ASSESSMENT OF CRITICAL TRANSPORTATION AND MARKETING ROADBLOCKS AND OPPORTUNITIES FOR GULF COAST SHELLFISH AQUACULTURE

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Recommended Citation: Petrolia, D.R., A. Nathan, B. Walton, W.C. Walton. 2024. "Assessment of Critical Transportation and Marketing Roadblocks and Opportunities for Gulf Coast Shellfish Aquaculture." Final Report, Department of Agricultural Economics, Mississippi State University.

Acknowledgements: The authors thank Rex Caffey, Gregg Cainnon, Seanicaa Edwards-Herron, Freedom Enyetornye, Rusty Grice, Dewey Houck, Jody Houck, Jim Gossen, J.T. McKissack, Earl Melancon, Hayden Miller, Chris Nelson, Wood Oglesby, Ryan Prewitt, Jason Rider, Leslie Sturmer, and John Supan for providing insights into oyster production and marketing. This research was supported by Cooperative Agreement Number 21-TMTSD-MS-0005 with the U.S. Department of Agriculture, Agricultural Marketing Service.

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September 20, 2024

Introduction

U.S. aquaculture generated over $1.5 billion in sales from nearly 3,000 farms in 2018 (USDA 2019). A major component of U.S. aquaculture is oyster production; oysters are the leading marine species by both volume and value and third overall behind catfish and crawfish (NMFS 2022). Oysters are in the top 15 seafood species for retail supermarket sales, and had the third-highest growth rate in sales volume over the past five years (Sun et al. 2023). The Gulf states (Alabama, Florida's Gulf Coast, Louisiana, Mississippi, and Texas) led U.S. regions in 2022 production with 25.5 million pounds of oyster meats, 37 percent of the national total (NOAA Fisheries 2024). U.S. oyster production includes both wild-caught and aquaculture, and although the Gulf states lead overall production, oyster aquaculture is relatively new to the Gulf Coast. The first off-bottom oyster farms were established in 2009 and now, a decade later, there are now hundreds of commercial oyster farms in the region. A majority of these farms are owner-operated, small business farms, producing a million or fewer oysters per year. Unlike wild-caught oysters, these off-bottom farmed oysters go almost exclusively to the high-value, live half-shell market. Botta et al. (2020) find that popularity of raw, half-shell oysters is growing among U.S. consumers.

The loss of markets with closures of restaurants due to the Covid-19 pandemic has introduced uncertainty (van Senten, Smith, and Engle 2020), with farmers concerned about a loss of buyers and a glut of product entering the marketplace (Bob Rheault, pers. comm.). Over 68% of seafood expenditures in 2017 by U.S. consumers was at restaurants (National Marine Fisheries Service 2020), with the half-shell oyster market likely substantially higher and thus even more vulnerable to Covid-based closures. Some New England states had to create oyster buyback programs just to keep producers afloat (Nargi 2021). Furthermore, smaller farms have been challenged recently in regard to their economic sustainability. Recent work by Parker, Lipton, and Harrell (2020), Engle et al. (2021), and Petrolia (2023) suggests that smaller farms are not profitable.

Some work has begun to study transportation and marketing challenges facing shellfish aquaculture (Love, Lane, and Hudson 2019), but not specific to the Gulf Coast region. Some growers outside of the Gulf Coast region, such as Island Creek Oysters in Duxbury, MA, have developed the means to reach alternative markets, such as direct sales to households. Marketing strategies such as this is almost non-existent in the Gulf Coast region, meaning this region's growers face the prospect of no buyers in the short-run and limited market opportunities in the long-run. However, other issues in transportation exist, such as extreme variations in temperature during transit, that introduce food safety concerns and threaten the success of such efforts (Love et al. 2020b). Given these questions about the viability of small farms, which currently dominate the US oyster aquaculture industry, it becomes critical to determine if there are different transportation and marketing strategies that provide economically viable pathways for these farms.

To this end, our study endeavored to better understand the challenges and opportunities associated with shellfish aquaculture in the Gulf Coast region. Our work consisted of three main components. The first component consisted of a literature search focused on production and marketing. Most of the literature covered is specific to oysters, but lessons are also learned from literature related to aquaculture and agriculture in general. The second component consisted of a quantitative analysis using Monte Carlo simulation to compare the feasibility, market demand and supply, and profitability of the two primary marketing strategies available to off-bottom oyster farmers: direct-sale by farmers into local markets and farmgate sales to a wholesaler/distributor. This analysis tackles the question of whether direct sales into local markets can be a more profitable option for small-to-medium oyster farmers. The third component consisted of outreach efforts, led by partner Oyster South, to disseminate marketing and other relevant information to oyster farmers.

What we found is that there is a dearth of knowledge and data regarding off-bottom oyster production. There is also a dearth of knowledge and data regarding the demographic makeup of the off-bottom oyster farming sector, particularly with regard to underrepresented populations. Key marketing challenges for off-bottom farmers include scaling up operations to a profitable farm size and establishing a marketing strategy that results in sufficient numbers of buyers willing to pay profitable prices. Our quantitative analysis found that a marketing strategy focused on selling product at the farmgate to a wholesaler is likely to provide the greatest opportunity to be profitable relative to a strategy focused on selling directly into local markets. This result is due primarily to the inability of the local market to absorb all locally grown oysters. This result holds across a range of farm sizes, prices, growing conditions, transportation distances, number and size of competing farms, and number and demand of local buyers.

A Review of the Literature Related to Oyster Farming

Demographic Overview of the Oyster Farming Sector

Very little data specific to the demographic makeup of the oyster farming sector exists. Here we rely on the unpublished results of a survey conducted in 2021 by Michaelis and Walton (2024) to provide some insights. They surveyed individuals working in shellfish aquaculture across the U.S. A total of 388 respondents completed the survey. Respondents were located in more than twenty-two states, with most respondents located in Florida (> 60), Massachusetts (> 40), New York (> 30), Maryland (> 20), New Jersey (> 20), and Washington (> 20). Most respondents reported being farm owners (> 300); the next-largest group were distributors/sellers (> 50). Most respondents reported working with oysters (> 300). Most respondents were male (74%), while females made up 21% of respondents. The shares of females comprising the total in each industry role were similar: hatchery (29%), farm owner (21%), gear/equipment (13%), distributor (25%), farm worker (30%), other (12%). Respondent ages ranged between 40 and 79 years old, with more in the 60-79 range. Over 350 respondents indicated their race as white, though of the ten respondents who identified with a race other than white, seven reported being farm owners/operators. Regarding ethnicity, eight respondents indicated being Hispanic or Latino, and seven of these reported being owners/operators.

Regarding the demographic makeup of the sector with regard to underrepresented producers, we found limited information beyond that noted in the above study. To quote Ms. Seanicaa Edwards-Heron of the Freedmen Heirs Foundation: "Finding specific data on Black aquaculture farmers (South or Chesapeake Bay Area) has proven to be challenging due to the limited breakdown of data within aquaculture industry. From the perspective of USDA data or BLS data, surveys and reports do not disaggregate data (due to confidentiality or not enough sample statistics) to the extent necessary to highlight the participation of specific racial groups when it comes to aquaculture. This lack of detailed data collection makes it difficult to pinpoint the exact number of Black participants in the industry and how that number has changed over time" (personal communication, April 21, 2024). We also note that we made repeated attempts to contact the organization Minorities in Aquaculture, whose mission is to "…bridge the gap between minority individuals aspiring to build careers in aquaculture and the industry's workforce development needs, requirements and goals...", but we never received any response.

Data Challenges

Froehlich et al. (2022) conducted a synthesis and comparison of species, volume, and value information on U.S. marine aquaculture over time, across the 23 marine coastal states. Comparing data from the U.S. Department of Agriculture (USDA), the National Oceanic and Atmospheric Administration (NOAA), and individual states, they uncovered numerous data gaps and discrepancies between and within sources. In particular, they found a dearth of volumetric data and millions in missing value. They attributed most discrepancies to policy. Specifically, they identified a lack of unified definitions across state and federal policies, such as what constitutes "aquaculture", a standardized data framework and collection approach, and clear coordination across state and federal agencies. They recommend U.S. state governments adopt a standardized, digital and annual data collection program, such as the NOAA Fisheries Information Networks.

Consumer Preferences for Farmed Oysters

Regarding fresh in-shell, frozen de-shelled, and cooked processed oysters, Willer, Nicholls, and Aldridge (2021) find that the greatest challenges to product demand is food safety, shell removal, and quality and palatability. In addition to some of these challenges, several factors limit the total population of potential consumers as shellfish allergies and lack of knowledge of how to safely choose, prepare, and cook bivalves prevent many consumers from considering purchases of oyster products (Willer, Nicholls, and Aldridge 2021).

Love et al. (2020b) report that oyster producers consistently mention reliability, reputation, food safety, and same-day shipping as important attributes of their product while restaurants and food retailers consistently mention sourcing from reputable sellers and variety as important attributes related to marketing their products (Figure 1). Their findings, which are based on responses from stakeholders near the Chesapeake Bay area, are similar to those expressed by Gulf coast and southern Atlantic coast stakeholders during Oyster South's recent 2024 Oyster South Symposium (Sullivan 2024).

Petrolia, Walton, and Yehouenou (2017) conducted a survey of U.S. oyster consumers to better understand preferences for oysters on the half-shell. They found that consumers tend to prefer oysters from their own region. Consumers from outside of the Gulf of Mexico region had a significantly lower WTP for Gulf oysters and tended to prefer East and West coast oysters. Louisiana and Florida oysters performed the best in terms of achieving higher WTP for oysters from the Gulf region; both states being well-known for the quality of their seafood in general. For the other attributes, small-sized and salty oysters were significantly less likely to be chosen compared to large and sweet oysters, and wild-caught oysters were more likely to be chosen over cultivated oysters. Gulf residents had a particularly strong preference for wild-caught and large oysters.

Richards, Vassalos, and Motallebi (2022) investigated the willingness of South Carolina residents to consume oysters at home. They found that 76% of respondents consumed oysters away from home. Lack of knowledge regarding at-home preparation and food-safety concerns were cited as key factors reducing consumption at home. Also, one-third of respondents reported having no local seafood market, but indicated a willingness to buy oysters for at-home consumption if such a market opened in their area.

Botta et al. (2023) analyzed U.S. restaurant menus and found price premiums associated with oysters from the East and West coasts, with lower average prices for oysters sold in the South. They found that more information, that is, branding and/or more detailed descriptions of the oysters are associated with higher prices, though they find that no specific attribute accounts for the increase. Also, in spite of the notion that consumers prefer locally grown foods, they found no premium associated with local oysters.

Figure 1. Oyster Quality Attributes Mentioned by Producers, Restaurant Chefs, and Food Retailers (taken from Love et al. 2020b).

Producers	Restaurant and Food Retailers
Oyster-specific: • Cleanliness • Consistency • Deep cup • Salinity • Shuckability • Unique grow-out methods **Marketing and Sales:** • Attractive packaging • Branding and storytelling • Large volumes for sale • Reliability • Reputation • Same day shipments • Unique brand name • Year-round sales **Other:** • Economic sustainability • Environmental sustainability • Food safety	**Oyster-specific:** • Cleanliness • Exclusive product line • Freshness • Meat that fills the cup • Nice looking oyster • Salinity • Shuckability • Shell quality • Taste and texture • Unique brand name **Marketing and sales:** • Customer experience • Knowledgeable staff • Locally sourced oysters • Menu rotates frequently • Price • Sourced from a reputable seller • Variety of oysters available (geography and salinity) • $1 happy hour oysters

Distribution Chains and Food Safety

Love et al. (2020a, 2020b) conducted interviews of businesses at all levels of the oyster supply chain and tracked interstate and out-of-country shipments of live/fresh oysters. They found that 18% of oyster shipments in their study exceeded 50°F, the minimum temperature set by the NSSP, and the study found that the median time oyster shipments spent out of temperature control was 2.5 hours. Potential causes of temperature abuse included faulty mechanical refrigeration units, delays in ground or air transit, not icing products on docks or loading docks, or forgetting to refrigerate boxes upon arrival at restaurants. Temperature abuse occurred in all stages of the supply chain from all actors at some point.

They also found that oyster producers sell a majority of their product through intermediated supply chains and maintain a small number of direct sales. They argue that most restaurants and food retailers source oyster supply from wholesalers to add variety for customers, diversify their supply, ensure fresher products, and obtain faster delivery. However, some restaurants prefer to order directly from oyster farms citing fresher product, faster delivery, connection to farms, and marketing opportunities as benefits for these direct relationships. Preference for selling through an intermediary may also be partly explained by the perception of some farmers that direct marketing is too costly and difficult (Tookes & Yandle 2021).

Additionally, they found that producers prefer refrigerated ground freight for deliveries on the East and West Coasts while shipments to the inland United States utilized a mixture of air and ground freight, depending on shipping price. Shipments between East and West Coasts were handled completely using air freight. The study also found that truck delivery was the safest mode of shipment for intermediated supply chains. They also found that direct supply chains showed lower rates of time and temperature abuse of oyster products compared to intermediated supply chains. Vertical integration seems prevalent in the supply chain as well with half of the producers in the study owning, operating, or being affiliated with a restaurant or raw oyster bar.

To prevent temperature abuse by oyster producers, Love et al. (2020a) recommend the following actions be taken: review state VPCs and strive to meet or exceed regulatory time and temperature requirements; remember that growth of *Vibrio* is most likely immediately after harvesting and during post-harvesting processing; and to use ice slurries or layer ice for cooling, which are found to be more effective in controlling for *Vibrio*. Likewise, they recommend to businesses that handle shellfish to verify that Hazard Analysis and Critical Control Point (HACCP)[1] plans are functioning properly and appropriately reduce *Vibrio* bacterial growth caused by time and temperature abuse; regularly review procedures for monitoring, taking corrective action, verification, and record keeping systems; use time and temperature indictors (TTIs) or other sensors up and down your supply chain to verify procedures and practices are working properly; and, lastly, perform recalls to verify that there is one-up and one-down traceability in your supply chain. Finally, Love et al. (2020a) recommend the following measures to government and industry stakeholders: develop guidance for shellfish industry regarding best practices for domestic and international air freight shipments; develop tools to assist shippers in making packaging decisions (authors suggest an online calculator where shippers could manipulate input variables); establish a working group within the Interstate Shellfish Sanitation Conference to address issues related to cold chains and microbial growth; and, lastly, validate the Food and Drug Administration *Vibrio* risk calculator for Pacific oysters (*C. gigas*).

Regarding food safety, *Vibrio* bacteria is a primary concern for stakeholders throughout the supply chain. *Vibrio* species of bacteria cause roughly 52,000 foodborne cases of vibriosis (CDC 2019). Patients suffering from Vibriosis commonly experiment symptoms such as vomiting, nausea, fever, chills, and stomach cramps, but in extreme cases can lead to death (CDC 2019). *Vibrio* outbreaks have a significant negative response from consumers resulting in decreased willingness to pay for raw oysters (Mazzocco et al. 2024). These effects, however, can be mitigated or complete negated when consumers are provided positive information regarding safety practices by restaurants, wholesalers, and producers (Mazzocco et al. 2024). Safety within oyster supply chains must adequately prevent, test for, and react to the occurrences of *Vibrio* in their product. The U.S. Food & Drug Administration (FDA) is the primary federal agency tasked

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[1] HACCPs are a supply chain management system developed by the FDA for the control of biological, chemical, and physical hazards from raw material production, procurement and handling, to manufacturing, distribution and consumption of the finished product.

with legislating federal safety regulations for oysters.[2] The way in which FDA carries out the enforcement of these laws relies upon a federal and state cooperative effort through the National Shellfish Sanitation Program (NSSP) and FDA's partnering with the Interstate Shellfish Sanitation Conference (ISSP) (Dore 1991). Love et al. (2020a) note that twenty of 23 shellfish-producing states in the U.S. have established *Vibrio* Control Plans (VPCs) to deal with *Vibrio* bacteria according to guidance from the NSSP. The NSSP regulates supply chain actors by placing temperature and time requirements on product.

Production and Marketing

Engle et al. (2021) found that marketing costs accounted for 13% of total costs of container-culture oyster farms. This often included greater investment in cold storage facilities (either a walk-in cold room or a refrigerated truck or trailer), equipment for washing and sorting oysters, marketing expertise of the owner/manager, advertising costs, and broker fees. Petrolia (2023) argues that direct marketing can yield higher prices, but also requires added travel distance, time, and costs, and requires more logistical and marketing efforts on the part of growers, that can erode much of the gains associated with higher prices. A shift in demand away from shucked to premium oyster products (e.g., raw oysters on the half shell) and declining harvest from wild oyster reefs has created a market opportunity for cultured oysters. However, the oyster industry is exposed to the same factors that are inhibiting aquaculture growth of all species in the U.S., including limited aquaculture lease zones, start-up costs, and maintenance costs. Engle et al. (2021), Petrolia and Walton (2018), and Petrolia (2023) point to hurricanes and other environmental hazards to which off-bottom farms are susceptible. Additionally, oyster aquaculture faces push back from waterfront owners who do not want farms near their homes, as well as wild oystermen who do not want increased competition. Farolfi and Johnston (2024), however, found overall support for shellfish aquaculture among a sample of Connecticut households, driven primarily by perceived water-quality and local employment benefits. Their finding on water quality is consistent with Petrolia, Walton, and Yehouenou (2017) and Li, Kecinski, and Messer's (2017), both of whom found a link between consumer willingness to pay for oysters and perceived water quality.

Schrobback et al. (2021), who interviewed Australian oyster farmers, found that small-scale farms face production and reliability challenges, making it difficult to establish a supply chain network, whereas large-scale farms face post-production challenges related to value creation and exploration of new markets. Both small and large-scale firms faced issues related to spat supply, the management of production risks (like environmental risks), and the limited access to financial capital. The authors noted that their findings are applicable to countries like the U.S.

There are also challenges due to competition from abroad. There has been an increase of imports of live/fresh farmed oysters into the half-shell market, particularly from Canada, and to a lesser extent, Mexico and South Korea. Canada exported 82% of all farmed oyster products to the U.S.

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[2] The FDA is responsible for enforcing the following federal laws: Federal Food, Drug and Cosmetic Act, 21 U.S.C. 301 et. seq.; the Fair Packaging and Labeling Act, 15 U.S.C. 1451 et. seq.; and certain sections of the Public Health Service Act, including 42 U.S.C. 241, 242, 243, and 264 (FDA 2019 MOU 225-84-2003).

in 2016, and Mexico exported 98% of its farmed oyster products to the U.S. in 2016 (Botta et al. 2020).

Covid

Van Senten, Engle, and Smith (2021) and van Senten, Smith, and Engle (2020) report on an online survey of 537 aquaculture farms and businesses conducted in 2020 to better understand the impacts of the COVID-19 pandemic, particularly access to marketing channels. The authors note that the USDA had, by late 2020, already released reports related to COVID-19 for grain crops, forestry products, meat processing industry, and some others but none existed for aquaculture. Eighty-four percent of respondents reported having experienced lost sales to domestic markets, cancellation of private contracts, cancellations of government contracts, and lost sales to international export markets in varying degrees across segments of US aquaculture. For shellfish aquaculture farmers, 95% reported lost sales channels, higher than the average of all segments. Eighty-six percent of respondents expected to experience further losses in the future. Very few respondents sold directly to retail grocery stores/supermarkets. Sales to distributors and restaurants were greatly impacted by COVID-19, according to survey responses. For aquaculture farmers that sold directly to customers or to a grocery store/supermarket, sales were disrupted as well, but slightly less than sales to restaurants and distributors. The first instance of COVID-19 in the United States occurred on January 20, 2020, and many sectors of U.S. aquaculture receive their highest prices during the period leading up to Lent in the spring. Losses to sales during this time hit these industries especially hard due to timing. Respondents reported challenges with labor, including temporary loss of employees due to shelter-at-home orders, illness, furloughs, and permanent loss of employees due to terminations forced by the lack of revenue from marketing channel disruptions. Difficulty acquiring inputs, repair/maintenance, and financial services was reported by survey takers. Among shellfish farmers, 22% experienced production input challenges, 36% experienced input challenges (repair, construction, consultant, and engineering services), 31% experienced financial service challenges, 46% experienced other challenges, and 17% experienced challenges they cannot identify at this time.

White et al. (2020) was published early on during the pandemic. Although the authors did not have much data yet, they captured initial responses to the pandemic by analyzing publicly accessible data and reviewing news articles. Concerning production and distribution, they assessed past and present landings and trade data and found substantial declines in fresh seafood catches (−40%), imports (−37%) and exports (−43%) relative to the previous year, while frozen seafood products were generally less affected. Google search trends and seafood market foot traffic data suggest that consumer demand for seafood from restaurants dropped by upwards of 70% during lockdowns, with recovery varying by state. However, these declines were partially offset by an increase (270%) in delivery and takeout service searches. Anderson et al. (2023) found that the seafood import market was not hurt as much as expected by COVID-19. Overall, U.S. seafood imports increased during the COVID-19 years. Availability of seafood was also high. However, they noted that different segments of the supply chain, particularly downstream due to restaurant closures, were hurt the most. They also found no drastic price fluctuations, which suggests that the COVID-19 measures did not lead to major supply or demand interruptions in global seafood markets.

Bassett et al. (2021) discussed the impact of COVID-19 on small-scale fishery supply chains. The supply chain shocks noted by the researchers included export-oriented distribution channels being inoperable, food distribution by smaller fisheries inhibited, loss of restaurant-oriented supply chains, initial glut in harvest without market access, and reduced demand due to loss of income by consumers. Researchers identified firms that were most resilient to challenges caused by the pandemic exhibited some combination of the following adaptive strategies: building local consumer base using social media or online sales to increase visibility; leveraging pre-existing social networks to access legal permission to distribute in the face of restaurant closures and shut downs; shifting distribution to retail markets and local distribution channels. A California sea urchin fishery faced issues from loss of export-oriented markets, gluts in the local supply chain because of lack of infrastructure and closed restaurants. Digital marketing was a way in which this fishery broke into the local market. The researchers noted the importance of social networks that facilitated adaptive responses to the pandemic, i.e., being connected with other growers and community organizations was a benefit to the fishery. The shift to local and national distribution channels, and agents' reliance on pre-existing networks, highlight the need to support development and maintenance of multiple distribution channels during normal times to meet the need for resilient local distribution systems during crises.

Finally, in some places, oyster farmers found relief by way of oyster restoration efforts. In response to sales losses due to COVID-19, the Mississippi-Alabama Sea Grant Consortium, along with five other Sea Grant programs and The Nature Conservancy, provided programs that purchased oysters from participating growers to donate to stock enhancement programs (Walton and Swann 2021; Nargi 2021).

Challenges and Opportunities Specific to Minorities and Underrepresented Populations

Mishra, Short, and Dodson (2024) used nationwide, farm-level data from 2009 to 2021 from the Farm Service Agency's direct farm loan program to investigate racial discrimination in the farm loan program. They found that loan processing times average longer for Black borrowers on operating loans, though with substantial state-level variation. Specifically, they found that it takes an average of more than two additional days for Black farmers' operating loan applications to be completed and another two additional days to be processed. However, there was no significant difference in time for farm ownership loans suggesting a more nuanced cause than outright racial discrimination.

Park, Martinez, and Ibrahim (2024) examined the impact of the use of direct marketing on farm sales for African-American-led farm operations. Across all farmers, they found a negative relationship between direct marketing efforts and overall sales. However, they found that African-American producers engaged in direct marketing can potentially experience higher sales premiums relative to other operations. They also found that the relative sales gap for African-

American-led operations decreases as farm size increases. They also found that African-American-led operations that access and consult price information see narrower sales gaps relative to other operations.

Using data from the 2009–2020 Agricultural Resource Management Surveys, Collins et al. (2024) compare the financial position and performance of African American farms to that of other U.S. farms. They find that the average African American farm has lower total value of production, net cash farm income, government payments, assets, and debts. They find mixed results regarding financial performance, with African American farms having lower profitability, liquidity, and efficiency, but higher solvency. Sant'Anna, Kim, and Demko (2024) used data from the U.S. Small Business Administration to examine Paycheck Protection Program lending among African American and white farmers. They found significant differences between approved loan amounts among African American farmers due to income level and location of their farms, whereas these factors had minimal effects on white farmers.

Zhao et al. (2023) hypothesized that consumers discriminated against female and beginning farmers but found no evidence from their survey of consumers. Vekemans et al. (2024) investigated USDA direct operating loans issued between 2011 and 2020 to determine whether Black farmers are more likely to default relative to other farmers. Controlling for financial, demographic, and other factors, they found that Black farmers have a higher incidence of default than other farmers. Schmidt et al. (2021) examine census data and find that female farm shares are higher near metropolitan centers, that female farmers pursue farm practices distinctly different from male farmers. Quaicoe et al. (2024) find the likelihood of profitability to be lower among first-generation and retiree farmers, and a higher likelihood of profitability among larger farms, full-time farms, farms engaged in commercial agricultural production, and those using paid family labor. They also find the likelihood of profitability to be higher among non-White minority farmers. Teal and Stevens (2024) found some evidence of crop insurance mis-rating linked to race for the Federal Crop Insurance Program.

We wrap up this section with another quote from Seanicaa Edwards-Heron: “While aquaculture has grown as a field, access to the industry for Black aquaculture farmers has often been (and is still being) restricted by systemic barriers such as discrimination, lack of access to capital, resources, market access and the lack of targeted research focusing on racial demographics. Without specific studies or initiatives to gather this data, the understanding of and history of Black participation in aquaculture will likely remain limited” (personal communication, April 21, 2024).

Marketing Analysis

There has been marked growth in the local food movement (Woods et al. 2013; Hardesty 2008; Ekanem, Mafuyai, and Clardy. 2016). Local food markets are sometimes perceived as providing an opportunity for beginning small-scale farmers who cannot yet take advantage of economies of scale and have higher production costs (Jablonski et al., 2017; 2022). Local food markets often have low barriers to entry and consumers are often willing to pay premium prices (Low et al., 2015). Local foods are sometimes promoted as helping local economies, though Stickel and Deller (2020) find no evidence that this is true. This trend is often supported by public funds, including the USDA Agricultural Marketing Service, through its Local Agriculture Market Program (LAMP), which "supports the development, coordination, and expansion of direct producer-to-consumer marketing; local and regional food markets and enterprises; and value-added agricultural products (USDA 2024). Since 2020, the LAMP – through its Farmers Market Promotion Program, its Local Food Promotion Program, and its Regional Food System Partnerships Program – has funded 691 projects across the U.S. with grant funds totaling $246,257,756 (USDA 2024). Of those funds, $14,185,258 (6%) has gone to projects that at least mention seafood or fish whereas only $1,660,170 (< 1%) has gone to projects that specifically mention shellfish. An example of public support for local foods specific to off-bottom oyster farming is the State of Louisiana, who began subsidizing off-bottom oyster farming in 2022, providing over $1.5 million in grants to grow-out farms, nurseries, a hatchery, and oyster "parks" (Petrolia 2023). O'Hara and Lin (2020) suggest that local food efforts may struggle without outside funding. These findings are consistent with Murray and Kirkley (2008), who note that the Eastern Shore Farmers' Market, which was established by the Virginia Department of Agriculture and the Virginia Market Board and was one of the few farmers' markets to sell seafood at the time, was generating quite a lot in sales, but still did not cover all costs of maintenance and infrastructure.

An important question is whether selling through local markets is profitable. O'Hara and Lin (2020) report that 39% of local food sales by farmers were to intermediaries and institutions in 2015, whereas 34% occurred at direct-to-consumer markets and 26% occurred directly to retailers. Low and Vogel (2011) found that small and medium-sized farms dominate local foods sales marketed exclusively through direct-to-consumer channels whereas large farms dominate local food sales marketed exclusively through intermediated channels. They also found that farmers marketing food locally are most prominent in the Northeast and on the West Coast where farms are close to densely populated urban markets. Park et al. (2014) found that farmers using direct-to-consumer-only outlets report lower sales than those using intermediated outlets only. Park (2015) analyzed the impact of direct marketing on the entire distribution of farm sales and found that it had a negative impact. Low et al. (2015) and Key (2016) found that beginning farmers were more likely to report positive sales and have higher survival rates when marketing through direct channels relative to traditional channels, though direct marketing was found to be associated with slower sales growth.

O'Hara and Lin (2020) investigated the link between market size, market proximity, and direct sales. They find that greater market size reduces the probability that local farmers sell products to distributors while also increasing their direct sales to retailers. They find that the value of distributors to local farmers is to increase the distances at which they market food products, particularly those with high transportation costs. They also find that less experienced farmers are more likely to sell directly to consumers whereas more experienced farmers are more likely to sell through a distributor. Their findings suggest that at the margin, relatively higher prices that farmers may receive from selling directly to consumers more than compensates for the increased marketing costs relative to selling through a distributor. However, this finding is predicated on being within 25 miles of their customer base, although for larger population centers, the distance extends to 100 miles.

Most recently, Jablonski et al. (2022) utilized the 2013-2016 USDA Agricultural Resource Management Survey (ARMS) data to assess the financial performance of U.S. beginning farmers and ranchers who generate sales through local food markets. They find that beginning operations with retail sales or through a distributor or institution perform better than those with direct-to-consumer sales. Thus, the marketing strategy, that is, the marketing channel through which to sell, is a key factor in the profitability of a farm. Although several studies have investigated consumer preferences, temperature and food-safety issues with transportation of shellfish, and other marketing issues, very little work has analyzed market supply and demand of off-bottom oysters, and none to our knowledge has addressed the issue of marketing strategy. A large part of the reason is that very little data exists regarding number of off-bottom oyster farms, volume of output, number of buyers, and market prices. Thus, many farmers (and researchers) are uninformed regarding the market conditions into which farmed oysters are likely to be sold.

Although there are several factors that affect the logistics of marketing oysters, the key factors affecting local market supply and demand are shown in Figure 2:

Figure 2. Key Factors Affecting Local Market Supply and Demand

Supply

- Number of farms
- Number of oysters produced and sold per farm
- Degree of access to wholesale buyers
- Degree of access to local direct-sale buyers
- Share of local competing farms selling in local market
- Capacity of wholesale market to absorb local oysters offered
- Imports from non-local markets (other states and overseas)
- External environmental factors (salinity, hurricanes, disease, etc.)

Prices

- Local market half-shell price
- Wholesale market half-shell price
- Sack-oyster market price

Demand

- Number of restaurants
- Number of oysters demanded per restaurant
- Share of total oysters demanded that are *local* oysters versus non-local oysters (imports from other states or overseas)
- External market factors (shifts in consumer tastes and preferences, shifts in meals away from home, household incomes, etc.)

Oyster farms have two general marketing strategies that they can follow: selling directly into local half-shell markets or selling at the farmgate to a wholesaler. The direct-sale strategy provides farmers with the highest price potential but requires farmers to act as both farmer and distributor, by delivering oysters themselves to retail buyers. It also limits sales to whatever the local market can absorb. Oysters that the local half-shell market cannot absorb will need to be sold on the lower-value sack-oyster market which acts as a backstop market. Some oysters are sold directly to households via online sales, farmers' markets, or special events, but these represent a small share of the total.

The wholesale strategy requires that the farmer establish a relationship with a wholesaler, and from there, the farmer sells oysters at the farmgate to the wholesaler who then distributes the oysters to both local and distant buyers. This strategy allows the farmer to reach more distant markets, but reduces the price potential since the wholesaler carries out the marketing and transportation efforts.

This analysis investigates the relative performance of these two marketing strategies. It builds upon the work of Petrolia (2023) who investigated the profitability of small-to-medium off-bottom oyster farms. That study focused on factors such as farm size, variations in production costs, and environmental factors that can affect yields. Although it discussed the issue of marketing and pricing briefly, it took these factors as fixed. Also, because the wholesale option was not feasible for off-bottom growers in Louisiana at the time of the study, it was not considered.

It is important to understand that the off-bottom oyster market is distinct from the traditional reef-oyster market, and local markets in different parts of the country are more or less influenced by one or the other, depending on what type of oyster production dominates. Traditional reef oysters supply both half-shell and shucked oyster needs and is by far the largest market. Oyster production in states such as Louisiana, Texas, and Virginia are dominated by traditional reef oyster production. These types of oysters are often called “sack oysters”, because they are usually sold in large 100-200 lb. burlap sacks containing anywhere from 100-200 oysters. They also tend to be larger and have larger and thicker shells than off-bottom oysters. Off-bottom oysters are intended for the half-shell market, though some end up in the sack-oyster market when half-shell demand is lacking. Oyster production in states such as Massachusetts and Washington are dominated by off-bottom oysters. Some states have both, such as Alabama, Virginia, and Florida. Prices in the half-shell market, especially for off-bottom oysters, tend to be higher than those in the sack-oyster market. Thus, there are two distinct markets, though the sack-oyster market can serve as a “backstop” market for off-bottom oysters that do not find a place in the half-shell market.

The present analysis also extends that study by converting the analysis from deterministic (fixed values) to stochastic (variable levels for multiple parameters). The local market is modeled based on several factors, including the number and size of local oyster farms (supply) and the number of local restaurants and number of oysters demanded per restaurant (demand).

The analysis is conducted for a representative study farm and includes six different farm sizes as shown in Table 1. Farm size is represented by the average number of oysters sold and acreage required. The number of oysters sold is determined first by the number of production lines of grow-out gear in the water. Assuming a floating bag system, a line is assumed to hold 200 floating bags. Each bag can hold between 100 and 200 oysters (based on final stocking density). Thus, a single line can yield between 20,000 and 40,000 oysters. See Petrolia (2023) for more detail.

Table 1. Farm Size, by average number of oysters sold, number of lines of gear, and lease size.

Average No. Oysters Sold	Lines (200 floating bags each)	Lease Size (Acres)	Oyster Harvest - Range (No. Oysters)
30,000	1	0.5	20,000-40,000
90,000	3	0.5	60,000-120,000
180,000	6	1	120,000-240,000
360,000	12	2	240,000-480,000
540,000	18	3	360,000-720,000
720,000	24	4	640,000-1,280,000

Monte Carlo Simulation

The analysis combines data obtained from a variety of sources with Monte Carlo simulation methods to generate all estimates. Monte Carlo simulation is a technique used to study how a model responds to randomly generated inputs, usually inputs that are unknown or known with uncertainty. The method was used previously by Petrolia, Walton, and Cebrian (2022) in an economic analysis of oyster production on bottom reefs, off-bottom farms, and non-harvested reefs. The method typically involves a four-step process: 1) define ranges and/or distributions for key variable inputs, 2) randomly generate values for each variable input based on the defined distributions and calculate the resulting value(s) of key output(s)/metric(s): this represents a single simulation, 3) repeat Step 2 for a desired number of simulations – usually in the thousands, drawing different values for input variables each time and calculating resulting output(s), and 4) aggregate and assess the results from all simulations. Common metrics of interest include the mean value of an output, the distribution of output values, and the minimum or maximum output values.

In the present study, the inputs are assumptions made regarding the values of key factors, such as farm size, number of competing farms, and number of restaurants. Table 2 reports the set of variable input assumptions in the analysis, the type of statistical distribution assumed for each from which values are taken, and the parameters of the distributions. This set of variables was chosen based on which factors were most likely to influence results and which factors have the greatest uncertainty regarding the values to be taken. These assumptions are discussed in detail below.

Transportation Distance for Direct Sale

Petrolia (2023) assumed 107 miles one-way travel distance from farm to buyer for his analysis of farms in Grand Isle, Louisiana, selling to buyers in New Orleans. In Mississippi, the distance from the Biloxi Small Craft Harbor – the nearest dock for access to the Mississippi off-bottom oyster farm – to Bay St. Louis, Mississippi, is 29 miles; to New Orleans is 91 miles. In Alabama, the distance from Bayou La Batre, a community in proximity to some of their oyster farms, to Mobile, a likely buyer location, is 28 miles. The distance from Galveston to Houston, Texas, is 51 miles. The distance from Mexico Beach to Destin, Florida, is 80 miles. Based on these examples, we assumed that travel distance to market for direct-sale was distributed uniformly, ranging from five to 100 miles one-way.

Table 2. Variable Input Assumptions for key parameters used in Monte Carlo simulation.

	Distribution	Minimum	Most Likely	Maximum
Direct-Sale Transportation Distance (Miles)	Uniform	5		100
Local Market Size (# Restaurants)	Triangular	5	20	35
Local Restaurant Demand (# Oysters Per Month Per Restaurant)	Uniform	5,000		25,000
Local Oyster Market Share	Triangular	0.25	0.50	0.75
Competing Local Farms (Number)	Triangular	1	15	35
Competing Local Farm Size Scale Factor	Uniform	0.50		2.00
Competing Local Farm Wholesale Share	Uniform	0.00		1.00
Direct-sale Half-shell Price ($/oyster)	Uniform	0.75		$1.00
Wholesale Half-shell Price ($/oyster)	Triangular	$0.25	$0.50	$0.75
Wholesale Sack Price ($/oyster)	Triangular	$0.15	$0.25	$0.35
Environmental Scenario	*Best Case*		0.25	
	Moderate Loss Case		0.60	
	Severe Loss Case		0.15	

Number of restaurants selling branded half-shell oysters

Petrolia (2023) estimates that there are 10-15 restaurants in the South Louisiana/Coastal Mississippi region selling branded oysters, most of which are in New Orleans. Houston, Texas, is the fourth-largest U.S. city by population and the largest in the Southern U.S. We investigated the number of restaurants in the Houston/Galveston Metro Area selling oysters, and of those, the number selling or potentially selling branded half-shell oysters. We identified fourteen restaurants selling branded oysters, and identified eighteen others that could potentially sell branded oysters, for a total of thirty-two restaurants with the potential to sell branded oysters. In coastal Alabama and Mississippi, there are likely not more than five restaurants selling branded off-bottom oysters. Based on these data, we assume a triangular distribution for number of restaurants selling branded half-shell oysters, with an optimistic twenty restaurants being most likely, a lower bound of five restaurants, and an upper bound of 35 restaurants.

Quantity of Oysters Needed per Restaurant

Petrolia (2023) reports a range of 4,000-17,000 branded half-shell oysters sold per month per restaurant. More recent information from personal communications with individuals in the industry indicate that the upper bound could be as high as 25,000 oysters per month for these kinds of oysters. We assume that the quantity of oysters needed per restaurant is uniformly distributed between 5,000 and 25,000 oysters per month. Note that the volume of oysters sold for the traditional oyster market can be significantly higher. For example, Acme Oyster House claims to shuck more than 83,000 per month and Drago's Seafood, one of the largest sellers of raw and charbroiled oysters, reportedly sells more than 250,000 oysters per month (Acme Oyster House 2024; Iknoian and Hodgson 2019).

Local Oyster Market Share

Restaurants that sell branded half-shell oysters tend to offer multiple varieties, often from all three coasts (East, West, Gulf) as well as Canada. The U.S. also imported 5.7 million pounds of live/fresh farmed and wild oysters from Mexico in 2023 (NOAA Fisheries 2024), but based on value and implied price per unit, we expect that most of these go to the shucked market. Petrolia (2023) assumes that one-third of the total oysters needed in a local market may come from local farmers, but in markets where oyster farming is more developed the share can be higher. We assume a triangular distribution with a most likely value of one-half, a lower bound of one-quarter, and an upper bound of three-quarters. We expect that as more local farms come online, local restaurants will be able to (and will want to) feature more of them on their menus, and they will thus command a larger share of the local market. Accordingly, we assume a correlation value of 0.75 between the number of local farms and the local oyster market share (Table 3).

Table 3. Correlation coefficients used in Monte Carlo simulation.

Variable 1	**Variable 2**	**Correlation Coefficient**
Local Oyster Market Share	Competing Local Farms (Number)	0.75
Direct-sale Half-shell Price ($/oyster)	Wholesale Half-shell Price ($/oyster)	0.75
Direct-sale Half-shell Price ($/oyster)	Wholesale Sack Price ($/oyster)	0.25
Wholesale Half-shell Price ($/oyster)	Wholesale Sack Price ($/oyster)	0.50

Competing Local Farms

Melancon (2023) reports that there are currently nineteen grant-funded off-bottom oyster farms operating in Louisiana. Prior to the state's grants program, he reported there being nine such farms in 2021, with that number dropping to zero post-Hurricane Ida, which made landfall in August 2021. Petrolia (2023) reports the number of farms operating in Alabama has declined from a high of 22 in 2018 to 10 farms in 2022. He reports that Florida had 125 farms in 2021; Maryland had 103 in 2021; North Carolina had 97 in 2020 and 119 in 2021; and that Mississippi had 17 in 2021. It is unknown how many of these farms are actively operating and selling oysters. We suspect that not all of them are, and that a reasonable upper bound for number of farms in a particular region of a state is 35. We assume that the number of competing farms is distributed triangular, with a lower bound of one, twenty as most likely, and an upper-bound of 35.

Competing Local Farm Size (Scale Factor)

We assume that all farms in a given geographic region will tend to be of similar size. Accordingly, we assume that competing farms will be uniformly distributed, ranging between one-half and two times the size, of the study farm. Thus, if the study farm size in a given simulation is 90,000 oysters per year, then the average competing farm size will range between 45,000 and 180,000 oysters per year.

Competing Local Farm Wholesale Share

This assumption captures the share of competing local farms selling into the wholesale market. Petrolia (2023) reports that off-bottom oyster farmers in Louisiana do not currently have access to a wholesaler. It is known that off-bottom oyster farms in other states sell to wholesalers, but it is not known the extent to which they do so versus selling directly. We assume that the share is distributed uniformly between zero and one.

Prices

Petrolia (2023) provides a rule of thumb: an oyster that sells for $3 each at an oyster bar was likely purchased from a wholesaler or a grower that sells directly for $0.75-$1. If the oyster bar purchased it from a wholesaler, the wholesaler likely purchased that oyster from a grower for approximately $0.50. He reports further that prices received by growers vary widely, with prices at or above $1 per oyster observed, but with average prices in the $0.40-$0.59 range. These latter prices are most likely wholesale prices. Petrolia (2023) includes quotes from representatives of the wholesale market, including:

- "Farmers can expect a distributor to pay between $0.55-$0.75/oyster, depending on the oyster. Other price factor to keep in mind is the cost of getting that product to the distributor."

- “50¢/oyster is a much more realistic expectation of price if selling to distributor. “
- “It’s very hard to get 95¢ for an oyster unless they distribute themselves.”
- “95¢ or $1 per oyster is at the restaurant level… distributor is not going to pay that since they have to pay for transportation costs.”
- “We have had some direct to restaurant relationships in the past that we paid 75¢ to 85¢ for. Of course, that required the farmer to bring the oysters to the restaurant.”

Petrolia (2023) reports that prices in the sack-oyster market are below $0.25 per oyster. Using commercial oyster landings data for Louisiana (NOAA Fisheries 2023), which is in pounds of meat, converted to number of oysters assuming 6.47 pounds of meat per sack (Keithly and Kazmierczak 2006) and 180 oysters per sack (Banks et al. 2016), Petrolia (2023) calculates average dockside prices of sack oysters at $0.27 (2020) and $0.28 (2021) per oyster.

In his analysis of Louisiana, Petrolia (2023) assumes a direct-sale price of $0.75 per oyster as most likely, but also considers $0.50 and $1.00 per oyster as possibilities. He assumes a sack-oyster price to grower of $0.25 per oyster.

Based on the above information, we assume that the direct-sale half-shell price is uniformly distributed, ranging between $0.75 and $1.00 per oyster. We assume that the wholesale half-shell price is distributed triangular, with a lower bound of $0.25, a most likely value of $0.50, and an upper bound of $0.75 per oyster. We assume that the sack-oyster price to grower is distributed triangular, with a lower bound of $0.15, a most likely value of $0.25, and an upper bound of $0.35 per oyster.

We assume that these three prices are correlated, that is, that they tend to move together to some extent (Table 3). We assume a correlation value between the direct-sale and wholesale half-shell price of 0.75 (strong positive correlation). We assume a correlation value of 0.50 (moderate positive correlation) between the wholesale half-shell price and the sack price, and a value of 0.25 (weak positive correlation) between the direct-sale half-shell price and the sack price.

Wholesale / Sack Market

We assume no limitations on the number of oysters that can be absorbed by the wholesale and sack-oyster markets. In reality, this may not be true. There may be cases where the wholesale half-shell market is saturated and that remaining oysters must go to the lower-value sack-oyster market. There may also be cases where the sack-oyster market is saturated.

Additional Assumptions

For each simulation, total supply and total demand are calculated. When total supply exceeds total demand, it is assumed that total demand is allocated evenly across farms until total demand is exhausted, and excess supply is redirected to the sack market.

The wholesale strategy assumes that oysters are sold at the farm gate, such that no transportation expenses, additional labor, or retail sales licenses are incurred. Oysters sold to the wholesale market receive the wholesale half-shell price. The direct-sale marketing strategy assumes that the farmer delivers oysters to restaurants in the local market once per week. In this case, the farmer incurs all the transportation costs associated with delivery, including mileage, additional labor for marketing and logistical efforts (assumed to increase labor requirements by 25%), and retail sales licenses. Oysters sold via direct-sale receive the direct-sale half-shell price, but local market conditions determine the number of oysters that may be absorbed by the local market. Any oysters in excess of local market demand are assumed to sell in the lower-valued sack-oyster market.

Some changes were made to the base model used in Petrolia (2023). First, we assume an established farm rather than a new farm; thus, we eliminate start-up planting limitations during initial years of operation. Second, we reduce the assumed percent dedication of boat and truck capital costs for small scales of operation. Specifically, we assume that a farm with 1-3 lines of gear has 25% of boat and truck dedicated to farm operations; a farm with 6 lines has 50% dedicated to farm operations; and a farm with 12-24 lines has 100% dedicated to farm operations. Third, we decrease the assumed one-way travel distance from home to farm from 81 miles to 25 miles.

Results

A total of 120,000 simulations were conducted, 10,000 simulations for each of the twelve farm-size/marketing (direct-sale vs. wholesale) strategy combinations. We then limited results to fall within 95% confidence intervals. This was done by ranking the 10,000 observations for each combination in ascending order by profit (our central performance metric) and dropping the top and bottom 250 observations (2.5% each) (Haab and McConnell 2002).

The results of the simulations are presented as average values, that is, as the mean value of each metric over all simulations for a given scenario. Because all results are averages, we drop the "average" label to simplify the discussion. For example, if we write "total revenue", we mean "the average of total simulated revenue over all simulations". For additional detail, summary statistics for each metric are also reported in Table A1 of the appendix and Figures A1-A6 of the appendix display histograms of simulated profit under direct-sale and wholesale marketing strategies at each farm size. These figures provide a more visual depiction of how the distribution of simulated profits compare across marketing strategies at each farm size and how they shift as farm size increases.

Figure 3 reports the average production cost per year for direct-sale and wholesale strategies at each farm size. Costs increase with farm size, ranging from less than $45,000 at the smallest farm size to just under $280,000 at the largest farm size. Because direct-sale requires more effort on the part of the farm to market oysters, costs are higher for that strategy.

Figure 3. Average Production Cost Per Year, by Farm Size.

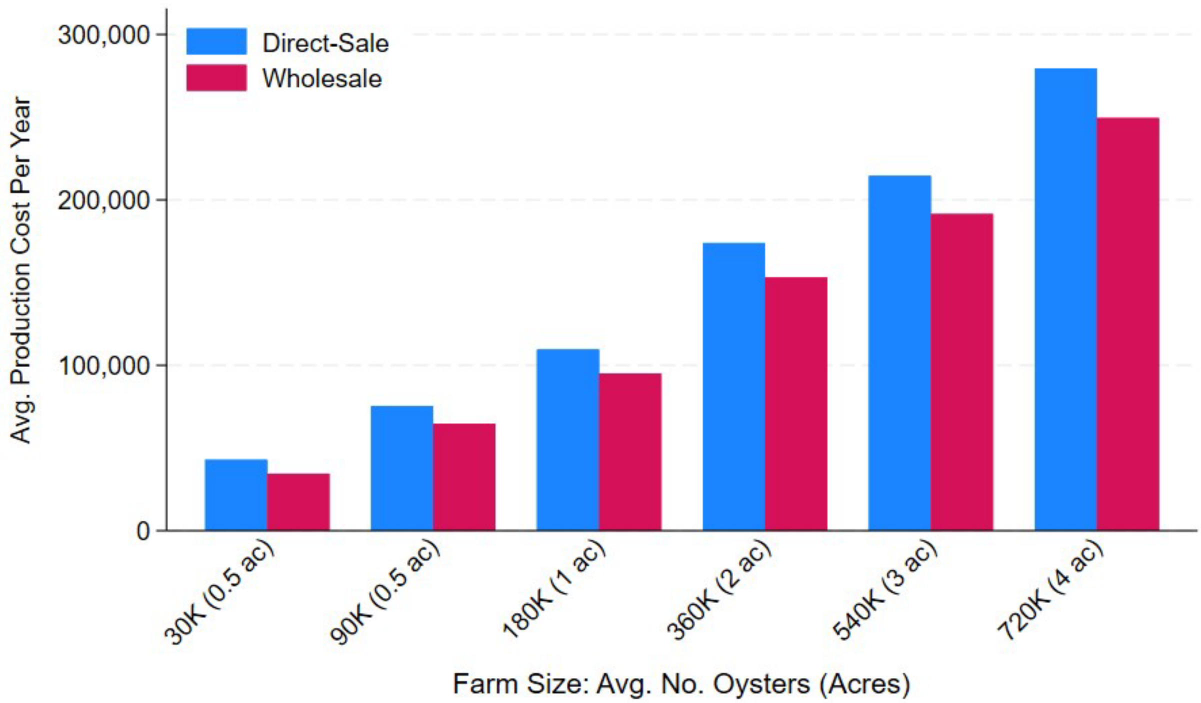


Figure 4 reports the probability of excess supply in the local market by farm size, that is, it shows the percentage of times that simulated supply exceeds demand in the local market. At the smallest farm size, it was near-zero, because, by design, all farms are assumed to be in the same neighborhood of size, specifically, that competing farms will be within one-half and two times the size of the study farm. The number of farms ranges between one and thirty-five, with twenty farms the most likely value. As the size of the study farm increases, the probability of excess supply increases, such that at the 180,000-oyster (one acre) size, supply is exceeding demand more than half the time. These results translate directly to the study farm's half-shell market allocation under the direct-sale strategy, shown in Figure 5. At the smallest farm size, the study farm operating under the direct-sale strategy is allocating 99% of its sales to the half-shell market. The allocation drops to 84% under the next-smallest farm size, then to 57% under the next size. At the 360,000 oysters (two acres) size, the half-shell market allocation has dropped to an average of 31%, then to 21%, then 15% under the largest farm size. Thus, the study farm is competing with other farms for market share, and as it and competing farms increase in farm size, market share decreases, meaning that more sales must go to the lower-value sack-oyster market.

Figure 4. Probability of Excess Supply in Local Market, by Farm Size.

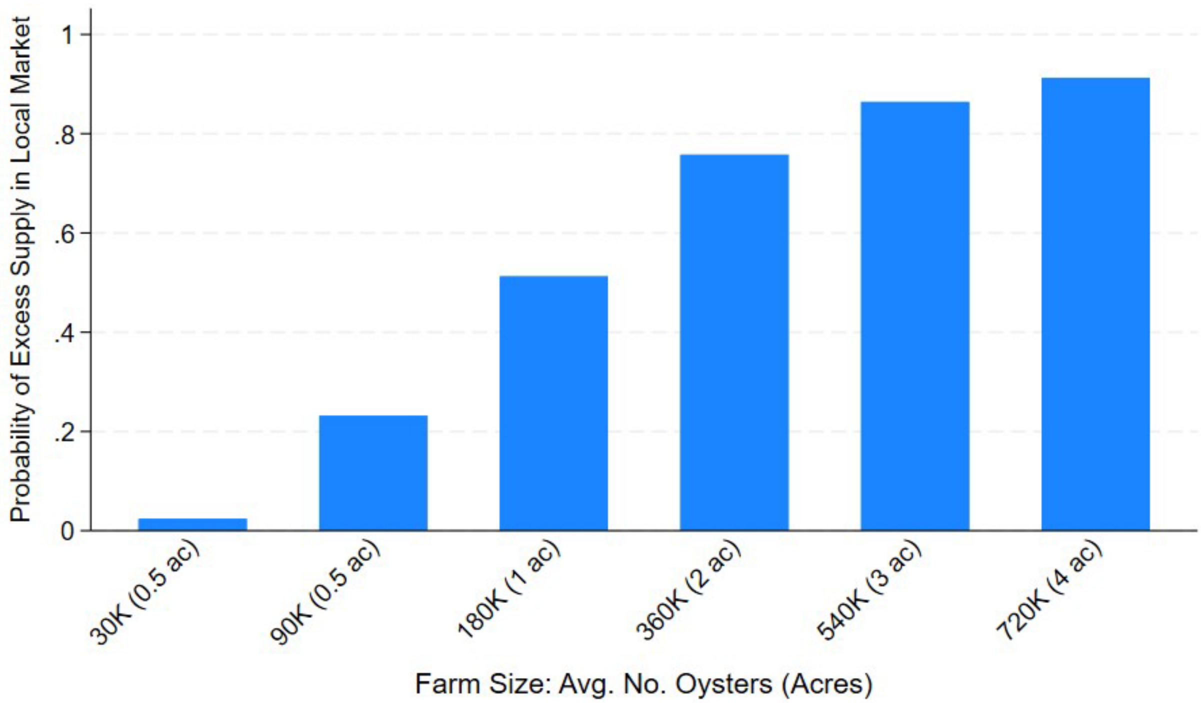
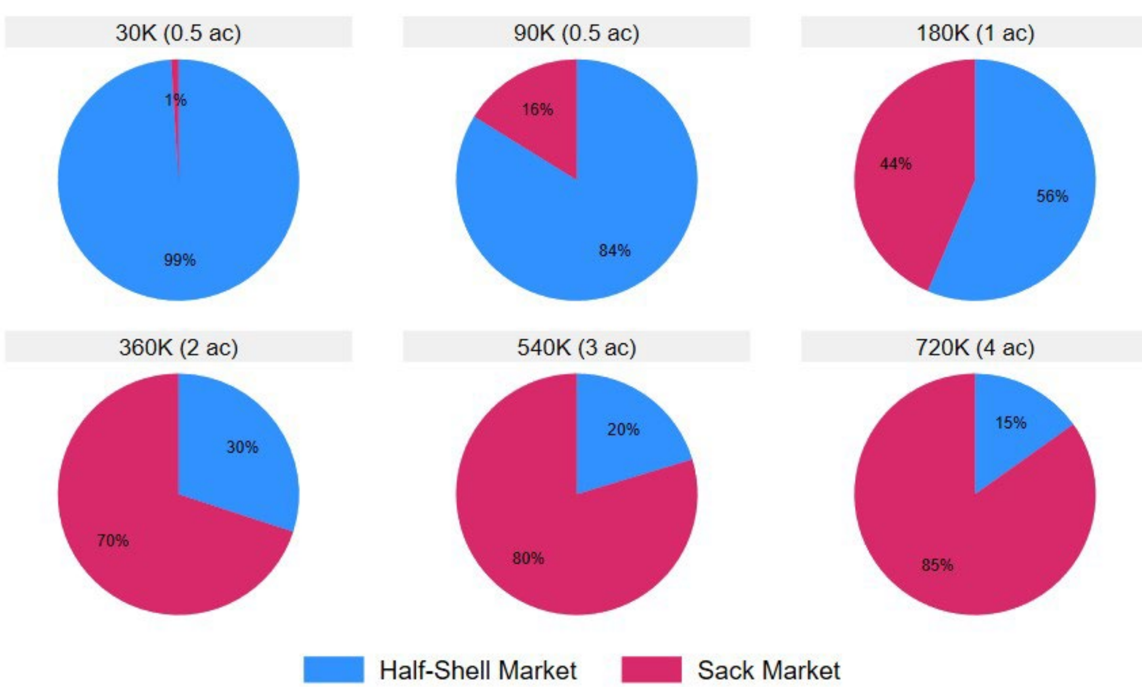


Figure 5. Oyster Market Allocation under Direct-Sale Marketing Strategy, by Farm Size.



Farm size, market shares, and prices combine to yield revenue. Figure 6 reports average revenue per year by market allocation and farm size for the direct-sale strategy. At the smallest farm size, most oysters go to the local market, but as farm size increases, total revenue increases but the share going to the half-shell market decreases, such that total revenue is comprised of more revenue from the sack-oyster market. Average revenue from the half-shell market exceeds $50,000 only under the 90,000 oysters (half-acre) and 180,000 oysters (one acre) farm sizes.

We now compare revenue under the direct-sale strategy to that of the wholesale strategy. Figure 7 reports average revenue by farm size and marketing strategy. At the three smallest farm sizes, total revenue under the direct-sale strategy exceeds that of wholesale, because most direct-sale oysters are being sold into the local market at premium half-shell prices. As the study farm and all competing farms increase in size, however, the local market is unable to absorb total sales and many end up being sold in the lower-value sack-oyster market. Under the wholesale strategy, however, the model assumes that all oysters can be absorbed by the wholesale market. Thus, under the three largest farm sizes, revenue from the wholesale strategy actually exceeds that of direct-sale.

Figure 6. Average Revenue Per Year by Market Allocation for Direct-Sale Marketing Strategy, by Farm Size.

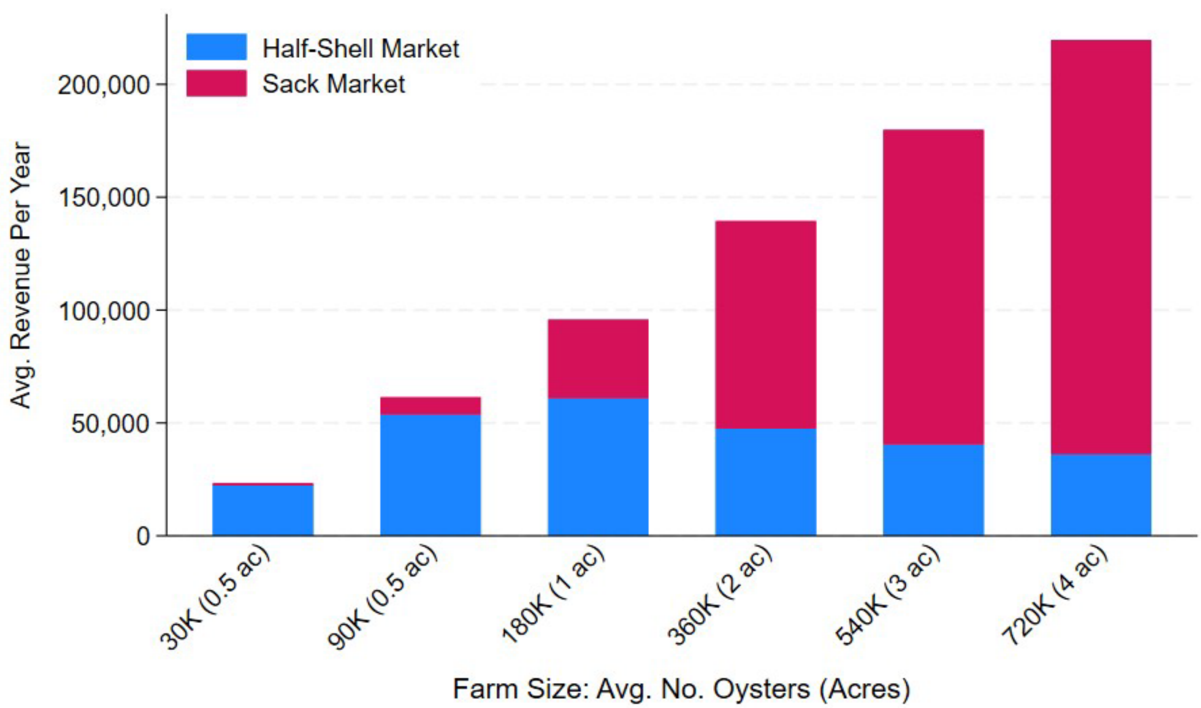


Figure 7. Average Revenue Per Year by Farm Size and Marketing Strategy.

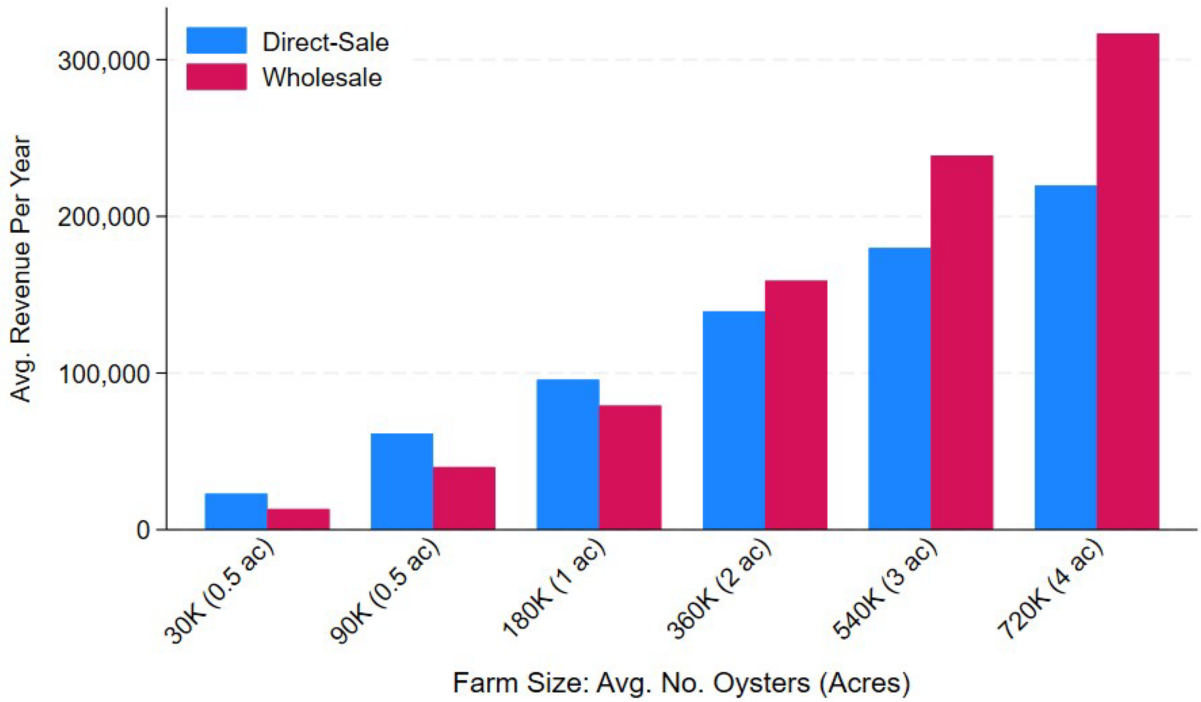


Figure 8 gives some additional insight into the dynamics of what is happening by reporting average price received by farm size and marketing strategy. At small farm sizes, the average price received under the direct-sale strategy far exceeds that of wholesale, with the average price under direct-sale exceeding \$0.80 per oyster whereas the average wholesale price is \$0.50. As farm size increases, however, the average price received under the direct-sale strategy falls as the share of oysters going to the sack-oyster market rises. Thus, the average price under direct-sale declines to less than \$0.50 at the 360,000 oyster (two acre) farm size, that is, the average is actually less than what would be received if selling into the wholesale market. Thus, the direct-sale strategy can deliver higher prices when the number of farms and farm sizes are small, but as those increase, the local market cannot absorb all oysters, forcing an increasing share to the sack-oyster market, thus pushing down the average price received, eventually below the wholesale market.

Figure 9 reports the central metric: average profit per year by farm size and marketing strategy. The key takeaway is that the direct-sale strategy is not profitable, on average, under any of the farm sizes analyzed, and in fact, profits decrease further as farm size increases. This result is due to a “squeeze” effect: at small farm sizes, higher prices are possible, but the inability to capitalize on economies of scale render the farm unprofitable. As farm size increases, economies of scale are possible, but market conditions put downward pressure on prices. The only profitable solution is to be able to scale up and survive at lower prices. We find that the wholesale strategy is not profitable, on average, at the four smallest farm sizes, but profitable, on average, at the two largest farm sizes. Thus, the larger farm sizes allow for sufficient economies of scale such that profitability is possible at a $0.50 farmgate price from the wholesaler.

Table 4 provides some additional insight into profitability: it reports the probability of positive simulated profit by marketing strategy and farm size, that is, it reports the percentage of times that simulated profit was positive. Under direct-sale, profit was never positive at the smallest farm size in any simulation. At the next-smallest farm size, profit was positive 18% of the time. The probability of positive profit under direct-sale peaked at 32% under the 180,000 oyster (one acre) farm size. Under the wholesale marketing strategy, profit was never positive under the smallest farm size and minimal under the next-smallest size. Substantial positive profits were observed beginning with the 180,000 oyster (one acre) farm size, at 28%, and increased thereafter as farm size increased, up to 72% under the largest farm size.

The key takeaway is that under no scenarios was profit always positive, and even under the best case – largest farm size of 720,000 oysters (four acres) with a wholesale marketing strategy – profit was positive only 72% of the time. Thus, all scenarios, even the best ones, involve some level of profit risk.

Figure 8. Average Price Received by Farm Size and Marketing Strategy.

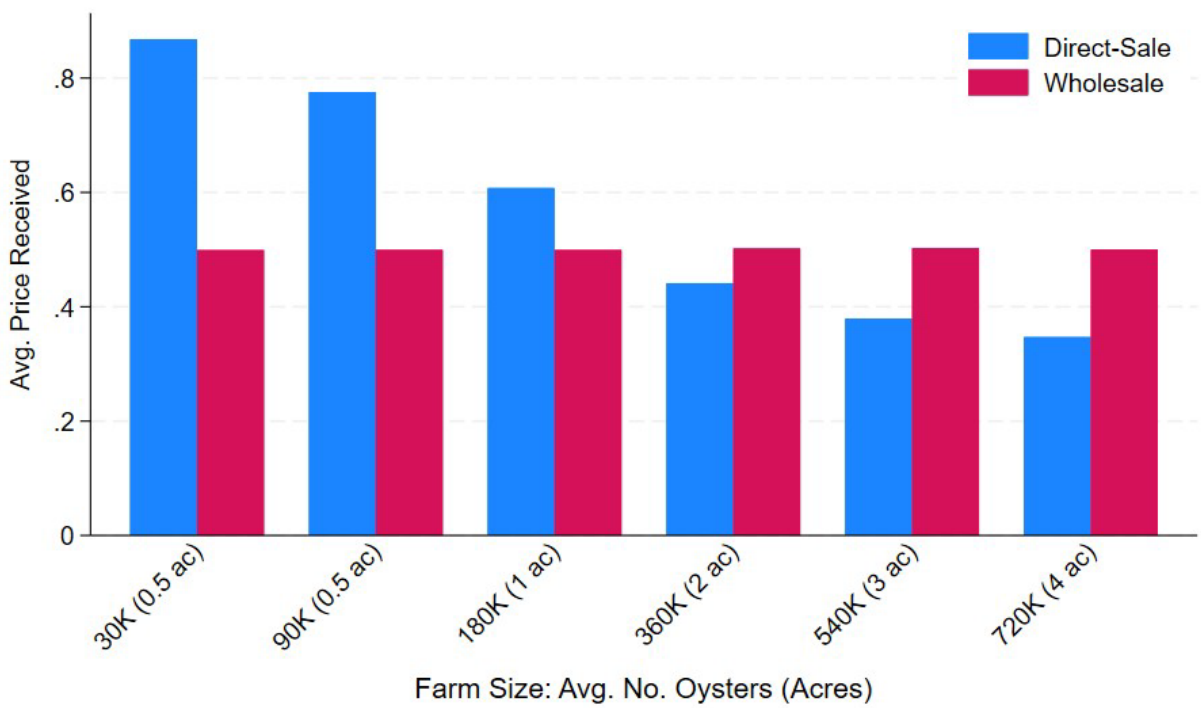


Figure 9. Average Profit per Year, by Farm Size and Marketing Strategy.

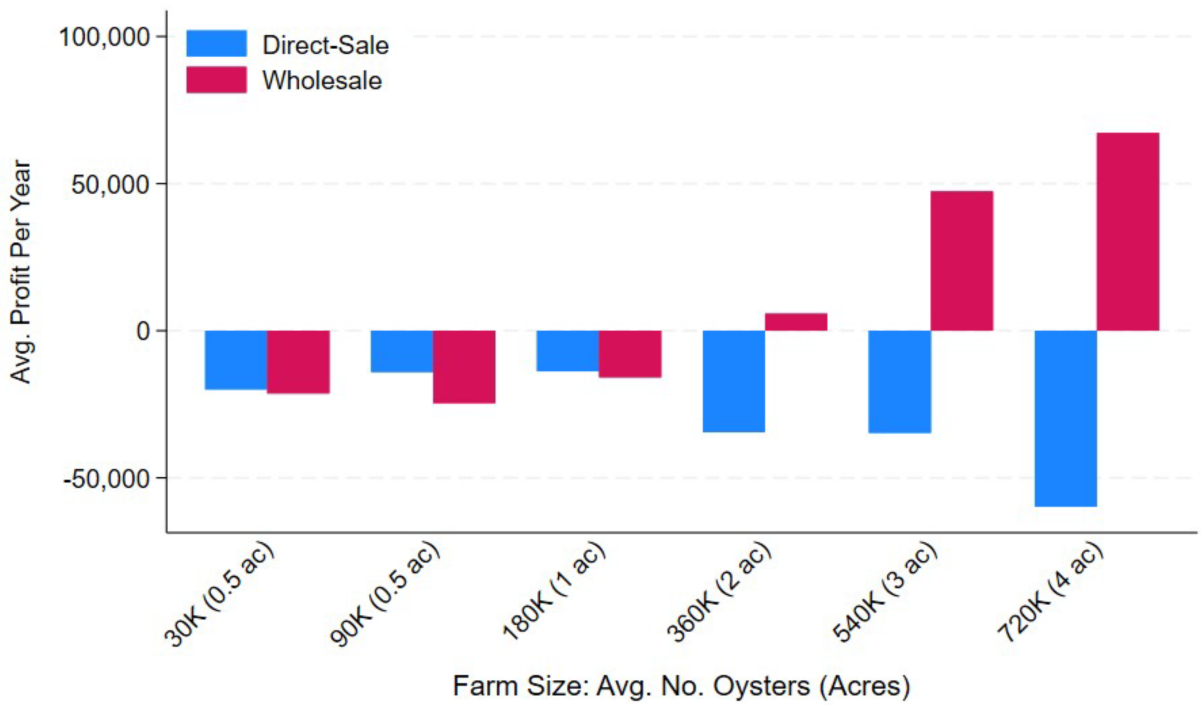


Table 4. Probability of Positive Simulated Average Profit by Marketing Strategy and Farm Size.

Farm Size	Direct-Sale	Wholesale
30,000 (0.5 ac)	0.00	0.00
90,000 (0.5 ac)	0.18	0.02
180,000 (1 ac)	0.32	0.28
360,000 (2 ac)	0.17	0.52
540,000 (3 ac)	0.19	0.70
720,000 (4 ac)	0.11	0.72

Discussion and Limitations

Our results indicate that the wholesale marketing strategy, though it is associated with lower prices to the farmer, provides a more consistent marketing outlet. The direct-sale strategy, though it is associated with higher prices to the farmer, is limited by the volume sales that it can accommodate, which ultimately leads to excess supply that is likely to end up selling in an even lower-valued market. Jablonski et al. (2022) conclude their work by stating that "Supporting beginning operations so they have better access to intermediated markets has potentially important implications for Farm Bill Investments and programming (p. 572-3)," and go on to cite the USDA-AMS's Local Food Promotion Program as a program particularly suited for this purpose.

This study does not assess approaches that could improve the market conditions or supply chain issues undermining profitability. For instance, the food hub model, which serves as a small, local, centralized processing and distribution hub, can help multiple small producers realize economies of scale through centralizing marketing, packaging, distribution and other activities. By aggregating and centralizing the production from multiple small producers, intermediaries like food hubs could also provide a mixed model of sale, enabling further price discrimination by selling at higher prices to low volume consumers, and discounting for higher volume buyers like local restaurants, and then packaging and selling excess supply to wholesalers. This study also does not consider the fact that some small- and medium-sized producers often engage in additional revenue streams and marketing channels. These include agritourism, value-added products, educational programs, and specialized events. Growers can potentially use these additional revenue streams to overcome some of the profitability challenges suggested in the study.

Project Outreach Efforts

Our outreach efforts had three main components, described below.

Promote southeastern US oyster aquaculture through social media, digital newsletters, and other means with assessment of engagement with at least monthly efforts throughout the project duration, with all efforts documented.

To specifically promote southeastern US oyster aquaculture, Oyster South used a combination of social media and digital newsletters authored by a professional free-lance writer (Jennifer Kornegay).

From March 2022 to December 2022, Oyster South produced and distributed two stories a month to promote southeastern US oyster aquaculture. These were posted on the Oyster South website and promoted on social media (Instagram and Facebook) to drive people to the website to increase engagement and awareness of southeastern US oyster aquaculture. This led to a massive increase in visits, unique visitors and page views from the prior year. According to Squarespace analytics, in 2021, the OS website had 10,402 visits, 8,096 unique visitors, and 20,749 page views. In 2022, those numbers increased to 18,777 visits, 14,539 unique visitors, and 35,075 page views.

To highlight several articles, in May our article on the Pensacola Oyster Cluster group was one of the top four pages visits on the site, with 115 page views. In July, our articles on Forgotten Bay Oysters and Women on the Water were in the site's top page visits, with 390 page views and 202 page views respectively. In September, our article on the FlipFarm gear system, had 150 page views. In October, our article on French Hermit Oyster Co. had 350 page views. In November, our article on Navy Cove Oysters had 507 page views.

In the same time period, we sent out a monthly oyster-eating-focused (included recipes) e-news called Eat UP, aimed at a broader oyster consumer audience. We also promoted this on OS social channels and encouraged people to visit the OS site and sign up to receive it in their inbox. We had more than 75 people sign up. The content of each e-news was also added to the OS website after the e-news went out.

Having all the fresh, new content dedicated to promoting southern oyster aquaculture to post about meant our social media posting frequency increased in 2022, which boosted engagement overall. In 2021, 915 OS website visits came through social channels. In 2022, OS website visits that came through our social channels totaled 3,082. On Facebook, the Navy Cove story post reached 4,000, the Flip Farm story post reached 4,300, the University of Florida's online aquaculture classes story post reached 1,100 and the Women on Water story post reached 8,900. On Instagram, most story-related posts hit approximately 50-150 likes while one generated 350 likes.

Three stories focused on underrepresented groups. View metrics provided below.

- https://www.oystersouth.com/stories/2022/12/14/farm-fresh-el-mcintosh-amp-son-oyster-co
    - Viewed 1,124 times (with 1:46 spent per view)
- https://www.oystersouth.com/stories/2022/7/12/farm-fresh-forgotten-bay-oysters
    - Viewed 133 times (with 1:41 spent per view)
- https://www.oystersouth.com/stories/2022/12/1/in-the-kitchen-with-chef-chris-hathcock
    - Viewed 60 times (2:23 spent per view)

Provide outreach to producers and other stakeholders about marketing, transportation challenges and opportunities, with preparation of materials for presentation to various audiences.

Beth Walton and Daniel Petrolia developed and contributed lessons to the University of Florida's Gulf Coast Grown Online Oyster Course (University of Florida 2021). The lessons included were "Introduction to Basic Marketing and Telling Your Story", "Oyster consumers: Preferences and Perceptions", "Planting Your First Crop", and "Considerations when Selecting Diploid and Triploid Oysters to Grow".

Organize and host workshops for oyster farmers in Alabama, Florida, Louisiana, Mississippi, and Texas, where information about this project can be shared.

A workshop was held in conjunction with the 2022 Oyster South Symposium, held in Biloxi, MS, in April 2022. This workshop was a moderated discussion about hurdles and opportunities for oyster farmers in region. The workshop was attended by over 45 individuals, representing growers from all five Gulf States and beyond. Distributors and chefs were also in attendance and contributed to the discussion. This workshop formed the basis for follow up conversations with oyster farmers, distributors and chefs about these challenges and additional small focus groups, including a focus group at the 2023 Oyster South Symposium, held in Savannah, Georgia, in March 2023.

Oyster South organized the following outreach talks particular to marketing at the 2024 Oyster South Symposium in New Orleans: "Alternative Income Streams for Oyster Farmers", "Stories of Oyster South", "What Chefs Want", and "Making the Most of Social Media".

Summary and Conclusions

The loss of markets with closures of restaurants due to the Covid-19 pandemic has introduced uncertainty (van Senten, Smith, and Engle 2020), with farmers concerned about a loss of buyers and a glut of product entering the marketplace (Bob Rheault, pers. comm.). Over 68% of seafood expenditures in 2017 by U.S. consumers was at restaurants (National Marine Fisheries Service 2020), with the half-shell oyster market likely substantially higher and thus even more vulnerable to Covid-based closures. Some New England states had to create oyster buyback programs just to keep producers afloat (Nargi 2021). Furthermore, smaller farms have been challenged recently in regard to their economic sustainability. Recent work by Parker, Lipton, and Harrell (2020), Engle et al. (2021), and Petrolia (2023) suggests that smaller farms are not profitable.

Some work has begun to study transportation and marketing challenges facing shellfish aquaculture (Love, Lane, and Hudson 2019), but not specific to the Gulf Coast region. Some growers outside of the Gulf Coast region, such as Island Creek Oysters in Duxbury, MA, have developed the means to reach alternative markets, such as direct sales to households. Marketing strategies such as this is almost non-existent in the Gulf Coast region, meaning this region's growers face the prospect of no buyers in the short-run and limited market opportunities in the long-run. However, other issues in transportation exist, such as extreme variations in temperature during transit, that introduce food safety concerns and threaten the success of such efforts (Love et al. 2020b). Given these questions about the viability of small farms, which currently dominate the US oyster aquaculture industry, it becomes critical to determine if there are different transportation and marketing strategies that provide economically viable pathways for these farms.

Our study consisted of three main components. The first component consisted of a literature search focused on off-bottom oyster production and marketing to identify challenges and opportunities facing off-bottom oyster farmers in the U.S. Gulf Coast. The second component consisted of a quantitative analysis using Monte Carlo simulation to compare the feasibility, market demand and supply, and profitability of the two primary marketing strategies available to off-bottom oyster farmers: direct-sale by farmers into local markets and farmgate sales to a wholesaler/distributor. The third component consisted of outreach efforts, led by partner Oyster South, to disseminate marketing and other relevant information to off-bottom farmers.

We conclude that there is a dearth of knowledge and data regarding the off-bottom oyster supply chain. There is also a dearth of knowledge and data regarding the demographic makeup of the off-bottom oyster farming sector, particularly with regard to underrepresented populations. Key marketing challenges for off-bottom farmers include scaling up operations to a profitable farm size and establishing a marketing strategy that results in sufficient numbers of buyers willing to pay profitable prices. Our quantitative analysis found that a marketing strategy focused on selling product at the farmgate to a wholesaler is likely to provide the greatest opportunity to be profitable relative to a strategy focused on selling directly into local markets. This result is due primarily to the inability of the local market to absorb all locally grown oysters. This result holds across a range of farm sizes, prices, growing conditions, transportation distances, number and size of competing farms, and number and demand of local buyers.

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APPENDIX

Table A1. Summary Statistics of Key Performance Metrics.

	Direct-Sale				Wholesale			
	Mean	**Std. dev.**	**Min**	**Max**	**Mean**	**Std. dev.**	**Min**	**Max**
				30,000 (0.5 ac)				
Cost	42,939	784	41,179	44,693	34,498	192	34,017	34,975
Revenue	22,981	3,772	14,379	33,304	13,201	4,007	6,041	22,516
Profit	-19,958	3,671	-27,421	-11,102	-21,297	3,948	-28,041	-12,329
Half-Shell Market Allocation	0.99	0.05	0.37	1.00	1.00	0.00	1.00	1.00
Average Price Received	0.87	0.08	0.47	1.00	0.50	0.14	0.25	0.75
				90,000 (0.5 ac)				
Cost	75,447	9,844	46,989	81,524	64,601	8,560	40,032	68,896
Revenue	61,386	14,138	22,310	95,206	39,974	12,459	12,463	71,428
Profit	-14,061	14,045	-45,096	14,722	-24,627	12,632	-46,967	2,828
Half-Shell Market Allocation	0.84	0.22	0.14	1.00	1.00	0.00	1.00	1.00
Average Price Received	0.78	0.15	0.34	1.00	0.50	0.14	0.25	0.75
				180,000 (1 ac)				
Cost	109,598	8,577	86,705	135,665	95,046	7,307	77,050	115,327
Revenue	95,780	27,740	28,711	183,205	79,195	24,283	23,297	150,615
Profit	-13,818	26,852	-60,974	50,388	-15,851	22,971	-56,562	35,641
Half-Shell Market Allocation	0.57	0.27	0.06	1.00	1.00	0.00	1.00	1.00
Average Price Received	0.61	0.17	0.25	1.00	0.50	0.14	0.25	0.75
				360,000 (2 ac)				
Cost	173,932	9,025	147,778	183,630	153,108	7,756	131,564	161,265
Revenue	139,446	36,880	58,202	256,820	158,897	48,861	58,033	272,649
Profit	-34,485	35,447	-92,965	74,808	5,789	46,939	-74,591	112,258
Half-Shell Market Allocation	0.31	0.18	0.02	1.00	1.00	0.00	1.00	1.00
Average Price Received	0.44	0.12	0.21	0.99	0.50	0.14	0.25	0.75
				540,000 (3 ac)				
Cost	214,572	18,764	189,667	249,603	191,477	16,321	169,798	220,608
Revenue	179,836	42,972	86,700	329,653	238,840	73,015	99,387	417,121
Profit	-34,736	39,316	-104,473	83,061	47,363	68,842	-71,163	199,026
Half-Shell Market Allocation	0.21	0.12	0.02	1.00	1.00	0.00	1.00	1.00
Average Price Received	0.38	0.08	0.18	0.84	0.50	0.14	0.25	0.75
				720,000 (4 ac)				
Cost	279,423	35,026	208,399	330,166	249,545	29,371	189,696	293,221
Revenue	219,657	50,075	72,303	396,950	316,752	97,158	103,607	553,498
Profit	-59,767	45,606	-152,218	68,859	67,206	90,082	-90,991	262,266
Half-Shell Market Allocation	0.15	0.09	0.01	0.91	1.00	0.00	1.00	1.00
Average Price Received	0.35	0.07	0.18	0.70	0.50	0.14	0.25	0.75

Figure A1. Histogram of Simulated Average Profit for 30,000 Oyster (0.5 Acre) Farm Size.

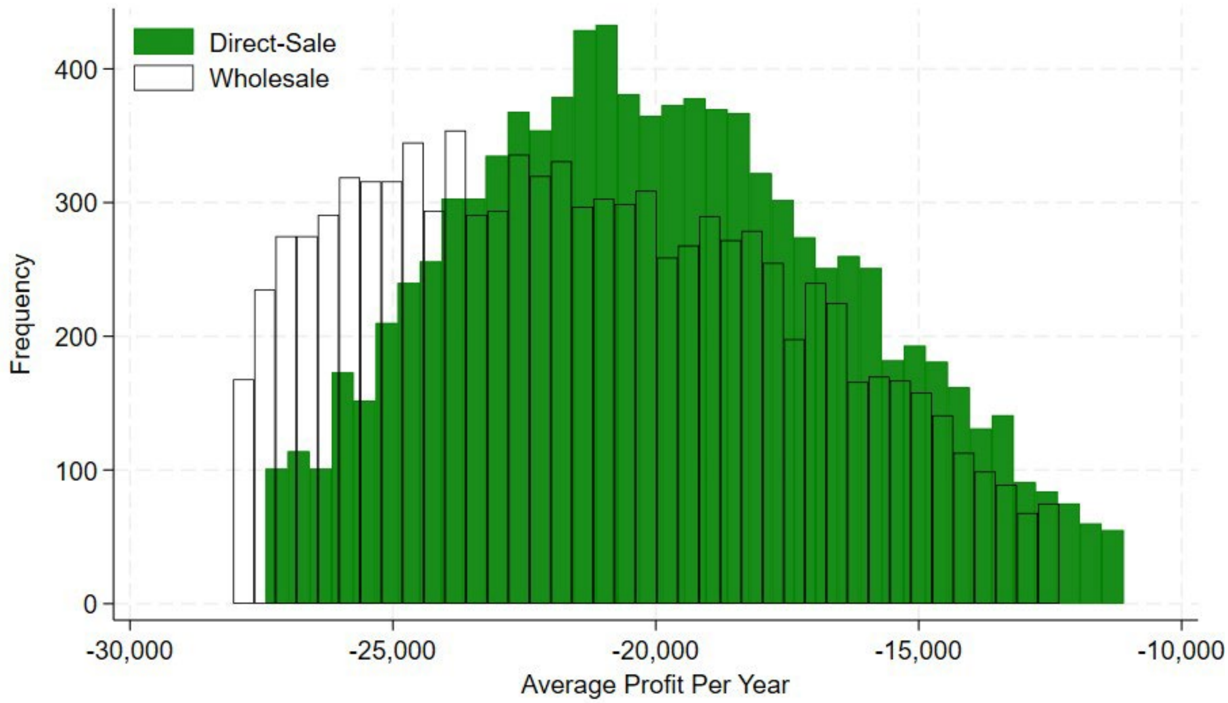

Figure A2. Histogram of Simulated Average Profit for 90,000 Oyster (0.5 acre) Farm Size.

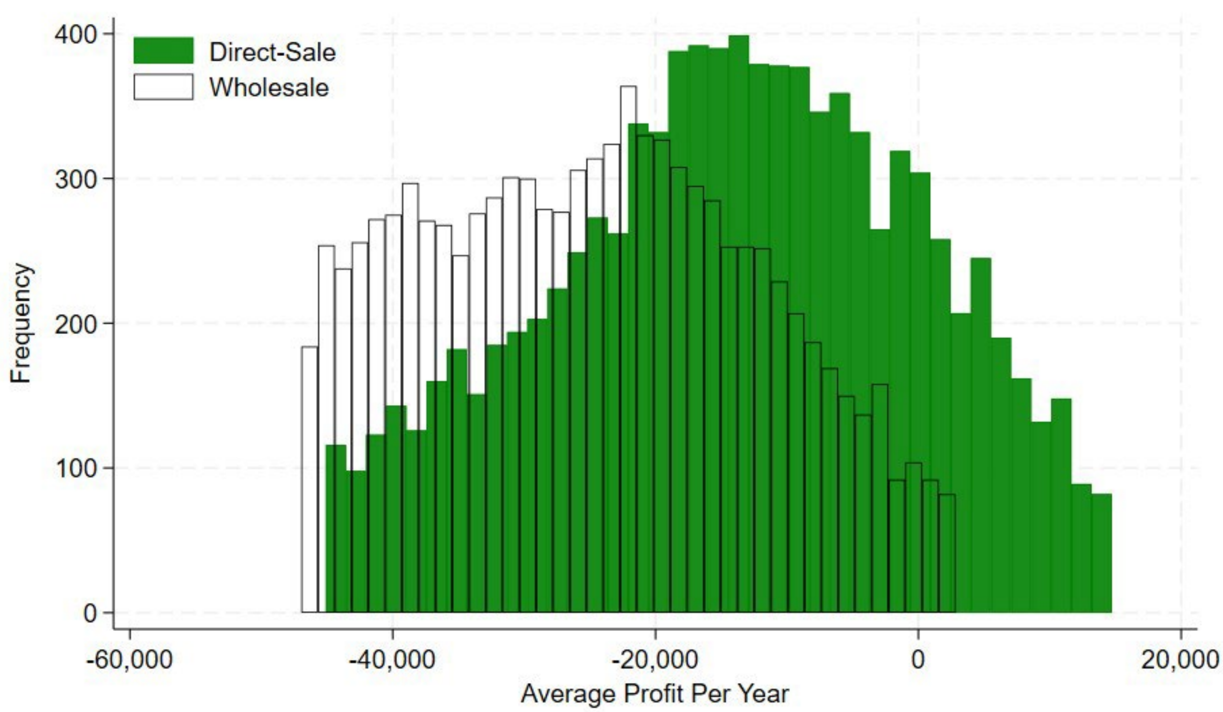

Figure A3. Histogram of Simulated Average Profit for 180,000 Oyster (1 acre) Farm Size.

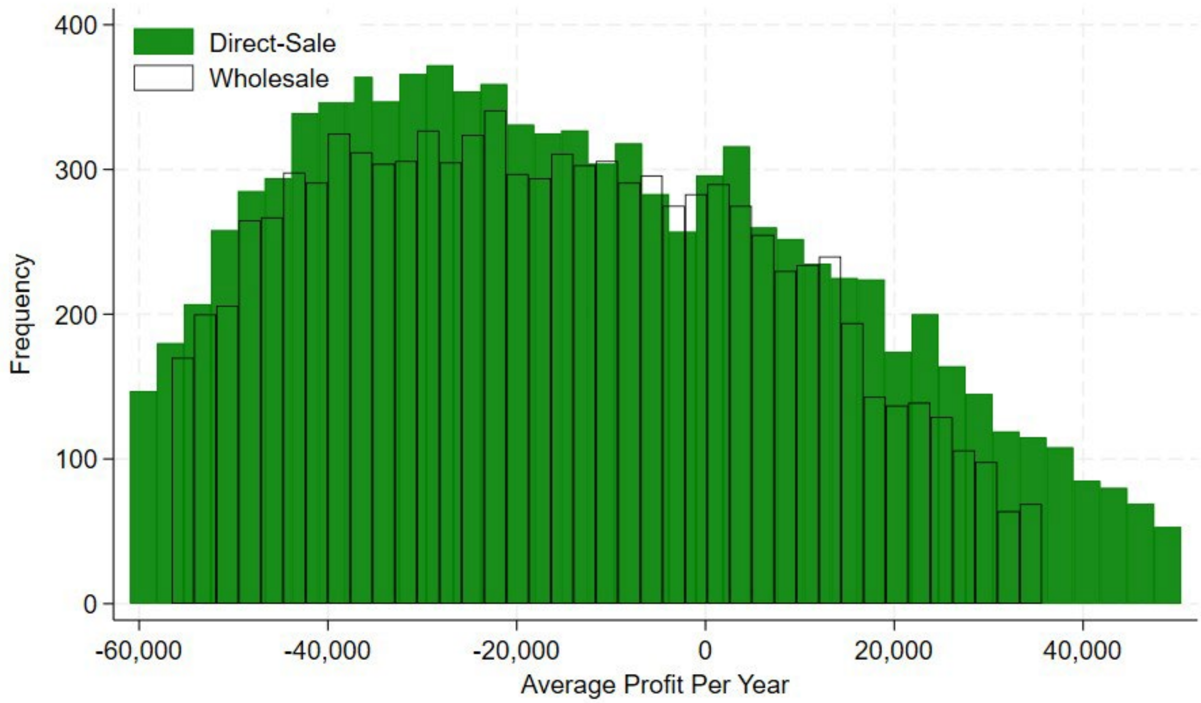

Figure A4. Histogram of Simulated Average Profit for 360,000 Oyster (2 acre) Farm Size.

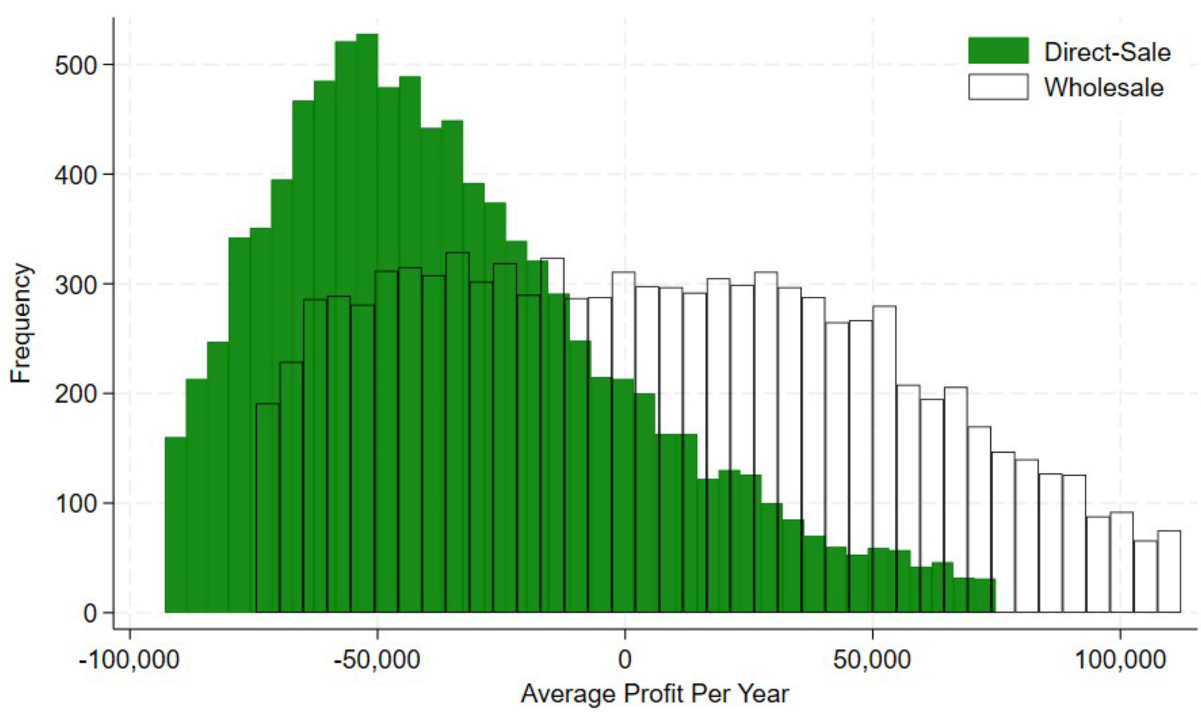

Figure A5. Histogram of Simulated Average Profit for 540,000 Oyster (3 acre) Farm Size.

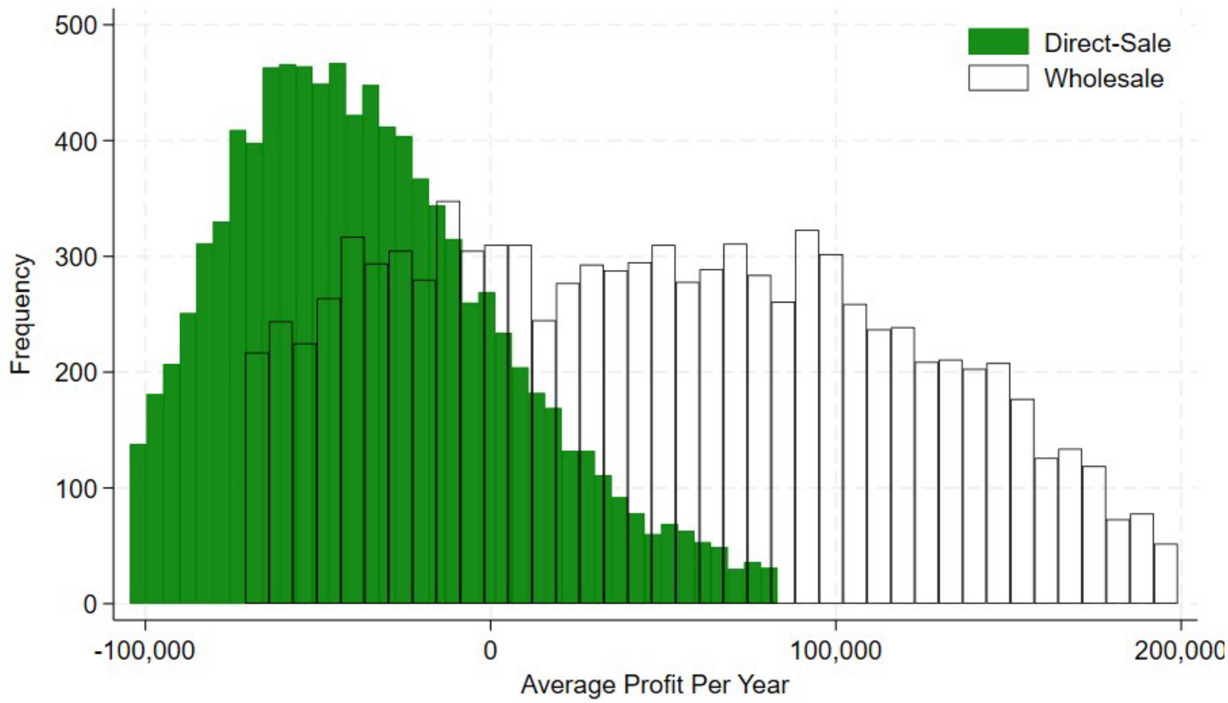

Figure A6. Histogram of Simulated Average Profit for 720,000 Oyster (4 acre) Farm Size.