessible to barge transportation. Another assumption is that competing port regions cannot increase infrastructure in the short term. Thus, current port capacities will be used, and an avulsion of the Mississippi at Old River would disrupt barge travel to the Mississippi Gulf. Additionally, it is assumed that approximately 48% of soybeans produced are exported to other countries and approximately 79% of soybeans exported are shipped to East Asia (Shanghai), EU-27, the United Kingdom, and South Asia (Rotterdam), and Mexico

(Veracruz). Because supply and demand in a minimum cost flow model must equal one another, the percentage of soybeans exported to the previously mentioned regions would represent the flow in the model.

For simplicity, we do not include local transportation from the harvest site to intermodal facilities or from the port of import to the final destination point. Additionally, we assume that rail and highway infrastructure is sufficient, and no additional costs are included to address capacity constraints of substituting rail hopper cars and trucking for barges. Based on the mathematical model presented, we used Microsoft Office Excel Solver to run the optimization scenarios considered.

Data and Scenario Analysis

Data for this research were obtained from the USDA Agricultural Marketing Service (AMS), which provides soybean movement data and barge rates. Modal transportation costs of truck and ocean rates were obtained from AMS *Grain Truck and Ocean Advisory* reports. Since ocean rates for certain port of export regions were not readily available, we used rates from multiple reports to determine the average mile per metric ton rates of bulk grain exports from reported port of export regions to the same destination. Ocean and truck routes were calculated using Netpas software and PC*Miler Copilot software. We also used the Surface Transportation Board (STB) Public Waybill Sample to analyze soybean rail movements from various Bureau of Economic Analysis business areas to port of export destinations. Rail rates for those movements were extracted from the Waybill Sample. Selected rail routes were extracted from the Tariff and Rail Rates for Unit and Shuttle Train Shipment dataset used in the *Grain Transportation Report*, a weekly AMS publication, and compared to Waybill Sample rail rates so that rates were within reasonable ranges. Soybean production data, measured in bushels, were obtained from the USDA National Agricultural Statistics Service (NASS) Quick Stats Database. Soybean export data were obtained from two databases—the Global Agricultural Trade System and Production, Distribution, and Supply—both of which are provided by the USDA Foreign Agricultural Service (FAS). Class I railroad network data and intermodal facility data were obtained from the U.S, Department of Transportation Bureau of Transportation Statistics (BTS).

A network optimization model was utilized to estimate the economic impact of U.S. soybean trade following an avulsion of the Mississippi River. Because this analysis assumes the most current logical and least-cost routes, routes were generated based on general assumptions of current shipping and future routes to ports of export assuming the impassibility of the Mississippi below Old River and the elimination of barge travel to the New Orleans Gulf Port Region. Production regions selected for the analysis are in the Midwest region of the United States, which produces over 80% of U.S. soybeans and is along the lower Mississippi River corridor.[1] Production regions are Region 1 (S1) (Illinois, Indiana, and Ohio), Region 2 (S2) (Minnesota, Wisconsin, and North

[1] In 2017 the top soybean-producing states were Illinois, Iowa, Minnesota, Indiana, Nebraska, Missouri, Ohio, Mississippi, Arkansas, North Dakota, South Dakota, Tennessee, and Kentucky. These states, except for Tennessee, all produced over 100 billion bushels of soybeans, with Iowa and Illinois both producing well over 500 billion bushels (U.S. Department of Agriculture, 2019).

and South Dakota), Region 3 (S3) (Missouri and Iowa), Region 4 (S4) (Nebraska, South Dakota, and Iowa), and Region 5 (S5) (Arkansas, Mississippi, and Kentucky). St. Louis (P1') is an inland port and will act as a route alternative for exports. Port of export regions are the New Orleans Gulf (Gulf), PNW, Atlantic, and the Great Lakes. We used ArcMap to identify truck, rail, and port intermodal facilities in each production region.

Approximately 89% of soybeans destined for export are shipped to a local elevator, while 11% are shipped directly from the harvest site (Informa Economics, 2016). Once soybeans arrive at the local elevator, they are transported via truck or rail to a nearby intermodal facility within a 50-mile radius for transport to a port of export destination. For simplicity, the analysis will consider transportation costs of shipping soybeans from an intermodal facility located in each production region to the port of export (transshipment point) and from the transshipment point to the port of import (destination). Figure 2 presents a map of the production regions, intermodal facility locations, and port of export regions.

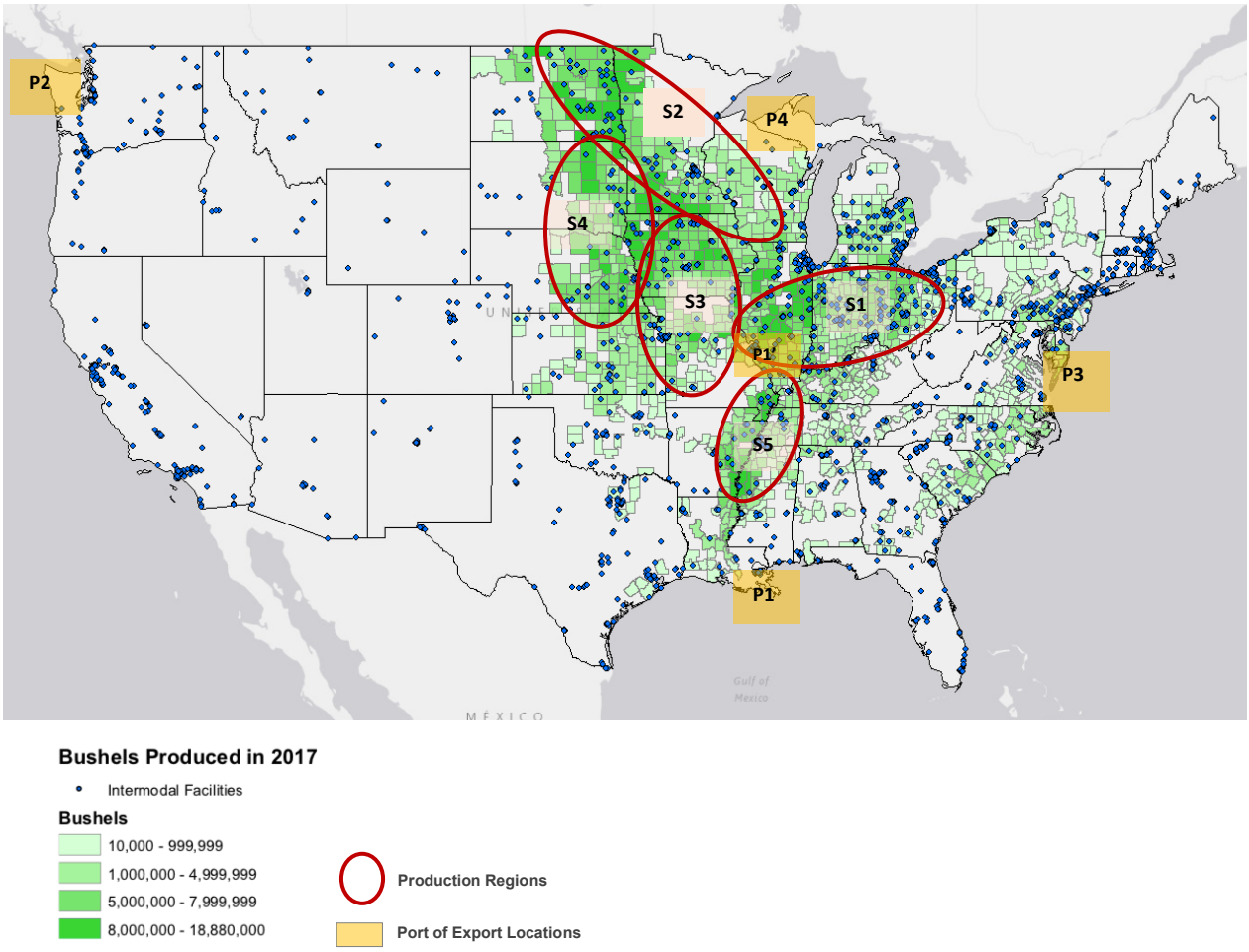

Figure 2. 2017 U.S. Soybean Production by County, Production Regions, Intermodal Facility Locations, and Port of Export Regions

Source: USDA National Agricultural Statistics Service and Bureau of Transportation Statistics Service.

Because the United States is a net soybean exporter, soybean exports for each region are based on the demands of the selected regions (Shanghai, Rotterdam, and Veracruz), all top importers of U.S. soybeans. To estimate the quantity of soybeans exported to these regions, we multiplied the percentage of soybeans exported to the world by the amount of soybeans produced in each production region state. Once we had estimated the export supply to the world, we multiplied soybean production by the export percentages to the regions. To eliminate the possibility of counting states represented in multiple production regions, we divided the export percentage of each state by the number of times a state appeared in each region. For example, Iowa is represented in two production regions; half of its total export production was distributed to each of the two regions in which it appeared.

For this analysis, two scenarios were used to show the differences in total transportation costs before and after an avulsion of the Mississippi River at Old River: a pre-avulsion and a post-avulsion scenario. To ensure parallelism in the results, each scenario used the same supply, demand, costs, and transshipment constraints. The pre-avulsion scenario attempts to replicate the current estimated transportation costs using transshipment constraints prior to an avulsion as well as all available transportation modes from the production regions to the transshipment regions and from the transshipment regions to the final port of import. As noted previously, the model does not include transportation costs from the harvest site to the local elevator to the intermodal facility. Additionally, routes from transshipment point to the final port of import will remain the same in both scenarios. In the pre-avulsion scenario, soybeans can be shipped via barge, rail, or truck to port of export locations. The post-avulsion scenario represents the transportation costs of shipping soybeans after an avulsion, removing the possibility of barge travel below the ORCS.

Table 2 presents capacity constraints for origins, transshipment locations, and destinations. Transshipment capacities were estimated using 2017 soybean exports to the selected regions. The difference in supply and demand capacity of soybeans resulted in an unbalanced optimization problem. To change the problem to a balanced problem, an additional production region (Dummy 1) was added to the model. The inclusion of a dummy variable allowed the production region supply to remain less than or equal to the considered supply constraint and the destination demand remains equal to considered demand constraint resulting in a feasible solution. Another way to solve this problem was to set the production region supply equal to the considered supply constraint and the destination demands remain less than or equal to the considered demand constraint. Production areas not included in the primary regions are represented by a dummy variable. The inclusion of the dummy variable requires its costs to equal 0. These costs will not be 0; therefore, the final transportation cost to export soybeans will be higher than the costs calculated in the optimization model.

Considering the finite export capacities of individual ports, this analysis uses port of export regions (unlike other optimization models). Typically, the USDA aggregates soybean exported within their respective port of export regions to represent total export percentages for that port of export region. For example, soybeans shipped through the New Orleans Gulf Port Region represent approximately 60% of U.S. soybeans exported, whereas soybeans shipped through the PNW region represent approximately 25% of soybeans exported (U.S. Department of Agriculture, 2017).

Due to variation in rail rates with identical routes, we used the average rail cost to represent the rail cost to port of export regions with multiple representative ports.

Simulation Results

Results of the optimization simulations are presented in Tables 3–5. Table 3 presents the per unit inland transportation costs for the pre- and post-avulsion scenarios. Inland transportation costs represent the total transportation cost of shipping soybeans from an intermodal facility within a production region to a port of export location and includes unitary modal change handling costs. The average inland transportation cost for all possible routes is $34.94/MT or $0.95/bushel, pre-avulsion. These costs increase to $49.63/MT or $1.35/bushel, an overall average of 42.06%, post-avulsion. However, given that the analysis considers the disruption of barge transportation in the lower Mississippi River and only those routes previously utilizing the lower Mississippi River for barge transportation, the three routes experiencing transportation cost increases are between the Gulf and Regions 1, 3, and 5. Inland transportation costs for shipping to the Gulf from Regions 1, 3, and 5 increased by 113.85%, 67.61%, and 289.65%, respectively.

The pre-avulsion scenario, which represents the pre-avulsion status quo, shows a transportation cost of $2.401 billion. When modal change costs of $0.228 billion are added, the final total transportation cost in the pre-avulsion scenario increases to $2.628 billion.[2] Shipments are considered to change modes when being loaded and unloaded for transition between transportation modes. For example, a total of three modal changes are assumed for a route leaving a local elevator destined for an intermodal facility in Region 1 to the Gulf and from the Gulf to the final destination. These changes are determined by the loading of soybeans onto shuttle rail cars or barge destined for the Gulf and the unloading and reloading of soybeans onto an ocean-going vessel to a region. In the pre-avulsion scenario, 68.87% of total shipments destined for all regions were transported to the Gulf via barge, while 30.25% were sent to the PNW via rail. All other shipments, less than 1%, were shipped by truck to the Great Lakes or shipped via the alternate dummy route to the Atlantic port region. This is most likely due to the high modal transportation costs; however, the low capacity of these ports for bulk agricultural commodities may have played a factor as well.[3] Regardless of the reason for the low quantity of shipments to the Atlantic and Great Lakes regions, this is logical given that the availability of barge travel along of the Mississippi River extends from Minneapolis–St. Paul down the Mississippi River to the Gulf of Mexico.

The least-cost alternative in the post-avulsion scenario is a transportation cost of $3.118 billion, a 29.88% increase. As discussed in the hypothesis, this result is consistent with expectations since

[2] Modal change costs are estimated to be approximately $0.05 per bushel per mode change.

[3] To ensure the existence of routes for each production region and port export region route, truck rates were substituted in cases when rail transportation costs were not available. The truck mile-per-metric ton rate obtained from the Grain Truck and Ocean Rate Advisory (U.S. Department of Agriculture, 2018) was multiplied by the average mileage of the intermodal facility geographically located in the center of Bureau of Economic Analysis business areas to the designated port of export region.

Table 2. Capacity Constraints for Origins, Transshipment Locations, and Final Destinations

Origins	Supply (MT)	Trans-shipment Locations	Port Capacity (MT)	Destinations	Demand (MT)
Region 1 OH, IN, IL (S1)	12,749,104	Gulf Region (P1)	30,219,834	Shanghai (C1)	35,294,766
Region 2 MN, SD, ND, WI (S2)	9,546,752	PNW Region (P2)	14,957,354	Rotterdam (C2)	6,471,701
Region 3 MO, IA (S3)	6,469,264	Atlantic Region (P3)	1,412,447	Veracruz (C3)	2,106,827
Region 4 IA, SD, NE (S4)	8,200,456	Great Lakes Region (P4)	704,881		
Region 5 MS, AR, KY (S5)	4,452,601				
Total	41,418,177			Total	43,873,293

Note: Capacities were estimated using USDA AMS GATS Database.

Table 3. Inland Transportation Cost Comparison

	Pre-Avulsion		Post-Avulsion		
Route	$/MT	$/bu	$/MT	$/bu	% Change
Region 1 to Gulf	20.98	0.57	44.87	1.22	113.87
Region 2 to Gulf	29.89	0.81	–	–	–
Region 2 to PNW	61.10	1.66	61.10	1.66	0.00
Region 2 to Great Lakes	33.21	0.90	33.21	0.90	0.00
Region 3 to Gulf	24.85	0.68	41.65	1.13	67.61
Region 4 to Gulf	–	–	54.10	1.47	–
Region 4 to PNW	61.42	1.67	61.42	1.67	0.00
Region 5 to Gulf	13.10	0.36	51.06	1.39	289.77
Average	34.94	0.95	49.63	1.35	42.06

Note: Hyphens in the pre- and post-avulsion columns indicate that soybeans were not shipped using that route. As a result, the percentage change for those routes could not be calculated.

Table 4. Port of Export and Port of Import Shipment Comparison

	Pre-Avulsion Scenario			Post-Avulsion Scenario			
Port of Export Route	**Soybeans (MT)**	**Cost ($/MT)**	**Total Cost**	**Soybeans (MT)**	**Cost ($/MT)**	**Total Cost**	**% Change in Shipment**
Region 1 to Gulf	12,749,104*	$20.98	$197,228,638	12,749,104**	$44.87	$501,766,486	0.00%
Region 2 to Gulf	6,548,865*	$29.89	$159,654,779	–	–	–	–
Region 2 to PNW	2,617,234**	$61.10	$145,478,951	8,841,871**	$61.10	$491,475,400	237.83%
Region 2 to Great Lakes	380,653***	$33.21	$11,241,825	704,881***	$33.21	$20,817,251	85.18%
Region 3 to Gulf	6,469,264*	$24.85	$125,089,688	6,469,264**	$41.65	$233,766,855	0.00%
Region 4 to Gulf	–	–	–	4,538,639**	$54.10	$220,532,479	–
Region 4 to PNW	8,200,456**	$61.42	$458,446,492	3,661,817**	$61.42	$204,713,868	−55.35%
Region 5 to Gulf	4,452,601*	$13.10	$33,808,599	4,452,601**	$51.06	$202,815,976	0.00%
Port of Import Route	**Soybeans (MT)**	**Cost ($/MT)**	**Total Cost**	**Soybeans (MT)**	**Cost ($/MT)**	**Total Cost**	**% Change in Shipment**
Gulf to Shanghai	22,027,139	$38.37	$845,137,269	20,016,913	$38.37	$768,008,926	−9.13%
PNW to Shanghai	13,267,627	$20.37	$270,301,364	14,953,625	$20.37	$304,650,198	12.71%
Great Lakes to Shanghai	–	–	–	324,228	$47.11	$15,274,919	–
Gulf to Rotterdam	6,471,701	$15.97	$103,320,706	6,471,701	$15.97	$103,320,706	0.00%
Gulf to Veracruz	1,720,994	$13.25	$22,803,170	1,720,994	$13.25	$22,803,171	0.00%
PNW to Veracruz	3,729	$86.78	$323,591	3,729	$86.78	$323,591	0.00%
Atlantic to Veracruz	380,653	$73.23	$27,877,075	380,653	$73.23	$27,877,075	0.00%
Great Lakes to Veracruz	1,451	$28.74	$41,706	1,451	$28.74	$41,706	0.00%

Overall Cost			**% Change in Cost**
Shipping Cost	$2,400,753,860	$3,118,188,606	29.88%
Modal Change Cost	$227,579,230	$226,983,563	−0.26%
Total Shipping Cost	$2,628,333,090	$3,345,172,169	27.27%

Note: Hyphens in the pre- and post-avulsion columns indicate that soybeans were not shipped using that route. As a result, the percentage change for those routes could not be calculated. Asterisks in the table represent modes used before and after avulsion. They are identified as follows: "Barge" *, "Rail" **, and "Truck" ***. Shipments destined for a Port of Import are transported on an ocean vessel. The cost of mode changes is estimated to be $1.84 per metric ton of soybeans which can range between two to four changes per route depending on modes used. Mode changes are assumed to occur when shipments are transported from a local elevator by rail or truck and unloaded at an intermodal facility; reloaded and transported from the intermodal facility by rail, barge, or both and unloaded at a port of export; and finally reloaded onto an ocean vessel for transport to a port of import. For example, a total of three modal changes are assumed for a route leaving a local elevator destined for an intermodal facility in Production Region 1 to the New Orleans Gulf Port Region and from port region to the final destination.

Table 5. Pre- and Post-Avulsion Transportation Costs for Alternative Routes ($/MT)

	Gulf			PNW		Great Lakes	
Pre-Avulsion Scenario	**Shanghai**	**Rotterdam**	**Veracruz**	**Shanghai**	**Veracruz**	**Shanghai**	**Veracruz**
Region 1 via Gulf to:	$59.35	$36.95	$34.23				
Region 2 via Gulf to:	$68.26	$45.86	$43.14				
Region 3 via Gulf to:	$63.22	$40.82	$38.10				
Region 4 via Gulf to:	–	–	–				
Region 5 via Gulf to:	$51.47	$29.07	$26.35				
Region 2 via PNW to:				$81.47	$147.88		
Region 4 via PNW to:				$81.79	$148.20		
Region 2 via Great Lakes to:						–	$61.95

	Gulf			PNW		Great Lakes	
Post-Avulsion Scenario	**Shanghai**	**Rotterdam**	**Veracruz**	**Shanghai**	**Veracruz**	**Shanghai**	**Veracruz**
Region 1 via Gulf to:	$83.24	$60.84	$58.12				
Region 2 via Gulf to:	–	–	–				
Region 3 via Gulf to:	$80.02	$57.62	$54.90				
Region 4 via Gulf to:	$92.47	$70.07	$67.35				
Region 5 via Gulf to:	$89.43	$67.03	$64.31				
Region 2 via PNW to:				$81.47	$147.88		
Region 4 via PNW to:				$81.79	$148.20		
Region 2 via Great Lakes to:						$80.32	$61.95

	Gulf			PNW		Great Lakes	
Percentage Change	**Shanghai**	**Rotterdam**	**Veracruz**	**Shanghai**	**Veracruz**	**Shanghai**	**Veracruz**
Region 1 via Gulf to:	40.25%	64.65%	69.79%				
Region 2 via Gulf to:	–	–	–				
Region 3 via Gulf to:	26.57%	41.16%	44.09%				
Region 4 via Gulf to:	–	–	–				
Region 5 via Gulf to:	73.75%	130.58%	144.06%				
Region 2 via PNW to:				0.00%	0.00%		
Region 4 via PNW to:				0.00%	0.00%		
Region 2 via Great Lakes to:						–	0.00%

Source: Author Calculations based on data from Table 3.

the optimized route in the pre-avulsion scenario utilized barge travel for most of the inland shipments to ports of export. The modal change cost of shipping soybeans decreased 0.26% in the post-avulsion scenario. When modal change costs of $0.227 billion are added, the total transportation cost increases by 27.27% to $3.345 billion.

Although the inland transportation cost of soybeans for individual routes increased significantly in the post-avulsion scenario, shipments from Region 1, 3, and 5 to the Gulf remain unchanged. An additional shipment route, Region 4 to the Gulf, is used in the post-avulsion scenario but was not used in the pre-avulsion scenario. Conversely, the Region 2 route to the Gulf, which was used in the pre-avulsion scenario, was not utilized in the post-avulsion scenario.

Soybean shipments to Shanghai and Veracruz from the Great Lakes are minimal in both scenarios when compared to shipments from the Gulf and PNW. Similarly, just a small fraction of total soybean exports was shipped from the Atlantic region. As mentioned previously, this could be due to the limited capacity of these port facilities and alternative cost estimates for those routes.

When ocean costs are added to the inland costs, the total transportation cost of exporting soybeans from Region 1 via the Gulf to Shanghai, Rotterdam, and Veracruz increases to $83.24/MT, $60.84/MT, and $58.12/MT, respectively (Table 5), due to a disruption caused by an avulsion at the ORCS, or a 40.25%, 64.65%, and 64.79% increase in total transportation costs, respectively. Similar increases are seen in transportation costs through the Gulf for the other production regions. Although the transportation costs for exports through PNW and the Great Lakes do not increase, these routes become more advantageous in relative terms given the cost increases of the Gulf routes.

In addition to comparing the total transportation costs per metric ton and bushel, we also estimated the cost, insurance, and freight (CIF) price of exported soybeans from an intermodal facility to a port of export region and from a port of export region to the final destination. For simplicity, these results are presented for delivery to Shanghai. To estimate the CIF prices, we calculated the 2017 average farm price received for states represented in each production region. Since this price is reported as a per bushel cost, we converted the cost to a metric ton cost. For this analysis, the farm price will serve as the free-on-board (FOB) intermodal facility price (USDA-NASS). The CIF prices for Shanghai is total transportation costs, which include the inland and ocean transportation cost, added to the FOB price. Table 6 presents the CIF price for soybeans delivered to Shanghai. An avulsion would result in a 5.79%, 4.23%, and 9.28% increase in CIF Shanghai price for soybeans shipped from Regions 1, 3, and 5, respectively, via rail to the Gulf.

Table 6. Calculated CIF Price, China

	2017 FOB	Pre-Avulsion			Post-Avulsion			
Route	Price Intermodal Facility ($)	Trans-portation Cost ($/MT)	CIF Price ($/MT)	CIF Price ($/bu)	Trans-portation Cost ($/MT)	CIF Price ($/MT)	CIF Price ($/bu)	Change in CIF Price (%)
Region 1 to Gulf	353.11	59.35	412.46	11.23	83.24	436.35	11.86	5.79
Region 2 to Gulf	333.72	68.26*	401.98	10.94	–	–	–	–
Region 2 to PNW	333.72	81.47	415.19	11.30	81.47	415.19	11.30	0.00
Region 2 to Great Lakes	333.72	80.32	414.04	11.27	80.32	414.04	11.27	0.00
Region 3 to Gulf	334.00	63.22	397.22	10.81	80.01	414.01	11.27	4.23
Region 4 to Gulf	334.00	–	–	–	92.47*	426.47	11.61	–
Region 4 to PNW	334.00	81.79	415.79	11.32	81.79	415.79	11.32	0.00
Region 5 to Gulf	357.42	51.47	408.89	11.13	89.43	446.85	12.16	9.28

Note: Prices with asterisks represent the transportation costs of that route, although product may not have shipped in the previous or current scenario.

Research Implications

Results from the analyzed scenarios indicate that an avulsion would cause soybeans to shift from shipment to the Gulf by barge to rail, significantly increasing total transportation costs of soybean exports to East Asia (Shanghai); EU-27, the United Kingdom, and South Asia (Rotterdam); and Mexico (Veracruz). This result is logical given that barge travel along the Mississippi River to the Gulf is currently the most cost-efficient mode of transportation for inland soybean shipments; its disruption would result in increased transportation costs. However, given that this analysis looked at the economic impact of an avulsion on soybean exports, the increase in cost represents a lower bound. Logistical capacity constraints and increased demand for transport services as a result of an avulsion also contribute to this being the lower-bound cost.

The estimated increase in soybean transportation costs from the initial shock of an avulsion of the Mississippi River is $716.8 million (Table 4). If soybean exports to Shanghai, Rotterdam, and Veracruz remain constant, the cumulative increase in transportation costs of soybeans on an annual basis will exceed billions of dollars in the long run. It is important to note that this cost represents only the cost of shipping soybeans to the selected regions for 2017 and does not account for the remaining 21% of soybeans shipped to the rest of the world. Neither does it consider other agricultural commodities shipped from the New Orleans Gulf Port Region such as corn, wheat, rice, and other bulk commodities. If transportation costs of soybeans are assumed to increase, then the transportation costs of other agricultural commodities frequently shipped by barge are expected to increase as well.

In the optimization model, there were no capacity constraints on the number of barges, rail hopper cars, or trucks that could be used to ship soybeans to port of export regions. Given shipping time constraints, the number of available railcars, labor, and other factors such as market power, the increase in rail movement capacity to the New Orleans Gulf Port Region will likely cause rail costs to increase due to increased demand. Similarly, post-avulsion demand for barges would decrease and likely reduce the price for barges elsewhere. After an avulsion, the optimization model indicated that the New Orleans Gulf Port Region exported a combined 28.2 million metric tons—or approximately 1,036.5 million bushels—of soybeans to Shanghai, Rotterdam, and Veracruz. In the pre-avulsion scenario, all soybeans transported to the New Orleans Gulf Port Region were shipped via barge. Using this information, it can be assumed that shipments to the Gulf via rail in the post-avulsion scenario would have been sent via barge if that mode were available.

A 15-barge tow hauls approximately 787,000–855,000 bushels of soybeans, the equivalent of 219 rail hopper cars (Soy Transportation Coalition, 2019). The number of rail car hoppers that would be added to the current rail movement following an avulsion is 185,058–209,920 or, in terms of a 100-car unit train, 1,850–2,100 additional unit-train shipments of soybeans annually. The number of unit-train shipments to the PNW would also increase given the projected increase in the quantity of soybeans shipped to the PNW. This increase in rail shipments is not as large as the increase in shipments to New Orleans ports. The increase in unit-train shipments would also increase CO_2 emissions, result in possible delays of shipments due to congestion at loading facilities, and increase daily commute times of citizens at rail crossings as a result of increased unit-train traffic.

With respect to the post-avulsion increases in inland transportation costs, producers in Regions 1, 3 and 5 will experience higher per bushel transportation costs increases than producers in Regions 2 and 4 with the elimination of barge travel. Barge travel may not be eliminated completely and product from production Regions 1 and 3 may be able to travel as far south as Vicksburg or Natchez, Mississippi, by barge and from there shipped to the New Orleans Gulf by rail. Shipments from Region 5, which experiences the highest increase in intermodal facility costs, would most likely not have that option given their location. Because this is a worst-case scenario analysis, the combined transportation cost of barge and rail was assumed to exceed the rail transportation costs directly to the Gulf.

Results in the post-avulsion scenario also indicate that an avulsion would negatively impact U.S. soybean trade by reducing U.S. competitiveness in the world market. Production regions with increased inland transportation costs will also see increases in their respective CIF soybean prices of soybean exports to Shanghai. The CIF price is the price the selected regions will pay for soybeans imported from the United States. An increase in the CIF price will likely cause decreases in quantity demanded for U.S. soybeans on the world market, at constant FOB prices. However, a likely scenario would be that the U.S. FOB price would adjust downward to maintain a competitive CIF price on the world market relative to its export competitors, Brazil and Argentina.

Policy makers should consider this information as they evaluate potential investment in additional river maintenance to prevent an avulsion. Avulsion prevention practices include dredging, maintaining flood control structures, and preserving levee systems. To provide perspective on the dredging costs associated with maintaining the river, a project promoted by Mississippi River stakeholders will deepen the lower Mississippi River from 45 to 50 feet along the lower Mississippi shipping channel. The project will cover the final 256-mile stretch of river between Baton Rouge, Louisiana, and the Gulf of Mexico. Costs include planning, design, and research and are an estimated $237.7 million, or just under $929,000 per mile. This is likely a high estimate because it estimates dredging of an additional 3 feet while the river is usually dredged to at least 47 feet (Grainnet, 2019).

Conclusions

This research identified immediate alternative soybean export routes following a Mississippi River avulsion and compared the least-cost alternatives of shipping soybeans to port of export destinations and final demand destinations using pre- and post-avulsion scenarios. The results found are consistent with expectations and the literature. An avulsion would result in modal shifts from barge to rail.

This analysis provides a major building block from which a more extensive aggregate economic impact and cost–benefit analysis could be undertaken on two fronts. First, should an avulsion occur, society would be impacted in an abundance of areas too numerous to consider in a single analysis. Not only would transportation be impacted, but other issues—ranging from the availability of drinking water to industrial plant location—would arise. Even with respect to agricultural trade, many other export commodities, not to mention import commodities, would be affected. Second,

with respect to a single agricultural export commodity such as soybeans, we narrow our focus to the immediate response. The intermediate and long-term responses to an avulsion should include increased capacity and price adjustments for other routes and modes as well as the potential development of alternative transportation infrastructure in the Gulf Region in response to the post-avulsion environment. These may include the development of the current lower Mississippi River as a slack-water estuary or the development of port infrastructure on the new lower Mississippi River.

This analysis makes several limiting assumptions, including holding alternative transportation costs (rail and truck) and domestic supply constant. It is important to note that holding transportation rates constant for other routes—such as the PNW, Great Lakes, and Atlantic regions—provides a lower bound for this analysis. The shift of product to these other routes or to other transportation modes to the Gulf will likely increase the respective transportation rates and further increase transportation costs beyond our calculations. Although domestic soybean supply was assumed to remain constant, longer-term impacts could experience a shift to alternative substitute crops, such as corn. However, given the export-dependence of the U.S. agricultural sector, those alternative commodities would likely experience the same transportation impacts as determined here. Future analyses could include the entire U.S. grains sector to better address this issue.

Relative to the $237.7 million dredging project between Baton Rouge and the Gulf of Mexico, the $716.8 million increase in the cost of transporting soybeans due to an avulsion warrants continued preventative maintenance of the lower Mississippi River. However, there are those who believe that an avulsion is an eventual certainty, regardless of human intervention (Barnett, 2017). Although continued upkeep and reinforcement of the ORCS and lower Mississippi River system is warranted, it would seem prudent for policy makers to consider options for investing in alternative transportation infrastructure. While this planning should consider options to guarantee low-cost access to the Gulf, forward-thinking leaders should also evaluate the vulnerability of the entire U.S. bulk-commodity transportation system. While an avulsion of the Mississippi River at the Old River Control Structure is certainly a possibility, it is not the only potential vulnerability either on the Mississippi River or throughout the entire U.S. transportation system. While the event considered in this analysis could certainly occur due to a natural disaster, this and other transportation infrastructure can fail for a variety of reasons, including terrorism and obsolescence. Some combination of appropriate maintenance and forward-thinking design is necessary to maintain U.S. competitiveness through an efficient transportation system. More detailed future analysis can contribute to this end.

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Consumer Perceptions of a Lamb Meat Communication Campaign: A Qualitative Study

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Abstract

This article provides early insight into the effectiveness of advertising posters designed to promote new cuts of lamb meat with a Protected Geographical Indication (PGI) and investigate consumers' perceptions of them; focus group techniques were utilized as part of the research. Lamb meat is associated with festive consumption and tradition. Regarding the advertising poster and its effectiveness, the majority of participants stated that they were unaware of the new lamb cuts and did not remember the advertising posters. Samples of the new cuts were presented to participants, and they perceived the new cuts to be innovative.

Keywords: advertising posters, consumer preferences, focus group, new lamb cuts

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Introduction

In the past decade, Spanish consumption of sheep and goat meats has declined significantly, culminating in a 40% overall drop between 2009 and 2018, with the largest decline (44%) between 2011 and 2014 (MAPA, 2019). The relative price of lamb has been noted as the main cause of the decrease in consumption (Du Plessis and Du Rand, 2012; Gracia and de Magistris, 2013) in certain market segments (Campo et al., 2008; Font-i-Furnols et al., 2011). Although the 2008 global financial crisis has been identified as the main reason for the decrease in lamb consumption, Blay (2017) suggests other possible causes, such as inappropriate cuts of lamb in the market or poor marketing communication.

Montossi et al. (2013) posit that an alternative to keep or even increase the amount of lamb consumed as a proportion of overall meat consumption is to focus on quality differentiation and to add value by offering a unique, healthy, tasty, safe, and distinguished product. Other authors indicate that differentiation can be accomplished by developing new cuts that were previously underutilized and by offering new presentation formats and packaging (Grunert et al., 2011). Vicente-Oliva, Garrido-Rubio, and Urquizu-Samper (2016) propose utilizing familiarity as a differentiation tool, since more awareness of the product reduces the search for alternatives, understanding familiarity as knowledge of the product because consumers have previously bought or experienced it.

To encourage demand for lamb and mitigate declining consumption, the Spanish sheep sector has invested in promoting lamb consumption by focusing on modernizing consumers' perceptions of lamb. To that purpose, producers have designed seven new cuts from the leg, skirt and neck as well as new preparations, such as brochette and hamburgers, to increase convenience and improve carcass use. Promotional campaigns for consumers promote these new cuts.

Measuring and quantifying the effect of marketing instruments has long been of great interest for industries. This task may become difficult since effectiveness can depend both on current and past marketing efforts as well as the co-occurrence of marketing instruments (Zenetti and Klapper, 2016). Consumers' evaluations of and preferences for advertising—and hence its effectiveness—may vary. Belenky (2001) finds that evaluating the economic effectiveness of an advertising campaign based only on revenue generated may not reflect the degree of influence on the targeted population.

The research described here is set in Zaragoza, Spain, a city in a region where lamb consumption has traditionally been higher than the national average and where promotional activities for lamb have been conducted at three levels: (i) a generic promotional campaign through an advertising spot on TV; (ii) a promotional campaign for Ternasco of Aragón's new cuts, sponsored by the Regulatory Council of Ternasco of Aragón (lambs produced under the Ternasco of Aragón PGI are young animals slaughtered at a carcass weight of 8–12.5 kg and at an age of 70–90 days), which included advertising posters; and (iii) brand promotional activities sponsored by a local sheep co-operative.

This work provides early insight into the effectiveness of advertising posters that were displayed throughout the city by the Regulatory Council of Ternasco of Aragón in collaboration with the local sheep co-operative by investigating consumers' perceptions of four of the new cuts. These advertising posters were designed by a marketing agency hired by the Regulatory Council of Ternasco of Aragón. The posters are meant to attract the attention of a younger consumer segment and modernize the image of lamb meat by making it more convenient for everyday consumption.

For the first goal of this study—providing early insight into the posters' effectiveness—it is important to consider the point in time at which advertising effects can be measured: before launching the campaign (pre-test), 24 hours after launching the campaign, and at the end of the campaign (post-test; Santesmases, 2004). In the final case, we measure the level of attention that the campaign has drawn, consumers' ability to recall the campaign (whether unaided or aided), consumers' perceptions of the message, whether the message has been understood by consumers, and the campaign's credibility (Rufín, 1998).

For our second goal—analyzing consumer perceptions of the new lamb cuts—it is important to consider that consumer acceptance has been investigated from multiple dimensions. Some research has focused on product characteristics—such as palatability, appearance, color, or flavor—while others have focused on consumer characteristics—such as attitudes, perceptions, and expectations (Meiselman, 2007; Brueckner, 2014). Furthermore, some researchers have demonstrated that consumers are open to innovations in traditional food products with different degrees of acceptance (Kühne et al., 2010; Vanhonacker et al., 2013; Pilonea et al., 2015).

Other researchers have studied innovations on the convenience dimension, an aspect that is becoming increasingly relevant when processing and marketing meat products. The convenience dimension is especially important for lamb, which is strongly associated with the way in which it is cooked and consumed: Lamb is perceived to be expensive with little versatility in cooking methods and to require time-consuming preparation (Bernués, Ripoll, and Panea, 2012).

Additionally, the familiarity factor is an important aspect affecting lamb flavor preferences and the appropriateness of lamb for specific circumstances (Font-i-Furnols and Guerrero, 2014). In particular, consumers' preferences for lamb are affected by sensory characteristics, which strongly depend on its origin (Montossi et al., 2013). For example, Font-i-Furnols et al. (2006) report that the overall acceptability of lamb is highly correlated with flavor and tenderness. Qualitative studies also demonstrate that intrinsic characteristics are important in consumers' perceptions and acceptance of lamb as a meat choice. Moreover, de Andrade et al. (2016) find that sensory characteristics, especially texture and flavor, are the most frequently mentioned dimension when consumers consider lamb.

Scozzafava et al. (2016) studied the role that different meat cuts play in consumers' purchase decisions. Their results reveal that the cut of meat is the third most important factor when choosing beef. Consumer segmentation reveals that more than half of the sample considered the

cut to be the most important driver when choosing beef and that the majority of consumers expressed a strong preference for particular cuts.

Generally, food is acceptable when its characteristics match expectations, when the product is attractive, and when consumers' physical, social, and economic circumstances are favorable (Brueckner, 2014). Therefore, it is important to understand how consumers perceive products, how their needs are shaped, and how they decide which product to purchase (van Kleef, van Trijp, and Luning, 2005).

Qualitative research methods can be applied for marketing purposes, including developing new products, evaluating whether product concepts meet consumers' needs, learning whether a product is perceived as innovative, investigating whether consumers will purchase a product, or studying brand positioning (Llopis, 2004). The focus group technique is a qualitative research method that has generally been used for exploratory purposes such as gaining insights into beliefs, attitudes, and intentions from diverse populations as well as product testing, marketing campaign testing, identifying product problems, and even recreating consumption situations. The number of groups depends on available resources. A guideline is to conduct interviews until the information reported by respondents is the same as that gathered from previous meetings. Krueger (1991) suggests that the first two groups generally provide a significant amount of new information, while the third and fourth sessions may duplicate opinions.

The present study implemented a focus group technique to recognize changes in lamb consumption habits, evaluate whether promotional campaigns attracted consumers' attention to the new cuts, and acquire a preliminary understanding of consumers' perceptions of the new cuts. As the aim of our investigation is to study consumers' knowledge levels regarding the new cuts after the promotional campaign had been conducted, we conducted the focus groups after the posters had been removed from the streets. Before conducting the focus group interviews, we hypothesized that the advertising posters would not have attracted consumers' attention and therefore that the new cuts might not be well known.

Materials and Methods

Participants

In this study, we conducted two focus groups involving a total of 16 participants at the University of Zaragoza in December 2016. The number of meetings was decided by following Andersen and Hyldig (2015). The number of participants was determined following data found in the literature and other available resources. Krueger (1991) indicates that discussion groups are generally composed of seven to ten people who do not know one another and have certain common characteristics relevant to the study's objectives. Since participants in this study were provided with a financial reward, the number of consumers in each group was limited. Each focus group consisted of eight consumers; all were lamb eaters. One group was composed of women and one of men (women's group $n = 8$; men's group $n = 8$). Participants were divided by gender to enhance integration and interaction, following research by Barcellos et al. (2010).

Participants were recruited through the Consumer and User Association of a Zaragoza neighborhood. Selection criteria were based on age (age ranges were 25–35 years of age, 35–55 years of age, and over 55 years of age, with representation for all age categories per group), and all participants were lamb eaters.

The two sessions were conducted at the library of the Agricultural and Environmental Science Department at the University of Veterinary Medicine of Zaragoza. Participants were comfortably accommodated around a table to allow interaction, visual contact, and relaxed discussion. Snacks and soft drinks were offered to create a friendly atmosphere. Each session lasted approximately 60 minutes and was videotaped and audiotaped. Participants received a financial reward of €20 at the end of the session. To facilitate the recruitment process, consumers were informed before the session that they would receive compensation for their participation, but they were not informed of the nature of the reward.

Topic Guide and Interview Procedure

During the session introduction, the moderator explained the purpose of the focus group and project goals; both anonymity and confidentiality were ensured. The moderator additionally emphasized that there were no right or wrong answers to encourage participants to express themselves.

The focus group discussions followed a protocol based on a semi-structured interview guide that facilitated conversation and ensured that all intended themes were addressed. The discussion guide was organized in two parts: First, a set of general questions queried reasons for purchasing lamb, evolution of lamb consumption, places of purchase, important aspects for buying lamb and consumption occasions (Table 1). The second part of the guided discussion consisted of specific questions about the new lamb cuts (Table 1). Participants were asked whether they were aware of the new cuts, and an explanation followed concerning the new cuts for those consumers who were unaware. Informational leaflets were distributed to show consumers images of new cuts (Figure 1).

Figure 1. Informational Leaflet Featuring New Lamb Cuts

Table 1. Discussion Guide

General questions about lamb meat
What are your reasons for lamb consumption?
Have you changed your lamb consumption frequency? Why?
Where do you usually buy lamb?
What aspects do you consider when you want to buy lamb?
On which occasions do you consume lamb meat, and how do you cook it?
Specific questions about the four new lamb cuts
Do you know the new lamb cuts?
If affirmative, where have you seen them?
If negative, explain the four new lamb cuts and supply informational leaflets.
Present the posters and ask:
Have you seen these posters around the city? (do not provide any information or explanation about them)
Then, cover or hide the posters and ask what these posters were advertising. Next, ask if it was clear that they were advertising the new lamb cuts.
Display the posters again and ask if the images attract their attention.
Provide participants with samples of the new cuts (real samples in the packaging; these cuts are commercialized).
Ask participants to say the first word or idea they associate with the new lamb cuts.
Do you think these cuts are traditional, or do you consider them innovative?
Do you think these new lamb cuts fit your needs and habits? What do you think about them?
Ask about their motives for purchasing these lamb cuts.
Do you think these cuts are convenient for everyday consumption?
Ask their opinions on each lamb cut (ask one by one about the four cuts):
What do you think about this cut? Is it attractive? Does it fit your needs? Is it convenient?
Do you have comments about the prices?
When and why would you consume this cut?
Encourage participants to make other comments.

Next, the promotional posters (Figures 2 and 3) that had been displayed throughout the city between May and June 2016 were presented to participants; they were asked whether they remembered the posters and what effect the posters had exerted on them. At this stage of the interview, participants were asked to provide their associations with lamb meat by saying the first word or image that arose in their minds when they thought of the new cuts.

The final portion of the interview investigated participants' opinions of each of the new cuts. For this purpose, the following packages of the new lamb cuts were displayed:

- Leg fillets: boneless fillets from the lamb leg, 7 mm thick (50 gr). They are designed to be grilled, breaded, or fried and quick to cook, 2 minutes per side.
- Churrasquitos: marinated pieces of bone-in lamb meat from the skirt of the lamb. They are designed to be easy to cook, for pan-searing, baking, or grilling.

Figure 2. Advertising Poster for Leg Fillet

Figure 3. Advertising Poster for Churrasquitos

- Collares: bone-in slices from the neck of the lamb, 10–12 mm thick. They are designed to be cooked in stews, grilled, or barbecued, 5–6 minutes per side.
- Tournedos: boneless medallions of leg lamb meat, designed to be easy to barbecue or grill, 5–6 minutes per side.

Each package featured a label indicating the actual supermarket price found.

Data Analysis

The analysis of the focus groups consisted of grouping similar opinions that expressed the same idea. For the first stage of the analysis, transcripts were written for both focus groups.

The second phase involved reading each transcript individually, generating initial codes and identifying provisional themes (Tan, Johnstone, and Yang, 2016). We employed open coding, a technique that consists of reading transcripts and comparing messages with the aim to group them into categories based on similarities (Hung, de Kok, and Verbeke, 2016a; Gibbs, 2012). Content analysis was performed using the NVivo software.

The main themes were identified based on the patterns of meaning in the content as outlined in the topic guide (Hung, de Kok, and Verbeke, 2016b). During the analysis, we considered that a group interaction creates a social context; participants' comments should therefore be interpreted in that context (Krueger, 1991).

Results

Consumption Habits

According to the general view of participants, the most relevant aspects for lamb consumption were organoleptic characteristics and tradition. The primary organoleptic characteristics mentioned by attendants were taste, texture, and juiciness. Furthermore, these characteristics were linked with the presence of children in the home. Although we cannot generalize due to the small size of our sample, participants who had children at home thought that these attributes were more important than people who did not prepare meals for children.

Tradition was also mentioned as important to lamb consumption, and lamb meat was associated with family celebrations, friends' meetings, or weekend meals, especially in rural areas. Participants further associated lamb consumption with restaurant dining. Younger participants declared that they did not include lamb in their daily consumption habits.

Almost all participants declared that they have decreased their lamb consumption because of the high price of lamb meat and the poor economic situation over recent years.

Another relevant aspect of lamb consumption was the place of purchase. The majority of participants stated that they purchased lamb in traditional butcher shops. In our study, participants also highlighted that they appreciate buying at butcher shops because they can see how butchers prepare their meat cuts and they can choose the cut and quantity they desire. However, younger participants declared that they usually purchase in supermarkets because it is more convenient for them. However, when they procure lamb meat for celebrations, they prefer to purchase it in traditional butcher shops.

Another aspect that emerged repeatedly during the meetings was the way participants cooked lamb. Women declared that they usually follow traditional recipes (stews, baked roasts, or breaded fillets), while men stated that they do not usually cook traditional dishes.

Table 2. Quotes from Participants regarding Lamb Consumption Habits

"I eat lamb meat because I like it a lot, because of its flavor; it has a strong taste, and I really like it."
"The reason why I eat lamb meat is tradition. At home, we have always eaten lamb meat and especially in the village and of course because it has a good taste."
"We eat lamb meat at home, because children usually eat it easier than beef."
"I buy lamb meat at the butcher's shop. The butcher already knows me. I prefer a small shop rather than going to a supermarket."
"I buy at the supermarket because it's convenient."
"In my family, we have decreased meat consumption in general but especially lamb meat."
"For cooking stews, it's better to use the neck or the breast. I frequently cook shoulder and ribs in the oven. I prefer that way of cooking lamb meat."

Factors Affecting the Purchase Process

To understand what consumers consider to be important in the lamb meat purchasing process, participants were asked about what aspects they usually ponder when they desire to acquire this meat (Table 1). The main factors participants revealed are meat cut, quality label linked to local origin, freshness appearance, meat color, size of cut, and presence of bone. Having children also influenced their purchasing decisions, since they think children prefer lamb meat due to its flavor and tenderness. Participants indicated that they are more likely to consider buying lamb meat when there are children at home.

Table 3. Quotes from Participants regarding Factors That Affect Purchase Decisions

"The cut is a very important aspect."
"It's important that it has the Aragón label."
"Important aspects for me are color and size."
"For children, the easiest cut to eat is lamb ribs. So, I look for ribs that have few bones."

Knowledge of the New Cuts and Posters' Effectiveness

When participants were asked whether they were aware of the new lamb cuts, they first answered that they were not. Then, informational leaflets (Figure 1) with images and a brief explanation of the four new cuts were provided. Upon viewing the leaflets, the majority of the men realized that they had seen some of these cuts previously, while only one woman recognized one of the cuts (tournedo). Therefore, men have a better knowledge of the new cuts than women. The majority of the men associated these cuts (especially churrasquitos and leg fillets) with "La Carpa del Ternasco de Aragón" (food and music event where the new lamb cuts were promoted) and the food trucks present during local festivities. The best-known cuts were leg fillets and churrasquitos.

The majority of participants agreed that at first sight they did not realize that the posters were advertising Ternasco de Aragón's new cuts; the packaging in the posters attracted participants' attention more than the product itself did. The poster featuring the churrasquitos image (Figure 3) attracted more attention. However, some participants expressed confusion, thinking that it could be an advertisement for chicken or French fries. The majority of participants agreed that they needed to read the text included with the picture to know that the posters were advertising Ternasco de Aragón.

Table 4. Quotes from Participants regarding Posters' Effectiveness

"The churrasquitos' poster attracts my attention because I want to know what they have in the box. It looks like chicken."
"I didn't realize they are announcing the new lamb cuts at first sight. Maybe, I can imagine it with the churrasquitos poster. . . But not at first sight."
"So, I should stop and read the poster to know what it's about, but you can't read it from far away."

Participants' Perceptions of the New Lamb Cuts

Participants mainly associated the new lamb cuts with dining at restaurants, enjoying a drink at a bar, or ordering food to take home. Thus, participants perceived the new cuts as a meat for dining out more than for dining at home. They also related the new lamb cuts to children in a positive way. Some participants compared tournedos to beef entrecôte, and churrasquitos were compared to pork ribs. Attendants recognized that these cuts lend a modern image to Ternasco de Aragón. For instance, churrasquitos were associated with the influence of American food and tournedos were associated with exclusivity.

Finally, some participants—primarily women—stated that these new presentations could allow them to change the way they cooked lamb.

Specific Perceptions of Each New Lamb Cut

Leg Fillets

The leg fillet was highly reported to be an appealing cut, especially for children, and was perceived to be simple to cook. However, the price was considered high in comparison to other types of meat. This cut was familiar to participants and similar to their usual fare. The leg fillet is the only new cut that is similar to a traditional cut already consumed in this region; the novelty lies in the way it can be cooked—it is faster, easier, healthier, and cheaper than the traditional method. Participants were also presented with a vacuum-packaged leg fillet to investigate whether they had any preference between the two presentations. Their opinions regarding vacuum packaging were negative; they said that they could not see the meat cut properly because the vacuum effect on the packaging causes the visibility of the meat cut and the number of fillets to be poor. Participants preferred packaging in trays rather than vacuum packaging for leg fillets.

Churrasquitos

Many participants stated that churrasquitos had an attractive appearance and thought that children might enjoy them. They were considered to be quick to cook and were frequently associated with meals on weekends and at barbecues. This cut was designed to be more convenient for everyday consumption.

Collares

According to the general view of participants, collares did not have a pleasant appearance. However, a few participants stated that they like this way of presenting lamb neck since they like the taste of neck and cooked with it.

Tournedos

Participants considered this cut to be attractive, and they mentioned that they were surprised to find tournedos significantly appealing. Participants also commented that it seemed simple to cook and remarked that it was for eating on special occasions due to its high price.

Table 5. Quotes from Participants regarding Their Perceptions of the New Ternasco Cuts

"I think of going out for a drink and tapas."
"The one that I liked the most was leg fillet. I would buy it because it's similar to what I usually take for lunch."
"The leg fillet would be more appropriate for kids, but not for me."
"Vacuum-packaged leg fillets look like a block; you can't distinguish the cut."
"Churrasquitos look modern."
"I think it is a product that young people and children would like. It's not like stews; it is something that you can take away as it shown on the advertising poster."
"Tournedo reminds me of a small entrecôte. It has surprised me."
"I would buy Tournedo for a special occasion."

Discussion

The first specific objective of this work was to investigate consumption habits related to lamb meat. According to participants in this study, the main reasons that they purchase this meat are because of its organoleptic characteristics and tradition, particularly those traditions associated with family and friends' celebrations. In agreement with our results, the research conducted in Brazil by de Andrade et al. (2016) also reveals that the words most frequently associated with lamb meat are related to consumption occasions (barbecue), followed by words related to sensory characteristics of the meat, such as *tasty, flavor, tenderness*, and *soft*. The majority of participants in our study (consumers in Zaragoza) declared that they have decreased their lamb consumption, a result that is in line with Fortuny's (2017) finding: Spanish consumption in 2008 was 2.69 kg/person, and it decreased to 1.68 kg/person in 2015, reaching as high as a 50% drop between 2011 and 2014.

Another relevant aspect related to consumption habits is the place of purchase. The majority of participants stated that they purchased lamb in traditional butcher shops. These results correspond with previous research conducted in Aragón (Feliciano, Camarena, and Albisu, 2003; Gracia, 2005; Sepúlveda, Maza, and Mantecón, 2010; Bernués, Ripoll, and Panea, 2012), which finds that more than half of the sample procured lamb at a traditional butcher. Participants explained that the most important reason that they prefer traditional butcher shops is personal attention. The relationship between butcher and consumers allows consumers to feel more confident in the product they are purchasing. McCarthy and Henson (2005) also suggest that confidence in the butcher was employed by many respondents to reduce the level of perceived risk when they purchased Irish beef. However, statistics from the Ministry of Agriculture, Fisheries and Food (MAPAMA, 2017) on the database of household consumption indicate that purchase establishments have changed in the past three years. The percentage of lamb purchased

at butcher shops and marketplaces has decreased, while the percentage of lamb purchased at supermarkets has increased. In 2014, 58.48% of lamb was purchased at butcher shops and marketplaces,[1] and 41.52% was purchased at supermarkets.[2] In 2016, 49.87% of lamb was purchased at butcher shops and marketplaces,[3] and 50.13% was purchased at supermarkets.[4]

Other factors affecting the purchase process according to participants were meat cut, quality label linked to local origin, and appearance. These results confirm those by Scozzafava et al. (2016), who analyze consumers' preferences for beef cuts and demonstrate that meat cut is the most important factor when consumers choose beef, followed by quality certification (origin). Gracia and de Magistris (2013) further find that the most important attribute preferred by the majority of consumers is the local origin of production. Furthermore, Bernués, Ripoll, and Panea (2012) find that respondents consider that the most important intrinsic quality of lamb meat to be the appearance of freshness.

The second specific objective of this study was to investigate whether consumers in the focus groups remembered the advertising posters and whether the posters were effective. The majority of participants stated that they were unaware of the new lamb cuts and did not remember the advertising posters. Furthermore, participants agreed that at first sight they did not realize that posters were advertising two of the new cuts. They stated that the churrasquitos poster attracted more attention due to the packaging containing the product. Some researchers have studied how people observe advertisements; Rayners, Miller, and Rotello (2008) demonstrate that the viewers' goals influence how they study the picture and the text. Consequently, viewers examine the portion of the advertisement that provides them with more information for their goals. They scan the picture as they evaluate the extent to which they like the advertisement, or they read the text when they consider purchasing the product.

The final objective of this work was to investigate consumers' perceptions of the new lamb cuts. Participants were presented with samples of four of the new cuts. Generally, participants said that all the cuts were appealing; however, some participants declared that the leg fillet was not new to them since they have traditionally ordered it in butcher shops. Some participants stated that they perceived the new cuts to be highly innovative and appropriate for restaurants, although the price was considered high.

During the group discussions, expectations emerged as an important factor in purchasing the product, and participants with higher expectations were more willing to pay for the more expensive cuts. Furthermore, their previous knowledge and experiences also influence their decisions. For example, some participants considered that thin fillets (leg fillets) could become

[1] This figure was calculated by totaling the butcher shop data category and the marketplace data category over the period from January 2014 to December 2014.
[2] This figure was taken from the supermarkets/shelf-service stores/shopping galleries data category over the period from January 2014 to December 2014.
[3] This figure was calculated by totaling the butcher shop data category and the marketplace data category over the period from January 2016 to December 2016.
[4] This figure was taken from the supermarkets/shelf-service stores/shopping galleries data category over the period from January 2016 to December 2016.

dry after cooking, while thick fillets (tournedos) could be undercooked; these preconceived ideas can negatively affect the purchase intention. These reactions demonstrate the importance of desires and previous expectations, as demonstrated by Andersen and Hyldig (2015), who reveal that expectations and desires are created by associations to previous food experiences. Researchers investigating beef consumers' choices reached similar conclusions: Consumers in this study were more concerned with wasting money (because the meat did not perform as expected) than they were with safety issues (McCarthy and Henson, 2005).

This study provides insight into how consumers perceive the new lamb cuts and the main reasons that they choose lamb over other meats. Furthermore, by using focus group techniques, we have demonstrated that the advertising posters have not attracted sufficient attention from consumers; clearer messages and images that focus on the product itself may facilitate the target populations' understanding of information regarding the new lamb cuts.

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Economic and Sociodemographic Drivers Associated with the Decision to Purchase Food Items and Nonalcoholic Beverages from Vending Machines in the United States

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Abstract

Using data extracted from BLS Consumer Expenditure Surveys between 2009 and 2012, we estimated a probit model concerning the decision made by household heads whether to purchase food items and nonalcoholic beverages from vending machines over a consecutive 2-week period. Key drivers associated with this decision are household income; urbanization; marital status; region; year; age; education level; hours worked; ethnicity; and expenditures made on potato chips and other snacks, candy and chewing gum, food away from home (excluding those made at vending machines), cola drinks, and tobacco products.

Keywords: BLS Consumer Expenditures Surveys, economic and sociodemographic factors, probit analysis, vending machines

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Introduction

The U.S. vending machine operators industry consists primarily of candy, food and snack, and hot and cold beverage sales, with a total projected revenue $7.7 billion in 2019. Revenue from 2009 to 2018 ranged between $7.9 billion and $8.9 billion (Figure 1), declining by 12.7% over the period. Total revenues are expected to decline by a further 2.5% in 2019 relative to 2018 (Zheng, 2019).

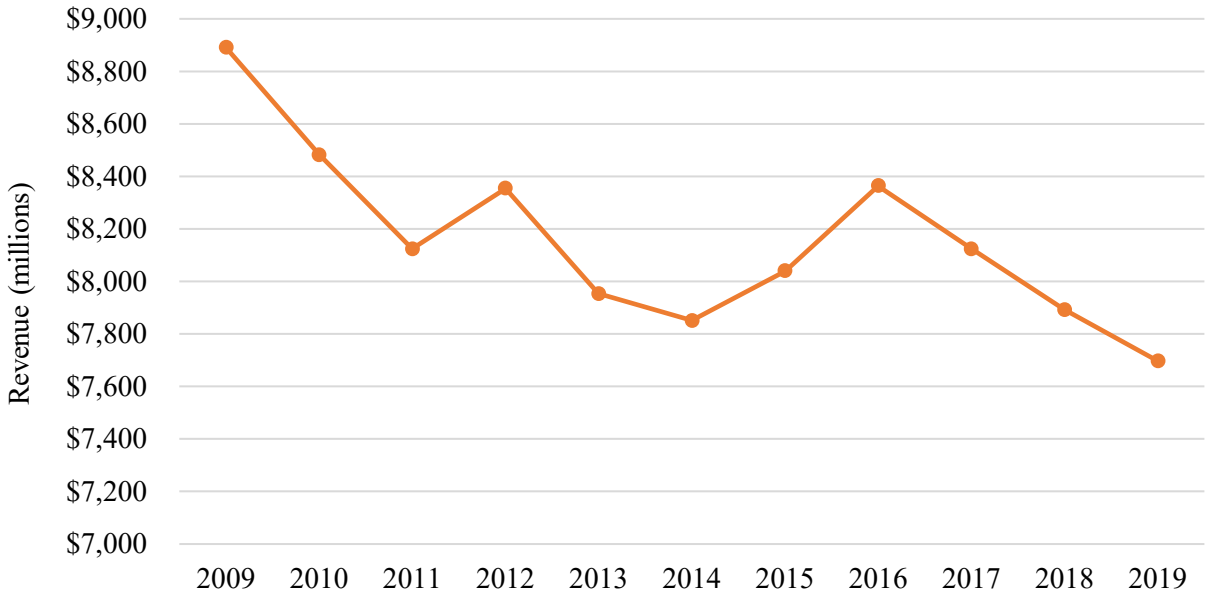

Figure 1. Revenue for U.S. Vending Machine Operators Industry, 2009–2019
Source: Zheng (2019).

The vending machine operators industry (NAICS code 454210) ranks 53rd in the retail trade industry by market size (in terms of revenue) and is the 567th largest industry in the United States (Zheng, 2019). Major U.S. companies include American Food and Vending, AVI Food Systems, and divisions of ARAMARK and Coca-Cola (Dun and Bradstreet, 2020). Among roughly 4.6 million vending machines currently in the United States, close to 60% of vending machine sales are for cold drinks, including soft drinks, juices, and other sugary options. Junk foods, such as soda and chips, typically make up the largest amount of industry revenue, but sales of healthy snacks and beverages are on the rise (Gaille, 2017).

Objectives

The ability to ascertain historical, current, and future patterns of food and beverage consumption is of extreme importance, yet our knowledge of the vending machine operators industry is meager at best. To fill this research void, this study develops a profile of vending machines users. We consider only purchases of food and nonalcoholic beverages made at vending machines.

We use 2009–2012 data from the Bureau of Labor Statistics (BLS) Consumer Expenditure Survey (CES) and a probit regression to accomplish the primary objective of this study.[1] In the probit specification, the dependent variable corresponds to a household's decision to purchase or not to purchase food items and nonalcoholic beverages from vending machines over a consecutive two-week period. The respective model centers attention on economic and sociodemographic factors as explanatory variables, including age, race, education level, income level, household size, employment status, ethnicity, gender, marital status, and region. From this analysis, public health officials, government policy makers, and industry stakeholders will have a better understanding of the factors associated with purchases of food items and nonalcoholic beverages from vending machines, which is presently lacking in the extant literature.

Previous Research

Much of the extant economic literature has centered attention on predominantly three topics: (i) the effect of price and promotion strategies on vending machine purchases; (ii) the nutritional content of foods in vending machines; and (iii) the availability of vending machines in public and private schools (Gvillo, 2014).

French et al. (1997), French et al. (2001), and Hua et al. (2017) investigated the effect of price and promotion strategies on purchases of low-fat snacks from vending machines. Reducing relative prices was effective in promoting lower-fat food choices, and vending machines provided a feasible way of implementing such nutrition interventions. When healthier vending snacks were available, promotional signs also were important to ensure purchases of those items in greater amounts.

Kubik et al. (2003) examined the association between dietary behaviors of young adolescents and purchases made at vending machines. Snacks procured from vending machines were negatively correlated with fruit consumption. Weicha et al. (2006) found that school vending machine use and fast food restaurant visits were associated with overall sugar-sweetened beverage intake. Additionally, French et al. (2003); Lytle et al. (2006); Finkelstein, Hill, and Whitaker (2008); and Pasch et al. (2011) noted that food items and beverages offered in vending machines at schools were high in fat and calories. Further, Cisse-Egbuonye et al. (2016) found that the food items most commonly available in vending machines were predominately foods of minimal nutritional value. Although few school food policies were reported that helped foster healthy food choices among students, Evans et al. (2005) found public support for restricting the availability of unhealthy foods in vending machines.

National data from the 2006 School Health Policies and Programs Study (SHPPS) revealed that 62.4% of middle schools and 85.8% of high schools had at least one vending machine available to students (O'Toole et al., 2007). Park et al. (2010) examined the prevalence of students buying snacks or beverages from school vending machines instead of buying school lunch. Based on data from the 2000 SHPPS, Wechsler et al. (2001) found that nearly all senior high schools, most

[1] These data were the most recent information available to us from the BLS at the time of this analysis. As such, this analysis serves as a benchmark for future analyses concerning vending machine purchases.

middle and junior high schools, and more than one-quarter of elementary schools had access to foods and beverages from vending machines.

To date, the extant literature has focused almost exclusively on vending machine product purchases and the potential health concerns related to such purchases. Unlike previous studies, we focus on the factors affecting the decision to purchase food and nonalcoholic beverages at vending machines. As such, we provide a unique contribution to the economic literature.

Model Development

Binary Choice Probit Model

Models of discrete choice such as probit and logit could be used to examine the factors influencing the decision to purchase food items and nonalcoholic beverages from vending machines. The use of the probit/logit analysis, particularly of binary choices, is well established in the economic literature (Maddala, 1983; McFadden, 1984; Pindyck and Rubinfeld, 1998). Capps and Kramer (1985) demonstrated that the probit and logit models yield similar results in the case of binary choice models. Additionally, since the logistic density function closely resembles the *t*-distribution with seven degrees of freedom (Hanushek and Jackson, 1977), the logit and probit formulations are quite similar. The only difference is that the logistic density has a slightly heavier tail than the standard normal density. In this study, we used a probit regression model.

The use of probit models is commonplace in economic analyses of the food industry (Byrne, Capps, and Saha, 1996; Alviola and Capps, 2010; Capps, Ahad, and Murano, 2017). The probit regression model in this analysis is a binary choice model, where the dependent variable takes on two values—0 for no vending expenditures made and 1 for positive vending expenditure made by reference person *i*. The reference person in the household is the household head who completed the survey. Mathematically, the probit model takes the following form:

$$y_i = \boldsymbol{x}_i'\boldsymbol{\beta} + e_i, \tag{1}$$

where $\boldsymbol{y_i} = \mathbf{1}$ if any vending machine purchase was made by reference person *i,* $\boldsymbol{y_i} = \mathbf{0}$ if no vending machine purchase was made by reference person *i,* $\boldsymbol{x_i'}$ is a column vector of explanatory variables, $\boldsymbol{\beta}$ is a vector of parameters associated with the explanatory variables, e_i is the random error, and

$$\Pr\left(y_i = 1 \mid \boldsymbol{x_i'}\right) = \Phi\left(\boldsymbol{x_i'}\boldsymbol{\beta}\right), \tag{2}$$

where Φ is the cumulative distribution function (CDF) of the standard normal distribution. Operationally, the decision to purchase food and nonalcoholic beverages at vending machines is denoted by

$$
\begin{aligned}
(3) \quad Vend\_Mach\_Purchase_i = {} & \beta_0 + \beta_1 Age_i + \beta_2 Fam\_size_i + \beta_3 Fincaftx_i + \beta_4 HHhours_i \\
& + \beta_5 Male_i + \beta_6 Asian_i + \beta_7 Black_i + \beta_8 White_i + \beta_9 Hispanic_i \\
& + \beta_{10} College_i + \beta_{11} Northeast_i + \beta_{12} Midwest_i + \beta_{13} South_i \\
& + \beta_{14} Married_i + \beta_{15} Urban_i + \beta_{16} Tobacco_i \\
& + \beta_{17} Frsh\_Fruit\_Veg_i + \beta_{18} Candy_i + \beta_{19} Potato\_Chips_i \\
& + \beta_{20} Cola\_Drinks_i + \beta_{21} FAFH_i + \beta_{22} Nuts_i + \beta_{23} Jan_i + \beta_{24} Feb_i \\
& + \beta_{25} Mar_i + \beta_{26} Apr_i + \beta_{27} May_i + \beta_{28} Jun_i + \beta_{29} Jul_i + \beta_{30} Aug_i \\
& + \beta_{31} Sep_i + \beta_{32} Oct_i + \beta_{33} Nov_i + \beta_{34} Year\_2009_i \\
& + \beta_{35} Year\_2010_i + \beta_{36} Year\_2011_i + e_i .
\end{aligned}
$$

Table 1 defines the dependent variable and the explanatory variables in the probit specification. Previous research generally depicts snack food and beverage items from vending machines as unhealthy (French et al., 2003; Evans et al., 2005; Lytle et al., 2006; Finkelstein, Hill, and Whitaker, 2008; Pasch et al., 2011; Cisse-Egbuonye et al., 2016). As such, we hypothesize that expenditures on tobacco products, candy, potato chips, and cola drinks—which are generally considered unhealthy foods (Chaloupka and Warner, 2000; Drewnowski, 2003; Dharmasena and Capps, 2011)—are positively related to the decision to purchase from vending machines. In contrast, expenditures on fresh fruits, vegetables, and nuts—typically regarded as healthy items (Drewnowski and Darmon, 2005; Jones, 2010)—are hypothesized to be negatively related to purchases made from vending machines.

Park et al. (2010) found that age, race, and Hispanic ethnicity were key factors of students buying snacks or vegetables from school vending machines. Therefore, we hypothesize that younger household heads and households of Hispanic ethnicity are more likely to purchase food and nonalcoholic beverages at vending machines. We also expect race to influence the decision to purchase from vending machines. Further, because education level often is positively associated with health consciousness (Alviola and Capps, 2010), we hypothesize that this sociodemographic factor is inversely related to the decision to purchase from vending machines. We hypothesize that the number of hours worked and expenditures on food away from home are positively related to the decision to purchase from vending machines in accordance with the opportunity cost of time (Byrne, Capps, and Saha, 1996). Hill and Lynchehaun (2002) and Dharmasena and Capps (2014) identified various cultural and socio-economic factors—including age, ethnicity, income, education, gender, presence of children, marital status, region, and race—influencing consumer preferences. Hence, we hypothesize that household income, household size, gender, marital status, and region are also determinants of the decision to purchase food and nonalcoholic beverages from vending machines. Finally, given the coverage of the data over 2009–2012, we capture seasonal trends through the use of monthly dummy variables and year-to-year trends through the use of

Table 1. Description and Descriptive Statistics of the Dependent Variable and Explanatory Variables included the Probit Regression

Variable	Definition	Mean
Age	Age of the reference person in the household (the household head who completed the survey)	50
Asian	= 1 if the race of the reference person is Asian; 0 otherwise	0.0429
Black	= 1 if the race of the reference person is Black; 0 otherwise	0.1178
Candy	Consecutive 2-week expenditure on candy and chewing gum	$3.13
Potato_Chips	Consecutive 2-week expenditure on potato chips and other snacks	$4.28
Cola_Drinks	Consecutive 2-week expenditure on cola drinks	$3.15
College	= 1 if the reference person has recorded at least some college education; 0 otherwise	0.6291
Fam_size	Number of members in the consumer unit (CU)	2.52
Fincaftx	Amount of CU income after taxes in past 12 months	$60,064
FAFH	Consecutive 2-week expenditure on food away from home, excluding monies spent at a vending machine	$91.15
Female	1 if the reference person is female; 0 otherwise (reference/base category)	0.5394
Frsh_Fruit_Veg	Consecutive 2-week expenditure on fresh fruits and fresh vegetables	$18.68
HHhours	Total number of hours usually worked per week by the reference person and spouse	41
Hispanic	= 1 if the reference person is Hispanic; 0 otherwise	0.1279
Male	= 1 if the reference person is male; 0 otherwise	0.4606
Married	= 1 if the reference person is married; 0 otherwise	0.5213
Midwest	= 1 if the CU resides in the Midwest; 0 otherwise	0.2399
Month_i	= 1 for recorded month *i* of CU vending machine expenditure; 0	
Jan	otherwise	0.0893
Feb		0.0789
Mar		0.0866
Apr		0.0914
May		0.0886
Jun		0.0910
Jul		0.0804
Aug		0.0818
Sep		0.0840
Oct		0.0860
Nov		0.0801
Dec	(reference/base category)	0.0619
No College	= 1 if the reference person has recorded no college education; 0 otherwise (reference/base category)	0.3709
Non-Hispanic	= 1 if the reference person is non-Hispanic; 0 otherwise (reference/base category)	0.8721

Variable	Definition	Mean
Non-Married	= 1 if the reference person is not married; 0 otherwise (reference/base category)	0.4787
Northeast	= 1 if the CU resides in the Northeast; 0 otherwise	0.1927
Nuts	Consecutive 2-week expenditure for nuts	$1.53
Other Races	= 1 if the race of the reference person is not white, Black, or Asian; 0 otherwise (reference/base category)	0.0194
Rural	= 1 if the CU resides in a rural area, 0 otherwise (reference/base category)	0.0535
South	= 1 if the CU resides in the South; 0 otherwise	0.3520
Tobacco	Consecutive 2-week expenditure on tobacco products	$9.46
Urban	= 1 if the CU resides in an urban area; 0 otherwise	0.9465
Vend_Mach_Purchase	= 1 if a food item or nonalcoholic beverage is purchased; 0 otherwise (dependent variable in the probit model)	0.2040
West	= 1 if the CU resides in the West; 0 otherwise (reference/base category)	0.2154
White	= 1 if the reference person is white; 0 otherwise	0.8199
$Year_i$	= 1 for recorded year *i* of CU vending machine expenditure; 0	
Year_2009	otherwise	0.2502
Year_2010		0.2533
Year_2011		0.2448
Year_2012	(reference/base category)	0.2517

Source: Calculations by the authors using EVIEWS v. 11 (IHS Global, Inc., 2020).

yearly dummy variables. We hypothesize that seasonal differences and year-to-year differences are evident in the decision to purchase food and nonalcoholic beverages from vending machines.

Data

The source of data for this analysis is the Consumer Expenditure Survey (CES), available from the Bureau of Labor Statistics (BLS). This survey includes two separate surveys—the Interview Survey and the Diary Survey. While both surveys provide information on American consumers' buying habits, the Diary Survey is of interest for this analysis.

The Diary Survey comprises several data files; for this study, we use the expenditure and family files. The expenditure files consist of a "diary" of expenditures in which the respondent records information for two consecutive 1-week periods. The family files contain demographic information and characteristics of the respondents, typically referred to as consumer units (CUs). The BLS defines a CU as comprising either (i) all members of a particular household who are related by blood, marriage, adoption, or other legal arrangements; (ii) a person living alone or sharing a household with others or living as a roomer in a private home or lodging house or in permanent living quarters in a hotel or motel, but who is financially independent; or (iii) two or more persons living together who use their income to make joint expenditure decisions. In essence, the term CU is synonymous with the term household.

For each household, there are two weekly observation periods. In this study, we merge the respective expenditures for the two consecutive 1-week periods for each household. The time period corresponds to 2009–2012, the most recent data available to us at the time of this analysis. Nonetheless, the most recent CES data are for 2018 (U.S. Bureau of Labor Statistics, 2020). As such, this analysis provides a baseline or benchmark study concerning vending machine expenditures made by U.S. households that could help as a reference for future studies using more recent data.

The expenditure files do not contain quantity or price information, only information on household expenditures over two consecutive weeks. Several vending machine expenditures are recorded in the Diary Survey, including breakfast, lunch, dinner, and snacks purchased from vending machines as well as tobacco or alcohol purchased from vending machines. Here, we focus exclusively on food and nonalcoholic beverage purchases at vending machines.

The dataset used in this study consists of 23,333 observations compiling 4 years of data from 2009 to 2012. Each observation corresponds to a unique household identification number. Thus, the dataset is equivalent to a cross-sectional representation of U.S. households across the 4-year period from 2009 to 2012. Prior to data cleaning, the original sample size was 27,225 observations. We dropped households with insufficient information and removed outliers associated with income and various food expenditures.[2]

In Table 1, we summarize the descriptive statistics (mean values only) for the sample of households included in our analysis. About 20% of the sample, or 4,670 of the 23,333 households in the sample, had nonzero (positive) vending expenditures associated with food items and nonalcoholic beverages over a 2-week period. Across all households, the average amount spent over two consecutive weeks at vending machines for food and nonalcoholic beverages was $1.39. For those households that made vending machine purchases, the average amount spent over a two-week period was $6.82.

The average age of the respondent (*Age*) in the sample was 50. Household size (*Fam_size*) was about 2.5, and the average income (*Fincaftx*) was roughly $60,000. Household hours worked (*HHhours*) combined for all members was, on average, 41. About 63% of the sample had at least some college education (*College*), slightly more than 46% of the sample were male, nearly 95% were in urban areas, about 52% were married, and nearly 13% were of Hispanic ethnicity. Further, roughly 82% of the sample were white, nearly 12% were Black, and about 4% were Asian. About 19% of the sample were located in the Northeast, 24% were located in the Midwest, 35% were located in the South, and almost 22% were located in the West.

On average, consecutive two-week expenditures on food-away-from-home, excluding vending machine expenditures, amounted to $91.15. Consecutive two-week average expenditures over the 2009–2012 period for nuts, potato chips and other snacks, candy and chewing gum, cola drinks,

[2] Households were dropped from the dataset if income or expenditures exceeded the mean value ± 3 times the corresponding standard deviation.

fresh fruits and vegetables, and tobacco products were $1.53, $4.28, $3.13, $3.15, $18.68, and $9.46, respectively.

Our sample of households is representative of the U.S. population during the 2009–2012 period. To support this contention, we compare the sociodemographic characteristics of our sample with population statistics provided by the U.S. Census Bureau for 2010 (U.S. Census Bureau, 2012, 2020; DeNavas-Walt, Proctor, and Smith, 2011). According to the 2010 Census, average household income was $58,500, slightly below the average income of our sample (see Table 2); household size was 2.34, in line with our average household size of 2.52. Further, similar percentages of race, region, age, gender, ethnicity, and marital status are evident. However, our sample had a much lower percentage of households in rural areas and a much higher percentage of households in urban areas compared to the 2010 Census. Finally, in our sample, the percentage of households whose heads received at least some college education was 63%, compared to 55% from the 2010 Census. Aside from population density and education of the household head, our sample of households matches up well to the U.S. population as represented by the 2010 Census.

Table 2. Representativeness of the Sample to the US Population According to the 2010 U.S. Census

Sociodemographic Characteristic	2010 U.S. Census	Sample
White (%)	80.17	81.99
Black (%)	13.34	11.78
Asian (%)	5.02	4.29
Other (%)	1.46	1.94
Household size	2.34	2.52
Age > 25	47	50
Northeast (%)	17.92	19.27
Midwest (%)	21.68	23.99
South (%)	37.10	35.2
West (%)	23.30	21.54
Household income	$58,500	$60,064
Female (%)	50.87	53.94
Male (%)	49.13	46.06
Hispanic (%)	16.27	12.79
Not Hispanic (%)	83.73	87.21
Married (%)	56.58	52.13
Not married (%)	43.42	47.87
Rural (%)	19.27	5.35
Urban (%)	80.73	94.65
At least some college education (%)	55.24	62.91
No college education (%)	44.76	37.09

Sources: DeNavas-Walt, Proctor, and Smith (2011), U.S. Census Bureau (2012, 2020).

Specification Tests

A concern in this analysis is that that the explanatory variables in the probit specification associated with expenditures on food away from home, nuts, potato chips and other snacks, candy and chewing gum, cola drinks, fresh fruits and vegetables, and tobacco products may be endogenous. If so, then the estimated coefficients are inconsistent (Greene, 2012). Using the Durbin–Wu–Hausman test (Guo et al., 2018), we reject the null hypothesis that the respective expenditure variables in the set of explanatory variables are exogenous.

Hence, to mitigate the endogeneity issue associated with each of these right-side expenditure variables, we employ a two-stage Tobit procedure, which we choose to deal with the issue of the censored response of the right-side expenditure variables. We incorporate instrument variables to circumvent the endogeneity issue (Sargan, 1958; Davidson and MacKinnon, 1993). In the first stage, each of the expenditure categories are expressed as a function of the sociodemographic variables (the instrument variables): hours worked, region, urbanization, race, Hispanic, education level, gender, and marital status as well as income, income squared, family size, family size squared, the interaction of income and family size, and monthly dummy variables. From this first-stage estimation process, we subsequently obtain predicted values of unconditional expenditures by way of calculating $Ey = G'\gamma F(z) + \sigma f(z)$, where $z = G'\gamma/\sigma$, $f(z)$ is the normal density function with standard deviation σ, and $F(z)$ is the cumulative normal distribution function (McDonald and Moffitt, 1980); G corresponds to the column vector of the aforementioned instrument variables, and γ represents the vector of parameters associated with the set of instrument variables. In turn, these predicted values (Ey) were used as the explanatory variables for expenditures related to nuts, fresh fruits and vegetables, tobacco products, candy and chewing gum, cola drinks, potato chips, and food away from home in the probit regression.[3]

We used variance inflation factors, condition indices, and variance proportions to examine potential collinearity issues in the probit model (Belsley, Kuh, and Welsch, 1980). No degrading collinearity issues were evident from this examination.

Results

Upon mitigating the endogeneity issues previously discussed, the estimation of the probit model was done using a maximum likelihood procedure from the software package EVIEWS v. 11 (IHS Global, Inc., 2020). Table 3 reports the parameter estimates, standard errors, and associated *p*-values of the respective explanatory variables in the probit model. The goodness-of-fit statistic, McFadden's R^2, is 0.0670. We tested the overall significance of the probit regression model using a likelihood ratio test. Specifically, we tested the null hypothesis that all estimated coefficients, except the intercept coefficient, are jointly equal to 0. The *p*-value associated with the likelihood ratio test (Table 3) suggests the null hypothesis is rejected and, therefore, at least one of the estimated coefficients is statistically different from 0.

[3] To conform to space limitations, details associated with the first-stage Tobit equations are available from the authors upon request.

Table 3. Parameter Estimates, Standard Errors, and *p*-Values Associated with the Estimation of the Binary Probit Regression

Variable	Coefficient	Std. Error	*z*-Statistic	*p*-Value
C	-0.8538	0.1023	-8.34	**0.0000**
Fincaftx	-5.30E-07	1.78E-07	-2.97	**0.0029**
White	-0.0025	0.0688	-0.04	0.9707
Black	0.0426	0.0743	0.57	0.5665
Asian	-0.0427	0.0828	-0.52	0.6063
Urban	-0.0941	0.0431	-2.18	**0.0291**
Married	-0.0653	0.0259	-2.52	**0.0117**
Northeast	0.0221	0.0312	0.71	0.4800
Midwest	0.1705	0.0294	5.81	**0.0000**
South	0.0643	0.0277	2.33	**0.0200**
Jan	-0.0565	0.0515	-1.10	0.2732
Feb	-0.0192	0.0524	-0.37	0.7133
Mar	0.0316	0.0508	0.62	0.5345
Apr	0.0094	0.0505	0.19	0.8519
May	0.0647	0.0504	1.28	0.1999
Jun	0.0462	0.0503	0.92	0.3582
Jul	0.0550	0.0516	1.07	0.2868
Aug	0.0232	0.0517	0.45	0.6544
Sep	0.0877	0.0510	1.72	0.0853
Oct	0.0227	0.0510	0.45	0.6557
Nov	-0.0136	0.0521	-0.26	0.7933
Year_2009	0.0988	0.0272	3.64	**0.0003**
Year_2010	0.0212	0.0274	0.78	0.4382
Year_2011	-0.0285	0.0277	-1.03	0.3028
Age	-0.0089	0.0007	-12.66	**0.0000**
Fam_size	0.0080	0.0080	1.00	0.3170
College	0.0493	0.0220	2.23	**0.0254**
Male	-0.0113	0.0197	-0.57	0.5665
HHhours	0.0037	0.0004	8.73	**0.0000**
Hispanic	0.0719	0.0312	2.30	**0.0212**
Nuts	-0.0026	0.0025	-1.06	0.2883
Potato_Chips	0.0062	0.0015	4.22	**0.0000**
Candy	0.0028	0.0014	1.94	**0.0519**
FAFH	0.0018	8.20E-05	21.70	**0.0000**
Cola_Drinks	0.0114	0.0016	6.97	**0.0000**
Frsh_Fruit_Veg	-0.0003	0.0005	-0.52	0.6060
Tobacco	0.0023	0.0003	7.80	**0.0000**
McFadden R^2	0.0670			
LR statistic	1,582			
Prob(LR statistic)	0.0000			
Observations with Dep = 0	18,573	Total observations	23,333	
Observations with Dep = 1	4,760			

Notes: Bold *p*-values indicate statistical significance at the 0.05 level.

The level of statistical significance chosen for this analysis is 0.05. All estimated coefficients statistically different from 0 are in bold. The key drivers associated with the decision to purchase food items and nonalcoholic beverages from vending machines are: (i) income; (ii) urbanization; (iii) marital status; (iv) region; (v) year; (vi) age; (vii) education level; (viii) hours worked; (ix) ethnicity; and (x) expenditures made on potato chips and other snacks, candy and chewing gum, food away from home excluding those made at vending machines, cola drinks, and tobacco products.

Households with lower incomes and in rural areas with individuals who are not married are more likely to purchase food and nonalcoholic beverages at vending machines than households with higher incomes and in urban areas with married individuals. Household heads who are Hispanic and college-educated and households in the Midwest and the South also are more likely to purchase food and nonalcoholic beverages at vending machines than household heads who are not Hispanic and not college-educated and households in the West. Moreover, households with younger heads who work more hours are more likely to purchase food and nonalcoholic beverages at vending machines than households with older heads who work fewer hours. As hypothesized, households that expend more on potato chips and other snacks, candy and chewing gum, food away from home, cola drinks, and tobacco products are more likely to purchase food and nonalcoholic beverages at vending machines.

No differences across months are evident in the likelihood of purchasing food and nonalcoholic beverages. Relative to 2012, the likelihood of purchasing at vending machines was statistically the same in 2010 and 2011. However, the likelihood of purchasing at vending machines was higher in 2009 relative to 2012.

Marginal effects, exhibited in Table 4, provide insight as to how changes in the right-side variables affect the probability of purchasing from a vending machine. To calculate the marginal effect for any explanatory variable, the estimated coefficient associated with that variable is multiplied by the standard normal density function, $f(\boldsymbol{x}_i'\boldsymbol{\beta})$. Because the marginal effects vary from observation to observation, they are calculated at the sample means for each of the explanatory variables in the probit model. We highlight the marginal effects for the statistically significant sociodemographic binary variables as well as for the continuous variables associated with the decision to purchase food and nonalcoholic beverages at vending machines.

As the household head ages each year, the probability of purchasing food and nonalcoholic beverages at vending machines is lower by about 0.2%. For college-educated household heads, the probability of purchasing at vending machines is higher by 1.3% relative to noncollege educated individuals. For household heads of Hispanic ethnicity, the probability of purchasing at vending machines is higher by 1.9% relative to individuals of non-Hispanic ethnicity. For households with married individuals, the probability of purchasing at vending machines is lower by 1.8% relative to households without married individuals. Households in urban areas are 2.5% less likely to purchase food items and nonalcoholic beverages at vending machines than those in nonurban areas. CUs in the Midwest are 4.6% more likely to make purchases at vending machines than those in the West. Similarly, households in the South are 1.7% more likely to make purchases at vending machines than those in the West. The likelihood of purchasing at vending machines was higher in 2009 by 2.7% relative to 2012.

Table 4. Marginal Effects and Elasticities Associated with the Probit Regression Estimates

Variable	Marginal Effects	Elasticities
Age	**-0.0024**	
White	-0.0007	
Black	0.0115	
Asian	-0.0115	
College	**0.0133**	
Fam_size	0.0022	
Hispanic	**0.0194**	
Male	-0.0030	
Married	**-0.0176**	
Midwest	**0.0460**	
Northeast	0.0060	
South	**0.0174**	
Jan	-0.0152	
Feb	-0.0052	
Mar	0.0085	
Apr	0.0025	
May	0.0174	
Jun	0.0125	
Jul	0.0148	
Aug	0.0062	
Sep	0.0237	
Oct	0.0061	
Nov	-0.0037	
Urban	**-0.0254**	
Year_2009	**0.0267**	
Year_2010	0.0057	
Year_2011	-0.0077	
Candy	**0.000752**	**0.0125**
Potato_Chips	**0.001669**	**0.0380**
Cola_Drinks	**0.003084**	**0.0516**
Fincaftx	**-0.000000143**	**-0.0456**
FAFH	**0.000480**	**0.2324**
Frsh_Fruit_Veg	-0.000069	-0.0068
Nuts	-0.000712	-0.0058
HHhours	**0.000996**	**0.2166**
Tobacco	**0.000618**	**0.0311**

Notes: Bold values are associated with statistically significant coefficients of the respective sociodemographic indicator variables as well as the nondiscrete variables.
Source: Calculations by the authors at the sample means of the data.

We also provide the elasticity or the percentage change in the probability of purchasing at vending machines attributed to a 1% change in the respective continuous variables (except for age and family size) in the probit model. The elasticity is always the product of the marginal effect and the ratio of the relevant continuous explanatory variable to the dependent variable. In our study, the appropriate value of the dependent variable is the probability that a food or nonalcoholic beverage purchase at a vending machine will be made. This probability is calculated at the sample means.

If household income were to change by 1%, the probability of purchasing at vending machines would decrease by 0.05%. Moreover, if the number of hours worked by household heads were to change by 1%, the probability of purchasing at vending machines would change by 0.22%. A 1% change in household expenditures related to candy and chewing gum, potato chips and other snacks, cola drinks, food away from home, and tobacco products yields a 0.01% change, a 0.04% change, a 0.05% change, a 0.23% change, and a 0.03% change, respectively, in the probability of purchasing at vending machines.

About 20% of the survey respondents purchased food and nonalcoholic beverages at vending machines. Hence, in the derivation of the prediction success (Table 5), the cutoff probability for classification purposes is 0.20. That is, we predict that the *i*th reference person will purchase at a vending machine if the probability of doing so exceeds 0.20. In agreement with Greene (2012, p. 658), "in general any prediction rule will make two types of errors; it will incorrectly classify zeros as one and ones as zeros." For binary choice models, to the best of our knowledge, no benchmark exists regarding correct classifications. Within the sample, the probit model correctly classifies the decision to not make purchases with 62.21% accuracy (11,555 out of 18,573). Within the sample, the probit model correctly classifies the decision to purchase with 65.48% accuracy (3,117 out of 4,760). Overall, within the sample, the model correctly classifies all decisions 14,672 out of 23,333 times, with 62.88% accuracy.

Table 5. Expectation-Prediction Evaluation of the Probit Model

	Dep = 0	**Dep = 1**	**Total**
P(Dep = 1) ≤ C	11,555	1,643	13,198
P(Dep = 1) > C	7,018	3,117	10,135
Total	18,573	4,760	23,333
Correct	11,555	3,117	14,672
% Correct	62.21	65.48	62.88

Notes: Success cutoff: C = 0.2040029. Dep = 0 indicates nonpurchase of food items or nonalcoholic beverages from vending machines. Dep = 1 indicates purchase of food items or nonalcoholic beverages from vending machines.

Concluding Remarks

To date, the extant literature has focused almost exclusively on vending machine product purchases and the potential health concerns related to such purchases. The purpose of this study was to examine economic and sociodemographic factors that influence individuals' decision to purchase food items and nonalcoholic beverages from a vending machine. Using data extracted from BLS Consumer Expenditure surveys over the period from 2009 to 2012, a probit model was estimated incorporating instrumental variables to address endogeneity issues. Results from this study could help vending machine operators to increase sales by targeting those individuals more likely to purchase food and nonalcoholic beverages from vending machines. Lower-income households with younger household heads who reside in rural areas, are Hispanic, are college-educated, reside in the Midwest and the South, and work more hours are more likely to make purchases from vending machines. Additionally, households that expend more on potato chips and other snacks, candy and chewing gum, food away from home, cola drinks, and tobacco products are more likely to purchase food and nonalcoholic beverages at vending machines.

This research provides a benchmark for future studies concerning purchases from vending machines. Additional research with more current data should be undertaken to examine whether the results of this study are robust. Because of public health concerns, the Food and Drug Administration (FDA) sets rules regarding calorie disclosure required by the Affordable Care Act enacted in March 2010. Moreover, the U.S. Department of Agriculture (USDA) proposed rules regarding the items allowed in school vending machines in order to help students make healthier snack choices (Vending Market Watch, 2019). Beginning in 2014, the vending machines industry was required to provide calorie counts of their snack foods and beverages.

Understanding why more educated individuals are choosing to purchase from a vending machine even though the items for sale are more or less unhealthy is another area to explore. As well, future research efforts should incorporate experiments, seeing whether having healthier options available for purchase in a vending machine leads to healthier items actually being purchased.

There are several limitations to this study. We are not able to discern the impacts of price on the decision to purchase food items and nonalcoholic beverages as prices were not available. Another limitation is that the data used in our analysis are self-reported. As such, measurement error may exist attributed to self-reporting. Further, exploring the use of a Tobit model or a Heckman two-step model is warranted to obtain information on unconditional and conditional demands of items purchased from vending machines. While this study has limitations, we have answered a question that had not previously been addressed, namely what economic and sociodemographic factors affect purchases of food items and nonalcoholic beverages from vending machines.

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