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# Investigating the Drivers of Farm Diversification Among U.S. Fruit and Vegetable Operations

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**Abstract:** Diversification of an agricultural operation's crop mix is considered an environmental and financial management strategy. Environmentally, crop diversification can stabilize the ecosystem via the introduction of biodiversity, allowing for more rapid response to physical and social changes. Economically, crop mix diversification can mitigate risk. Though there are environmental and economic benefits of crop diversification, little economic work has been conducted on crop diversification outside of the row crop industry. This study estimated how internal and external factors affect crop diversification among fruit and vegetable (FV) operations. External factors included access to markets and land; internal factors included farmer beliefs and access to information from extension and network sources. An OLS regression was conducted using data from 1532 farmers across 16 states in the United States. Endogeneity was addressed using an instrumental variable approach and a score endogeneity test indicated that endogeneity was not an issue. OLS results indicate that selling locally increases diversification, while reliance on other farmers for information decreases diversification. A conditional quantile analysis was conducted to reveal factors' effects across different degrees of diversification. Quantile results indicate that selling locally, season extension technologies, and use of organic practices positively influence crop diversification across all levels of diversification. Receiving information from farmers negatively influences diversification for specialized farms, but positively influences diversification for highly diversified operations.

**Keywords:** farm diversification; fruit; vegetable; economic factors; marketing channels; specialty crops; local foods; local markets

## 1. Introduction

The fresh fruit and vegetable (FV) sectors in the U.S. have greatly increased over the past few years. The value of fruits produced domestically increased from $9.1 billion in 1995 to $21.3 billion in 2016 [1]. The value of vegetables produced domestically increased from $7.4 billion to $13.1 billion in the same period [2]. Similarly, imports of fresh market fruits increased from 15% to over 40% [1] and imported fresh vegetables increased from 13% to 29%, from 1995 to 2017 [3]. Increases in production and imports of FVs is mainly driven by a growing demand of fresh produce, coupled with federal and state initiatives to promote the consumption of FVs, and the growth local foods movement [4]. For example, the MyPlate initiative from USDA educates consumers on the value of FV in their diet and recommends that FVs occupy half of a plate per meal [5]. Further, consumers have become increasingly concerned with the source of foods, giving rise to local food movements and the growth of farmers markets and other farmer-sourced market outlets [6].

The phrase "don't put your eggs in one basket" captures the motivation of farmers to diversify under the current agricultural environmental and market climate. From a financial standpoint, diversification may mitigate risk and improve financial sustainability [7]. In contrast with farm specialization, in which success depends on economies of size, farm diversification is likely to rely on economies of scope and access to diverse markets [8]. By spreading risk through more products and selling them in niche markets (i.e., organic and agritourism), farmers can manage market saturation and price volatility [8]. Crop diversification may also be a response to government support to trade agreements, in which farmers would plant fewer crops to take advantage of crop subsidies (in North America and Europe) or plant a wider range of crops to protect against lower market prices (in the developing world) [9].

From an environmental standpoint, crop diversification is one of the main strategies adopted by farmers to mitigate long-term changes in climatic conditions around the world [10–12]. Diversified operations tend to build more stable ecosystems overtime allowing faster response to physical and social changes [13]. To illustrate, consider a situation where a farmer adds cover crops to her/his existing crop rotations. This enlarged crop mix can help promote root development and plant health of the upcoming planting and increase soil water retention, which tends to decrease the prevalence of pests [14,15]. Moreover, crop diversification has been shown to reduce pest and pesticides applications, and increase rice yield in Thailand [16]. Diversified agricultural operations can also be more resilient to increased temperatures and other natural shocks [17].

Several studies have investigated the impact of farm diversification [8]; however, current literature is lacking investigation of the drivers of crop diversification among FV operations in the U.S. Furthermore, there is little information indicating how diversification may be motivated by the choice of marketing channels. According to Izumi et al. [18], farm diversification could be one of the main strategies adopted by farmers as a way to respond to the increasing demand of local foods and farm-to-fork movements. For example, farmers selling in local markets may choose to grow more crops to showcase a colorful supply of FV, a marketing strategy that can help attract customers. Investigating the relationship between market channels and diversification can have major implications in the development of policies and incentives for sustainable agriculture.

A final motivation for this study relates to the definition of farm diversification in the FV industry. Numerous USDA reports, which tend to focus on traditional row crop production, indicate that a farm producing four or more crops is considered highly diversified. For example, with the surge of organic grains, the traditional row crop industry has begun exploring the value of adding more crops to the widely adopted corn–soybean rotation, and defines a diverse operation as those rotating three to four crops [19,20]. In the context of fresh market FV production, where the average operation grows 17 crops [21], a crop mix of three to four crops does not accurately represent farm diversification.

This study builds on Anosike and Coughenour [22] and Norman and Gilbert [23] to frame drivers of crop diversification as external and internal factors. While external factors are those outside the control of the farmer (e.g., market access), internal factors are those controlled by the farm owner (e.g., demographics). The objectives of this study are two-fold. First, the authors sought to identify external and internal factors influencing crop diversification of FV operations. Specifically, the results provide a detailed understanding of factors that promote or hinder crop mix diversification. Second, this study conveys a comprehensive picture of the effect of external and internal factors at different degrees of crop diversification (i.e., low, medium, and high diversification). Third, the study provides a categorization of crop diversification for fruit and vegetable operations.

The current study developed an identification strategy that addressed potential sources of endogeneity. First, an extensive list of variables at the individual and farm levels were utilized. Additionally, an instrumental variable approach (IV) was used to control for unobserved factors that may motivate farmers to sell locally and diversify their crop mix. Endogeneity was tested using an endogeneity score test [24] and results indicated endogeneity was not an issue, thus robust OLS regression results were used. Lastly, a robust quantile regression was used to assess the effect of the explanatory variables on specific quantiles of the response variable (number of crops). The quantile regression allows comparison of how certain factors may affect different degrees of crop diversification.

## 2. Literature Review

This study builds on Kremen et al. [25] to define crop diversification as the intentional biodiversity of inputs and outputs in an FV production system. In this context, crop diversification is a strategy adopted by FV farmers to survive and even thrive in today's agricultural markets. According to Pingali and Rosegrant [7], farmers can adopt two types of diversification: market and crop diversification. This study focuses on crop diversification among fresh market FV farming operations, and defines it as the inclusion and/or rotation of multiple crops in the production system.

### 2.1. Characteristics of U.S. Fruit and Vegetable Operations

The size of the FV industry reached over $48 billion in sales according to the 2017 Census of Agriculture [23]. One way to categorize FV farms is by the annual gross sales in dollars. In the present study, small farms are defined as those with less than $50,000 in annual sales, while medium and larger operations exceed $50,000 in gross sales [26]. According to the 2017 Census, over 80% of vegetable and 73% of fruit and tree nuts operations were small farms. Acreage is another way to characterize farm size. Data from the 2017 Census reported there were 74,276 vegetable farms comprising nearly 4.4 million acres of farm ground in 2017 [26]. Of those, 18,618 operations (25%) farmed less than 1 acre and only 94 operations farmed 5000 acres or more. Noncitrus fruits were grown on almost 75,000 farms comprising almost 2.2 million acres, with approximately 13% farming in less than 1 acre. Additionally, citrus fruits were grown on over 12,000 farms on nearly 825,000 acres. Similarly to noncitrus fruits and vegetables, citrus fruit farms were notably small farms.

Market opportunities for fresh market FV have generated two main trends among fresh market FV growers. On one hand, the demand for local foods and farm-to-fork movement has resulted in the growth of direct-to-consumer (DTC) and intermediate market channels [27]. Local foods are primarily sourced from two markets, with DTC sales accounting for approximately 20% and intermediate sales accounting for the remaining 80% [28]. Direct-to-consumer markets are defined as channels where the farmer makes direct contact with the customer such as farmers' markets, internet sales, Community Supported Agriculture (CSA), at-farm sales, and festivals. Intermediate markets include sales to local and regional distributors and independent grocery stores, restaurants, and other local retailers [29]. As the demand for local foods increased, the participation of farmers in local food systems adjusted accordingly. In 2012, about 8% of U.S. farms sold their produce directly to consumers, an increase of 6% since 2007 [30]. By selling through direct-to-consumer (DTC) market channels, farmers are more likely to improve farm resiliency to market saturation and volatility [15], and to increase profitability and access to price premiums [31,32].

On the other hand, the growth in the demand of FV supports farmer motivations to increase farm size through mergers and land acquisition. Literature has reported that due to the benefits from economies of size, larger operations are more likely to specialize [22,33]. In other words, when operations are large, economies of size offer incentives to grow few crops to increase productivity and decrease the production costs. This farm specialization has been labeled as the industrialization of farming [34]. Crop specialization may also limit the types of markets where farmers sell, as farmers markets tend to promote FV differentiation [35]. Considering larger production of fresh market FVs, these specialized producers may be better suited to succeed in an environment where large wholesalers and food distributors are their main customers.

### 2.2. Crop Diversification among Fruit and Vegetable Operations

Researchers have reported farmers around the world grow diversified crop systems as a major strategy to manage climatic and market changes [11]. A study conducted in Thailand, China, and Vietnam showed that expanding the crop mix reduced pests and pesticide applications, and increased rice yields, leading to improved economic standing [16]. Additionally, it is predicted that African agriculture will become more profitable via diversified crop and livestock operations as the global climate continues to experience more extreme temperatures [17]. In Italy, Moretti et al. [10] found that crop diversification may be a substitute for adopting disaster insurance and an important risk management strategy.

The present study builds on Anosike and Coughenour [22] and Norman and Gilbert [23] to frame the drivers to crop diversification. These researchers proposed a framework to explain how external and internal drivers impact farm diversification. External factors are those outside the control of the farm owner, such as market access, institutions, and cultural factors [22,23]. Internal factors are those controlled or modified by the farm owner, such as demographics, labor, and inputs [22,23]. According to economic theory, external and internal factors driving farm diversification can be further divided into three motives: risk management, efficiency gains, and market access [36]. Risk arguments propose that farmers have an incentive to spread risks associated with agricultural production over multiple outputs to generate a more stable income stream [36]. While efficiency gains are related to the advantages obtained from economies of scope, in which producing FV jointly is less costly than separately [36].

### 2.3. External Factors Influencing Crop Diversification

Agricultural markets are ever-changing with the introduction of new technologies and crops, in addition to variable consumer preferences. Under this scenario, farmers are likely to experience risk and uncertainty, for which farm diversification can be adopted as a reasonable risk management strategy to thrive in the current agricultural setting [37]. Diversification allows farmers to spread risk over multiple inputs/outputs while achieving economic and environmental resilience [34,38]. Changing climatic conditions can motivate farmers to diversify their crop mix as a major risk management strategy [12]. A diverse crop mix provides farmers with diversity in income sources and a "natural" form of insurance to overcome weather and market variations [10,11].

There are multiple external factors influencing the adoption of crop diversification, such as control of market volatility and saturation [38], availability of new growing technologies [7], potential labor and input costs [7], and access to markets and farmland [39]. Access to land proves a major factor for diversification among agricultural operations [39,40]. Lack of access to farmland can constrain farmers to remain small, where product differentiation, local labelling, and selling to high-value markets help farmers overcome lower yields and remain profitable [39,40]. Consider a situation where a farmer is leasing farm ground. A situation such as this could discourage that farmer from making long-term improvements to soil health and pest resistance, including diversification of the crop mix. Therefore, crop mixes on leased land may be less diverse than crop mixes on owned land [39], as the farmer may not be as invested in improving the soil health and resilience of future crops. According to the separation theorem [41], the decision to diversify the crop mix can be considered independent from the extent of the commitment to leasing land. In other words, while land ownership is likely to affect land conservation practices, the authors expect major leasing conditions such as lease type, duration or amount of land leased to not impact land stewardship practices such as crop diversification [42].

Crop diversification can also be seen as a strategy of farmers to improve access to high-value local markets. Most fruit and vegetable farmers tend to sell their produce through two main outlets: DTC and wholesale markets [43]. Kremen et al. [44], found farmers selling in DTC markets are more likely to have strong and direct relationships with customers. By relying on customer–farmer relationships, DTC markets tend to provide farmers with customer feedback allowing supply adjustment that matches consumer preferences [43,45]. This direct feedback is likely to have a direct impact on the crop mix of local farmers, some of them growing up to 40 fruits and vegetables [21]. The authors expect that farmers selling in DTC markets tend to grow and offer a wide variety of crops not only to attract customers to their stands, but also to comply with their adoption of organic or sustainable practices, which involve growing more crops, than their conventional counterparts [46].

The 2017 Census of Agriculture reported most FV production comes from either few large operations or many small farms [23]. As agricultural production becomes consolidated into larger operations to access wholesale markets, many small and mid-sized farms are selling directly to consumers through local markets [47,48]. Though this movement started as a survival strategy for smaller farms, rise in consumer interest regarding the location and people involved in growing food expedited the growth of the movement [49]. Rushing and Ruehle [50] found that two-thirds of consumers purchase local foods in an effort to support the local economy. Further, community supported agriculture (CSA) has increased from two CSAs in mid 80s to nearly 3700 by 2009 [51]. Additionally, the USDA's farm to school programs totaled nearly 39,000 schools participating in the 2011–2012 school year [52]. This growth in consumer interest provides benefit to local, and presumably, small farms.

On the other hand, selling to wholesalers and food distributors seems to facilitate the adoption of crop specialization [53]. Trends such as the industrialization and vertical integration of farms aim to achieve higher productivity and a more competitive operation, in which farmers leverage on economies of scale to specialize in fewer crops [53]. Operations that are able to specialize tend to be larger in size, such that levels of land and financial capital allow the operation to participate economies of size, permitting farmers to access wholesale markets with large volumes [34].

Access to support networks such as University Extension services, other farmers, and farmers associations can motivate farmers to change crop mixes and crop rotations [54,55]. While extension often serves as the primary source of information about new agricultural technologies [56], information spreading by word of mouth is also key to the flow of information. Farmers have been shown to have either a direct or indirect influence on other farmers in their area [57], allowing information to quickly spread throughout the farmer network. The rationale for the network effect is that having access to technical information and business opportunities can motivate farmers to adopt new production strategies [54].

Access to production technologies can also impact the adoption of crop mix diversification among FV operations. One such technology is the high tunnel greenhouse. The use of high tunnels allows producers to lengthen the production season, while improving yields and enhancing pest and disease management [58]. Depending on the location, farmers using high tunnels can extend harvesting season and potentially receive price premiums for early- and late-season local crops. The adoption of high tunnels has been supported by the USDA-NICS EQIP (Environmental Quality Incentives Program), which assists farmers in the financial responsibilities related to high tunnel adoption. This program has aided with the installation of over 2400 high tunnels in KY, IL, IN, IA, GA, OH, TN, and WV [59].

Farmers may also choose to diversify due to policy changes and incentives. Bradshaw and Smit [60] reported that farmers in Saskatchewan diversified their crop mix after the removal of incentives from the Western Grain Transportation Act and the Gross Revenue Insurance Plan. There are many programs in place to support sustainable and diversified farming. At the federal level, the USDA has created the Sustainable Agriculture Research and Education (SARE) division in order to promote research that will support sustainable agriculture. Many university Extension programs exist to support diversified and sustainable farming, such as Purdue University's Diversified Farming and Food Systems, the University of Minnesota's Minnesota Institute for Sustainable Agriculture, and Michigan State University's Michigan Organic Farming Exchange within the Center for Regional Food Systems.

The United States Agricultural Act of 2014 [61] also provides some distinct incentives for farms that choose to diversify their production. Through this act, government microloans of up to $50,000 are available to small and beginning farmers that plan to start a diversified operation aiming to serve local markets. The Agricultural Act of 2014 offers whole farm revenue protection for diversified farms, making revenue available to protect against low yields or price drops. Interestingly, according to this legislation, diversified farms are considered those which produce two or more crops. Numerous USDA reports indicate that a farm producing four or more crops is considered highly diversified [19,20]. However, most of these reports focus on row crop grain production. Given the data, it is evident that the USDA definition of diverse farms is not applicable as the present sample indicates that FV operations grow on average 17 crops with a maximum of 49 crops.

### 2.4. Internal Factors Influencing Crop Diversification

Diversification in agricultural production can be considered both financially and environmentally sustainable. A study conducted in Belgium classified farmers into successful and unsuccessful enterprises, using income below the poverty line as the determining factor to categorize these operations [32]. Successful operations were also classified as problem-solving farmers that had adopted some form of agricultural diversification [32]. Thus, diversification presents as one methodology for farm survival and success.

Expectations of increased farm income seems to be an important driver of crop diversification. A study analyzing diversification among Texas farmers revealed that diversification is a useful method to contribute to increased farm income [39]. Farm diversification has been positively correlated with farmer's skills, entrepreneurial mindset, and farming experience. Entrepreneurial skills and strategic mindset have been strongly correlated with farm diversification in developed and less developed countries [62,63]. Similarly, age and farming experience seem have been cited as a strong predictor of farm diversification strategies [64,65]. In addition, diversification of farm enterprises results in increased leverage of resources allowing more flexibility to adapt to new demands of the agricultural system, expand into new markets, and keep labor fully employed [39]. Farmer perceptions related to farming systems can also influence the diversification of crop mixes. The belief that specialization can help achieve higher technical efficiency can discourage the adoption of crop diversification [33]. Alternatively, farmers may be motivated to diversify the crop mix to balance the family–business interface through the creation of new enterprises [66].

## 3. Data and Methodology

### 3.1. Data Description

The data for this analysis was sourced from a 2012 web-based survey of fruit and vegetable farmers contained in the Food Industry MarketMaker database. The database provided 4312 mail addresses and 3015 email addresses of growers located in sixteen states (AL, AR, DC, FL, GA, IA, IL, IN, KY, MI, MS, NE, NY, OH, PA, and SC). The questionnaire was reviewed by knowledgeable colleagues and analysts to elicit suggestions based on experience with previous surveys and knowledge of study objectives [67]. Using cognitive interviewing, the survey questionnaire was pretested with 20 farmers that composed the farmer advisory board of the project. Farmers were visited and the questionnaire was used to identify potential problems for respondents during data collection and analysis. Revisions were made to the survey questionnaire and design and the survey was presented to researchers non-related to the subject to obtain final feedback. The Purdue University Institutional Review Board for compliance with ethical standards for human research approved the questionnaire and survey protocol.

A 53-question web-based survey was conducted using a mixed-mode design. To increase participation rate, a two-dollar bill was included in the invitation letter and email reminders were sent at two-week intervals. A total of 1559 farmer responses (36% response rate) were received, which is considered an effective rate for similar methodologies [67]. The survey asked for farm characteristics, farmer demographics, sources of information, and farmer beliefs and perceptions towards their farm and agriculture. This study focused on a sample of 1532 farmers that, on average, grew 17 crops and sold through three market channels. Twenty-seven farmers were removed from this study because they did not report growing any crops. A sample of only farmers growing crops provided clear-cut results and allowed investigation of the driving factors to on-farm diversification. Table 1 describes the variables used in this study, such as dependent variables, farm characteristics, farmer demographics, and farmer perceptions and beliefs.

**Table 1.** Categories, means, standard deviations, and descriptions of the variables used to investigate the drivers of crop diversification among fruit and vegetable farmers of 16 U.S. states (N = 1532 farmers).

| Variable | Obs | Mean | Std. Dev. | Description |
|---|---|---|---|---|
| Dependent variable | | | | |
| NCROPS | 1532 | 16.57 | 12.77 | Number of crops |
| Explanatory Variables | | | | |
| DTC | 1451 | 0.42 | 0.49 | 1 = if farmer uses only direct to consumer market channels (at farm, farmers markets, CSA, internet, roadside stands, delivery, word of mouth, festivals) |
| ONLYFRUIT | 1532 | 0.13 | 0.34 | 1 = if farmer grows only fruit crops (Reference Group) |
| ONLYVEG | 1532 | 0.18 | 0.38 | 1 = if farmer grows only vegetable crops |
| FRUITVEG | 1532 | 0.65 | 0.48 | 1 = if farmer grows fruit and vegetable crops |
| ORGANIC | 1456 | 0.36 | 0.48 | 1= if farmer has acres being organic certified, transitioning to certification, or using organic practices |
| NMARKET | 1532 | 2.77 | 1.87 | Number of market channels including DTC, wholesale, processors, restaurants, retail, schools, wineries, and miscellaneous |
| SEASONEXT | 1408 | 0.51 | 0.50 | 1 = if farmer uses season extension: hoop-house, greenhouse, high tunnels |
| TLAND | 1413 | 211.11 | 532.54 | Number of acres farmer rents or own |
| RENT | 1406 | 0.32 | 0.47 | 1 = if farmer rents land |
| SOLE | 1398 | 0.61 | 0.49 | 1 = if farm's business structure is sole proprietorship |
| LABOR | 1393 | 8.04 | 19.40 | Number of people working on the farm including family members and respondent |
| SOUTH | 1532 | 0.15 | 0.35 | 1 = in Florida, Georgia, South Carolina, 0 otherwise |
| DELTA | 1532 | 0.07 | 0.25 | 1 = in Alabama, Arkansas, Mississippi, Louisiana, 0 otherwise |
| MIDWEST | 1532 | 0.51 | 0.50 | 1 = in Iowa, Illinois, Indiana, Michigan, Nebraska, Ohio, and Kentucky, 0 otherwise |
| NORTHEAST | 1532 | 0.18 | 0.39 | 1 = in New York and Pennsylvania, 0 otherwise (Reference Group) |
| SMALL | 1343 | 0.59 | 0.49 | 1 = if annual gross sales are $50,000 or less (Reference Group) |
| MEDIUM | 1343 | 0.41 | 0.49 | 1 = if annual gross sales are larger than $50,000 |
| COLLEGE | 1532 | 0.55 | 0.50 | 1 = individual has college degree or postgraduate work |
| FEMALE | 1532 | 0.30 | 0.46 | 1 = if farmer is female |
| NOWHITE | 1375 | 0.06 | 0.23 | 1 = if farmer is black, African American, American Indian, Asian, Multiracial, or other race |
| PARTTIME | 1386 | 0.41 | 0.49 | 1 = if farmer works in the farm part-time |
| YFARM | 1412 | 21.53 | 15.92 | Number of years farming |
| YFARM2 | 1412 | 716.88 | 963.59 | Square of number of years farming |
| INFOEXTENSION | 1384 | 0.75 | 0.43 | 1 = if farmer perceives university extension provides useful information |
| INFOFARMER | 1390 | 0.62 | 0.49 | 1 = if farmer perceives other farmers provide useful information |
| SATISFIED | 1413 | 0.84 | 0.36 | 1 = if farmer is satisfied with his/her present farming system |
| POSEXPECT | 1453 | 0.55 | 0.50 | 1 = if farmer has positive expectations for the future years |
| ORGDIVERSE | 1160 | 0.45 | 0.50 | 1 = if farmer perceives organic is a good way to diversify his/her operations |

The authors used attitudinal questions to examine farmer perceptions towards their current farming system (SATISFIED), the future (POSEXPECT), and the influence of organic agriculture as a good way to diversify (ORGDIVERSE). Likert-like scales were chosen because of their easiness to be responded in an web-based survey and their good performance to capture farmer perceptions [68,69]. Perceptions were rated on a five-point Likert-like scale from strongly disagree (1) to strongly agree (5). The variables using Likert-like scales were dichotomized such if the respondent answered somewhat agree (4) and strongly agree (5), the variable would be equal to 1, and zero otherwise.

### 3.2. Theoretical Framework

The mean-variance (E-V) approach, an extension of utility theory, was utilized to model the decision of a farmer to choose the appropriate crop mix that maximizes income utility [64]. Under this approach, utility depends on the mean and variance of returns. The mean-variance approach can be considered a valid first approximation of farmer's behavior under the assumptions that a farmer maximizes his/her expected utility and either the distribution of returns involves only the mean and variance, or the underlying utility function is approximately quadratic in income. Markowitz's [70] utility function of income $U(E, V)$, where $\frac{dU}{dE} > 0$ and $\frac{dU}{dV} < 0$ served as beginning framework for the present model. The preference function can be linearized to $U(E, V) = E - b$, where b represents the risk component of the farm operator. To simplify Equation (1) models the selection of two diversification portfolios, in which the equation maximized is

$$U(Z) = \lambda\mu_x + (1-\lambda)\mu_y - b\left[\lambda^2\sigma_x^2 + (1-\lambda)^2\sigma_y^2 + 2\left(\lambda - \lambda^2\right)\sigma_{xy}\right] \quad (1)$$

where Z represents the aggregated return from both portfolios x and y, $\lambda \geq 0$ is the fraction of total portfolio allocated to portfolio x and $1 - \lambda$ is the fraction allocated to portfolio y. In Equation (1), $\mu_x = E(X)$ and $\mu_y = E(Y)$ are the expected mean of returns from each diversification portfolio. The variance of returns from portfolios x and y is $\sigma_x^2$ and $\sigma_y^2$, respectively. Lastly, the covariance of returns is $\sigma_{xy}$. Under this scenario, the expected value of returns for each portfolio is

$$E(Z) = \lambda\mu + (1-\lambda)\mu_y \quad (2)$$

and the variance of returns for the same portfolio is

$$\sigma_z^2 = \lambda^2\sigma_x^2 + (1-\lambda)^2\sigma_y^2 + 2\left(\lambda - \lambda^2\right)\sigma_{xy} \quad (3)$$

Farmers were assumed to maximize U and the level of $\lambda$, which yields the following first-order condition:

$$\frac{dU}{d\lambda} = \mu_x - \mu_y - b\left[2\lambda\sigma_x^2 - 2(1-\lambda)\sigma_y^2 + (2-4\lambda)\sigma_{xy}\right] = 0 \quad (4)$$

An empirical representation of the first-order condition that related diversification to internal and external explanatory variables, is given by

$$Y_i = Z_i\beta + \psi_i \quad (5)$$

where $Y_i$ is the measure of diversification; $Z_i$ is the vector of internal and external explanatory variables; $\beta$ is the vector of parameters to be estimated; and $\psi_i$ is the residual term.

### 3.3. Empirical Model and Estimation

The empirical model of Equation (5) can be expressed as

$$D_i = \beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \ldots + \beta_k X_{k,i} + \phi_i \quad (6)$$

where $D_i$ is the level of crop diversification, X is the vector of explanatory variables, and β is the vector of unknown parameters to be estimated.

In the current model it is proposed that crop diversification, measured by the number of crops grown by FV farmers, is a function of the internal factors represented by the vector X that includes access to markets and land availability, and external factors represented by the vector Z that includes farm and farmer characteristics. The model is such that:

$$\mathrm{NCROPS} = \beta_0 + X\beta_1 + Z\beta_2 + e_i \tag{7}$$

First, an ordinary least square (OLS) regression with robust standard errors was used to assess the effect of external and internal factors on the adoption of crop diversification among FV operations. The dependent variable, NCROPS, is the number of crops grown by a respective farmer, which varies from 1 to 49 crops. The average number of crops grown by FV operations was 17, while the median was 15 crops. Preliminary results indicate that the OLS model meets the normality assumption that applies to errors [71], in which errors in the OLS regression are independent and identically distributed (i.i.d). Thus, it was confirmed that the dependent variable NCROPS did not need to be transformed to the logarithmic form.

The key explanatory variables are the external (X) and internal (Z) factors influencing the adoption of crop diversification. The authors hypothesized that farmers selling mainly in local markets are more likely to diversify their crop mix, which is due to the strong customer–farmer relationship that allows farmers to receive direct feedback from customers and adapt produce supply to match consumer preferences [43,45]. Additionally, operations having more farmland were expected to rely on economies of scale and specialize their operation [22,33]; thus, it was hypothesized that access to farmland is a barrier to crop diversification.

The vector Z controlled for an extensive set of internal farmer- and farm-level factors that affect the decision to diversify. Farmer demographics included education, gender, race, part-time status, and farmer's experience and perceptions. Other internal variables include farm characteristics were growing only fruit crops, production practices, ownership status, legal structure, and location. Table 1 describes the all explanatory variables used in this study, as well as the respective means and standard deviations.

### *3.4. Dealing with Heteroskedasticity, Multicollinearity and Endogenity*

To address the potential of heteroskedasticity, the dependent variable (NCROP) was transformed using a natural log transformation. Skewness of NCROP and its natural log transformation were investigated along with normality of errors. The natural log transformation is not considered in this analysis as the normality of error terms was better in the untransformed variable. To consider multicollinearity, the variance inflation factor (VIF) was calculated for each of the independent variables. Values of the VIF did not indicate any concerns for multicollinearity, and the average VIF was 2.16.

While the set of control variables is extensive, it is possible that unobserved factors can lead to farmers selling in local markets and adopting crop diversification as a way to contribute to the biodiversity of community and farming system [22,72]. To address potential endogeneity, the authors used an instrumental variable approach as an auxiliary model to control for bias caused by omitted variables [73], in which the instrumental variable (i.e., average distance to markets in miles and number of farmers markets in the state where farmer is located) was designed to extract the exogenous variation in access to local markets [4]. Results from the Chi-Square Wooldridge's score endogeneity test [24] indicates that the IV approach does not seem to be endogenous (Chi-square = 0.78; P-value = 0.79), which suggests that endogeneity is not an issue. Thus, this study uses OLS coefficients to provide results and draw conclusions on the drivers of crop diversification.

### 3.5. A Quantile Model to Esimate the Drivers of Diversification at Different Degrees of Diversification

OLS estimates provide the average effect of the explanatory variables over the mean of the dependent variable *NCROPS*. However, it is likely that, for example, the effect of selling locally has a different effect for highly diversified farms than for those growing fewer crops. Similarly, access to more farmland may have a different effect for specialized and highly diversified operations. A conditional quantile regression (CQR) approach with robust standard errors was utilized to control for the effect of the explanatory variables on the distribution of the dependent variable [74]. The use of a CQR was motivated by the documentation of a significant degree of heterogeneity in crop diversification among FV operations, illustrated in Figure 1.

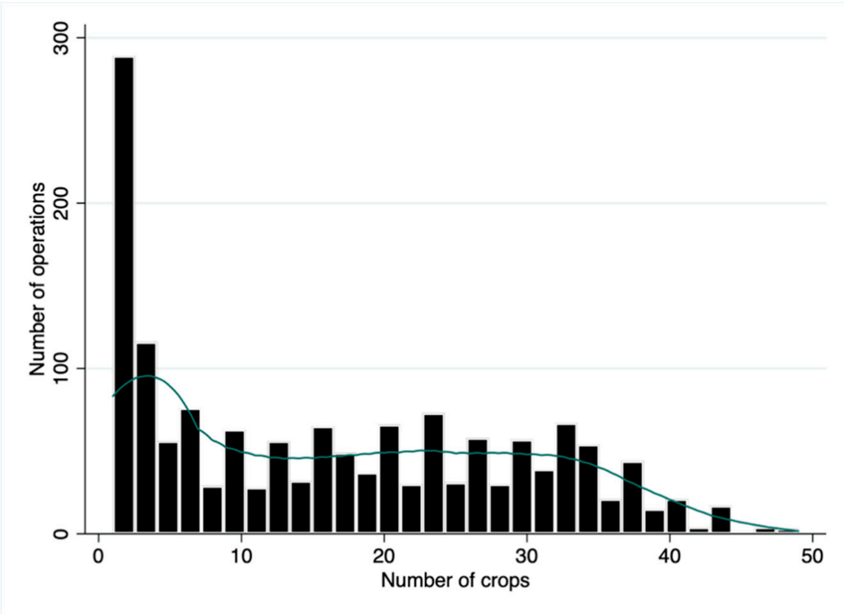


**Figure 1.** Frequency (bars) and kernel density (line) distribution of the number of crops.

Figure 1 shows that the largest share of producers with fewer crops gathered at the lower and mid-level of crop diversification. In this case, OLS would fail to capture such heterogeneity, as this model assumes that the dependent variable *NCROPS* has the same behavior at upper and lower tails of the distribution, as it does at the mean. In contrast, the CQR captures the distribution of the conditional mean of *NCROPS* by weighting different portions of the sample to generate coefficient estimates. By characterizing the effect of the explanatory variables on the entire distribution of *NCROPS*, the quantile regression provides a much more complete picture of the factors influencing crop diversification. The CQR is given by Equation (8), which models the change in conditional explanatory variables at the q$^{th}$ quantile:

$$Q_\tau(y_i|x_i) = x_i\beta_\tau \tag{8}$$

with $Q_\tau(y_i|x_i)$ being the conditional quantile function at quantile $\tau$, with $0 < \tau < 1$. The vector $x_i$ includes the same covariates as in Equation (7). The vector $\beta_\tau$ is the vector of parameters to be estimated at quantile $\tau$, which were obtained via minimization using linear programming methods [75]. Quantile functions were estimated simultaneously at four different levels of the conditional distribution of *NCROPS* ($\tau$ = 0.25, 0.50, 0.75, 0.99).

One of the major contributions of the CQR methodology is that quantile estimations provide a categorization of different degrees of farm diversification. For example, farms in the 0.25 quantile grew between one to four crops, which can be categorized as specialized operations. On the other hand, farms in the 0.50, 0.75, and 0.99 quantile were categorized as those with low (5 to 15 crops), medium (16 to 28 crops), and high diversification (29 to 43 crops), respectively. A Wald test was utilized to determine if the slopes of the explanatory variables were equal between different pairs of quantiles. A statistically significant Wald test statistic leads to the rejection of the null hypothesis of equal slopes, implying that the explanatory variable effect is not constant across the distribution of NCROPS, which justifies the use of CQR.

## 4. Results

### 4.1. Summary Statistics

Table 1 illustrates the descriptive for key variables in Equation (7). The results show that the average farmer produced a diverse variety of crops. On average, farmers in the sample grew 17 fruit and vegetable crops. Almost half of farm owners (42%) sold only in local markets, while the other 58% sold fresh produce to wholesale markets or a mix of wholesalers and DTC. The average farm size was 211 acres, which is notably less than the 434 acres average farm size reported in the 2012 Census of Agriculture. One explanation for this is that the census is a complete count of U.S. farms and ranches that produce not only fruits and vegetables, but also grains, oilseeds, dry beans, and tobacco. Most of the operations in the sample (65%) grew a mix of fruit and vegetable crops, and 51% utilized season extension technologies such as hoop houses, greenhouses, or high tunnels. About a third of respondents (36%) reported using organic agricultural practices.

Consistent with the Census of Agriculture, most respondents (60%) were small operations, with annual gross sales of $50,000 or less. Results showed that nearly a third (32%) of farmers rented their land, and 61% of the operations were structured as sole proprietorships. The flexibility of sole proprietorship may be appealing to specialty crop farmers, especially among those that prefer to engage in local markets and grow a highly diverse mix of crops [4]. The average farm labor was eight employees, including family members and the farm owner. Most of the survey respondents (51%) were located in the Midwest, which includes states such as Iowa, Illinois, Indiana, Michigan, Nebraska, Ohio, and Kentucky.

The majority of farmers (55%) that responded to the survey had obtained college education and nearly a third of farms (30%) had female principal operators. Consistent with the 2012 Census of Agriculture, a little over 40% of farm owners operated their farm as a part-time business. The degree of satisfaction with the farming system (84%) and positive expectations regarding the future (55%) among survey respondents was high. Similarly, most of the farmers reported relying on support networks to obtain useful information. Three quarters (75%) of farmers received useful information from University Extension services and 62% from networks with other farmers.

### 4.2. Results from the OLS Model

Table 2 contains the coefficients and robust standard errors from the OLS model. Selling locally and directly to consumers significantly increases crop diversification under the OLS regression. The results provide empirical evidence that selling in local markets is a major factor influencing crop diversification among fruit and vegetable operations ($P < 0.01$). Selling directly to consumers, on average, increases farm diversification by three additional crops. One explanation is that farmers selling in local markets tend to trust in farmer–customer relationships to receive direct feedback from customers [4]. This feedback allows farmers to adapt their crop mix and production practices to meet demand. Another explanation is that crop diversity contributes to colorful supply of FV, which is considered an important marketing strategy to attract customers in local markets [76].

**Table 2.** Results from the ordinary least square (OLS) robust regression to explain crop diversification.

| | OLS | | |
|---|---|---|---|
| | **Coef.** | **Std. Err.** | **P-Value** |
| DTC | 2.34 | 0.65 | 0.00 |
| ONLYVEG | 3.18 | 0.74 | 0.00 |
| FRUITVEG | 13.89 | 0.67 | 0.00 |
| ORGANIC | 5.93 | 0.65 | 0.00 |
| NMARKET | 1.31 | 0.20 | 0.00 |
| SEASONEXT | 5.64 | 0.62 | 0.00 |
| TLAND | 0.01 | 0.00 | 0.90 |
| RENT | 0.52 | 0.61 | 0.40 |
| SOLE | 0.36 | 0.59 | 0.54 |
| LABOR | –0.02 | 0.01 | 0.05 |
| SOUTH | –3.58 | 0.98 | 0.00 |
| DELTA | –1.74 | 1.06 | 0.10 |
| MIDWEST | –0.42 | 0.74 | 0.56 |
| MEDIUM | –0.93 | 0.71 | 0.19 |
| COLLEGE | –0.44 | 0.54 | 0.42 |
| FEMALE | 0.85 | 0.63 | 0.17 |
| NOWHITE | 1.04 | 1.20 | 0.39 |
| PARTTIME | –1.73 | 0.65 | 0.01 |
| YFARM | –0.04 | 0.05 | 0.47 |
| YFARM2 | 0.00 | 0.00 | 0.28 |
| SATISFIED | 0.97 | 0.75 | 0.20 |
| POSEXPECT | 0.73 | 0.56 | 0.19 |
| ORGDIVERSE | –0.16 | 0.56 | 0.78 |
| INFOEXTENSION | 0.53 | 0.66 | 0.42 |
| INFOFARMER | –1.25 | 0.56 | 0.03 |
| INTERCEPT | –1.50 | 1.71 | 0.38 |
| N. Obs | | 1047 | |
| Prob > F | | 0.0 | |
| $R^2$ | | 0.54 | |

The largest effect on increasing crop diversification is obtained by growing a combination of fruit and vegetable crops (+14 crops; $P < 0.01$), using season extension technologies (+6 crops; $P < 0.01$), growing crops organically (+6 crops; $P < 0.01$). Growing vegetables is typically more economically feasible and requires less land than fruit production systems [77]; thus, it is suspected that increasing the diversity of vegetable and fruit crops is usually perceived as a profitable strategy. In addition, the market volatility and saturation of vegetable crops may influence farmers to find new varieties to differentiate in the marketplace. For example, in a farmers' market saturated with tomatoes, a producer may decide to produce a highly appealing variety of tomatoes, such as heirloom, that few competitors in the market sell, allowing them to differentiate themselves in the marketplace. Similarly, selling peaches, apples, cucumbers, and tomatoes, among a mix of fruits and vegetable crops, can provide farmers with more colorful displays to attract more customers looking for a one-stop shop. Organic fruit and vegetable farmers are more likely to use crop rotations of specialty varieties and grow a larger number of crops than those farming conventionally [4]. Growing crops in season extension technologies helps farmers prolong the growing season, command higher prices for selling produce before and after the typical market window, and increase the number of crops grown [78].

Factors deterring crop diversification are being located in the South (–4 crops; $P < 0.01$) and Delta regions (–2 crops; $P < 0.$ 10) and farming part-time (–2 crops; $P = 0.01$). An explanation for lower diversification among South and Delta operations may be related to the production market characteristics of fruits and vegetables, where farms may be specializing in fewer crops to increase production efficiency, deal with pest pressures, and access wholesale markets. For example, most of the agriculture production in Georgia and South Carolina is dedicated to pecans, watermelon, peaches, peanuts, and cotton [79,80]. Additionally, decreased diversification in the South and Delta regions could be linked to a warmer climate and elevated humidity influencing pest population and growth of FV. As expected, part-time farmers may be less likely to have a bigger variety of crops due to the lack of time for farming.

The OLS shows that relying on other farmers for information decreases the number of crops for the average specialty crop operation ($P < 0.05$). In contrast, Thomas et al. [81] and Valliant et al. [66] reported that farmer networks can positively influence farm diversification. It is likely that obtaining information from peers allows farmers to avoid trial and error of crop mixes. Knowing what crop is economically feasible can help growers to adapt their crop mix to select crops that are more profitable or more productive, which may result in a smaller pool of crops.

### *4.3. Results from the Quantile Model*

The CQR regression provides a more complete picture of how the internal and external factors influence crop diversification at different degrees of diversification. The CQR helped characterize the effects of access to local markets, farmland size, and other explanatory variables on the entire distribution of crop diversification. In other words, the CQR allows for examination of whether the effect of the explanatory variables is uniform across all degrees of diversification. An additional advantage of using CQR is the categorization of an operation's diversification degree by the number of crops grown. Table 3 categorizes FV operations as specialized (quantile 0.25 with 1 to 4 crops), low diversified (quantile 0.50 with 5 to 15 crops), medium diversified (quantile 0.750 with 16 to 28 crops), and highly diversified (quantile 0.99 with 29 or more crops) and estimated the effect of the explanatory variables over each quantile.

Table 3 illustrates the results from the CQR estimation for each quantile and Figure 2 shows the quantile estimates plotted with 95% confidence intervals and OLS estimates. Selling in local markets positively influences crop diversification across all quantiles. For example, having access to DTC markets can add about two additional crops to specialized, low, medium, and highly diversified operations. A Wald test verified that the slope parameters showed that the effect of DTC is equal across all quantiles ($P < 0.01$).

Factors that can help growers to diversify their crop mix, regardless of their degree of diversification, are growing a mix of fruits and vegetables, using organic agricultural practices, accessing a variety of market channels, and using season extension technologies. Minority and other non-white specialized farmers tend to increase their crop mix ($P = 0.01$). Positive attitudes and beliefs regarding agriculture and their farming system can encourage medium and highly diversified farmers to become more diversified ($P < 0.05$). It is likely that having positive expectations motivates farmers growing 29 crops or more to perceive diversification as an economic strategy that helps deal with risk and improves farm sustainability.

Interestingly, diversification efforts among specialized farmers are negatively influenced by farming experience ($P = 0.07$); however, the relationship of farming experience and crop diversification starts to increase with years of farming at an decreasing rate ($P < 0.05$). It is likely that accumulating enough years farming experience can help specialized farmers to increase the number of crops. Farming part-time has a negative effect on diversification among low and medium diversified operations. These farmers seem more likely to attune their crop mix as a strategy to deal with lack of time and other farming resources.

The literature shows inconsistencies regarding farm size and farm diversification. While Mishra and El-Osta [82] reported a negative relationship between diversification and farm size, McNamara and Weiss [36] and Pope and Prescott [83] reported that farm diversification tends to increase with farmland. On the contrary, CQR results elicit that increasing farm acreage has a no significant effect on crop diversification, regardless of the diversification degree. An explanation for this is that the current sample of farmers is based on small- and medium-sized operations.

**Table 3.** Results from the quantile regressions at the 0.25, 0.50, 0.75, and 0.99 quantiles to explain crop diversification.

| | **Quantile 0.25 NCROPS = 0–4** | | | **Quantile 0.50 NCROPS = 5–15** | | | **Quantile 0.75 NCROPS = 16–28** | | | **Quantile 0.99 NCROPS = 29–43** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Coef.** | **Std. Err.** | **P-Value** | **Coef.** | **Std. Err.** | **P-Value** | **Coef.** | **Std. Err.** | **P-Value** | **Coef.** | **Std. Err.** | **P-Value** |
| DTC | 2.25 | 0.67 | 0.00 | 1.26 | 0.62 | 0.04 | 2.33 | 0.57 | 0.00 | 1.94 | 1.06 | 0.07 |
| ONLYVEG | 0.79 | 0.70 | 0.26 | 1.99 | 0.72 | 0.01 | 4.86 | 0.80 | 0.00 | 14.44 | 1.49 | 0.00 |
| FRUITVEG | 9.76 | 0.66 | 0.00 | 13.78 | 0.71 | 0.00 | 17.38 | 0.59 | 0.00 | 28.39 | 1.52 | 0.00 |
| ORGANIC | 3.69 | 0.83 | 0.00 | 6.82 | 0.81 | 0.00 | 6.73 | 0.54 | 0.00 | 3.88 | 1.17 | 0.00 |
| NMARKET | 1.33 | 0.26 | 0.00 | 1.24 | 0.17 | 0.00 | 1.37 | 0.15 | 0.00 | 0.57 | 0.27 | 0.03 |
| SEASONEXT | 5.43 | 0.72 | 0.00 | 5.47 | 0.51 | 0.00 | 6.24 | 0.53 | 0.00 | 4.49 | 1.10 | 0.00 |
| TLAND | 0.00 | 0.00 | 0.18 | 0.00 | 0.00 | 0.25 | 0.00 | 0.00 | 0.56 | 0.00 | 0.00 | 0.13 |
| RENT | 0.08 | 0.64 | 0.91 | 0.57 | 0.74 | 0.44 | 0.22 | 0.53 | 0.68 | −0.91 | 0.97 | 0.35 |
| SOLE | 0.29 | 0.62 | 0.64 | 0.80 | 0.59 | 0.18 | 0.30 | 0.47 | 0.53 | −1.22 | 1.02 | 0.23 |
| LABOR | −0.02 | 0.01 | 0.02 | −0.02 | 0.01 | 0.16 | −0.01 | 0.02 | 0.59 | 0.04 | 0.07 | 0.53 |
| SOUTH | −3.28 | 0.93 | 0.00 | −3.80 | 0.85 | 0.00 | −4.40 | 0.91 | 0.00 | −1.93 | 1.83 | 0.29 |
| DELTA | −0.92 | 1.09 | 0.40 | −2.49 | 1.28 | 0.05 | −2.56 | 0.71 | 0.00 | 0.74 | 2.10 | 0.73 |
| MIDWEST | −0.05 | 0.87 | 0.95 | −0.37 | 0.55 | 0.51 | −1.03 | 0.68 | 0.13 | 0.23 | 1.16 | 0.85 |
| MEDIUM | −0.96 | 0.73 | 0.19 | −0.28 | 0.74 | 0.70 | −0.60 | 0.63 | 0.34 | 1.87 | 1.27 | 0.14 |
| COLLEGE | −1.51 | 0.56 | 0.01 | 0.11 | 0.52 | 0.84 | −0.47 | 0.49 | 0.34 | −1.56 | 0.97 | 0.11 |
| FEMALE | 0.39 | 0.72 | 0.59 | 1.40 | 0.71 | 0.05 | 0.72 | 0.48 | 0.14 | −0.23 | 1.07 | 0.83 |
| NOWHITE | 2.34 | 0.86 | 0.01 | 1.85 | 1.50 | 0.22 | 0.70 | 1.08 | 0.52 | −2.79 | 3.20 | 0.38 |
| PARTTIME | −0.89 | 0.67 | 0.19 | −1.17 | 0.67 | 0.08 | −1.14 | 0.53 | 0.03 | −0.08 | 1.40 | 0.95 |
| YFARM | −0.11 | 0.06 | 0.07 | −0.05 | 0.07 | 0.43 | 0.03 | 0.05 | 0.57 | 0.13 | 0.11 | 0.24 |
| YFARM2 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 | 0.65 | 0.00 | 0.00 | 0.09 |
| SATISFIED | 1.03 | 0.76 | 0.18 | 0.79 | 0.74 | 0.29 | 1.05 | 0.86 | 0.22 | −0.57 | 2.06 | 0.78 |
| POSEXPECT | −0.22 | 0.61 | 0.72 | 0.14 | 0.58 | 0.81 | 0.93 | 0.47 | 0.05 | 2.25 | 0.89 | 0.01 |
| ORGDIVERSE | 0.03 | 0.63 | 0.96 | 0.11 | 0.61 | 0.86 | −0.16 | 0.51 | 0.76 | 0.27 | 1.15 | 0.81 |
| INFOEXTENSION | −0.20 | 0.85 | 0.81 | −0.27 | 0.65 | 0.67 | 0.85 | 0.51 | 0.10 | −2.72 | 1.16 | 0.02 |
| INFOFARMER | −1.14 | 0.57 | 0.05 | −0.76 | 0.53 | 0.15 | −0.67 | 0.49 | 0.17 | 1.95 | 0.89 | 0.03 |
| INTERCEPT | −1.92 | 1.93 | 0.32 | −0.41 | 1.36 | 0.76 | −0.30 | 1.53 | 0.84 | 6.70 | 5.23 | 0.20 |
| N. Obs | | 1047 | | | 1047 | | | 1047 | | | 1047 | |
| R2 | | 0.29 | | | 0.38 | | | 0.40 | | | 0.39 | |

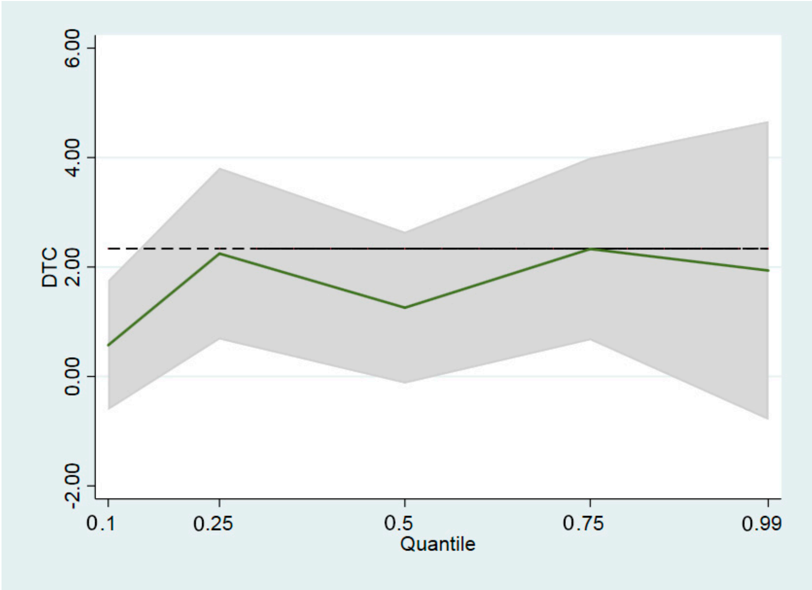


**Figure 2.** Quantile plot for access to local markets (DTC). Thick solid line represents quantile estimates, with quantiles depicted on the x-axis, and magnitudes of the estimates shown on the y-axis. Shaded areas indicate 95% confidence intervals. Horizontal line indicates OLS estimates.

Sources of information are key factors influencing crop diversification, but the relationship is a complex one. On one hand, receiving information from Universities Extension can increase diversification among medium diversified operations ($P = 0.10$), but the effect is negative for highly diversified farms ($P < 0.05$). On the other hand, receiving information from other farmers has a negative diversification effect for specialized operations ($P = 0.05$), but a positive effect on highly diversified farms ($P < 0.05$). An explanation may be that these specialized operations are more likely to rely on farmer networks to obtain information regarding production efficiency and adoption of new technologies to enhance productivity, rather than looking for new crops to diversify their operation. It is also likely that farmer networks of highly diversified operations have different characteristics that support rotation of new crops to improve farm ecosystem, access to markets, and product differentiation in local markets.

## 5. Summary and Conclusions

The purpose of this paper was to examine the effect of external and internal factors influencing crop diversification of FV operations. First, the authors investigated the effects of an extensive list of explanatory variables on the number of FV crops grown for fresh markets. Second, a quantile regression was used to examine the effect of explanatory variables at specific degrees of crop diversification, such as specialized, low diversification, medium diversification, and high diversification. This analysis contributes to the current local foods and farm diversification literature and sheds light on the barriers and drivers to increase farm diversification among FV operations.

The present study found that crop diversification was significantly related to some internal factors (i.e., farm and farmer characteristics) and external factors (i.e., market access), at all degrees of diversification. In particular, the linkages between market access and crop diversification were provided and proved to be statistically significant. Farmers with access to local markets may be leveraging customer-farmer relationships and direct feedback from consumers to adapt their crop mix to meet demand. Local markets may also be influencing FV operations to supply a wider range of crops to provide colorful displays and serve as "one-stop" supplier in DTC and intermediate markets. This finding has clear policy implications, in which policymakers aiming to support farm diversification should consider the market accessibility and availability of FV farmers in their design and implementation of policies. The results suggest that FV farmers are more likely to diversify their crop mix if they have access to local markets. Thus, developing incentives to increase farm sustainability may have a minimal effect on crop diversification if farmers lack the access to markets and useful market and production information via farmers networks and Extension programs. Findings from this study also suggest that policies and strategies should be more region and state specific, than industry-wide in nature; in which environmental and market conditions may play a role on the farmer's decision to diversify their crop mix. For example, pest pressure and warmer climate during growing season in the Delta and South regions can affect the adoption of crop diversification strategies among FV farms.

The study also contributes to the farm diversification literature by defining diversification in the context of fresh market FV operations. Building from the traditional row crop industry (e.g., corn, soybean, and wheat), previous literature categorized diversified farming operations as those with three to four crops. In this study, a quantile regression estimated different levels of diversification and classified operations as specialized (1–4 crops), low (5–15 crops), medium (16–28 crops), and highly diversified (29 crops or more). For example, results showed access to more acreage can help specialized operations increase their crop mix, but having more farmland has a negative effect in highly diversified operations. This categorization of farm diversification can help researchers and policymakers to further understand the specific drivers and barriers of farm diversification for specialized and low, medium, and highly diversified FV farms.

Implications from this study can be applied to a broad scope of further research and extension activities. Understanding drivers of on-farm diversification can help the sustainability of FV operations. This may be largely impactful as the local food trend continues to appeal to consumers and increasing numbers of beginning farmers enter agricultural production. Information provided by this study will equip farmers and extension specialist alike with additional knowledge that can impact business decisions related to marketing channels and on-farm crop diversity. Aside from domestic support, this study can also motivate work in international development where diversified agricultural production is being introduced and/or incentivized.

While this study provides insight into drivers of crop mix diversification, applications beyond the FV industry may be limited. Other agricultural enterprises (e.g., row crops) typically do not allow large numbers of crops to be feasibly grown at a profitable level, as was found in the FV industry. This study did not explore on-farm diversification into non-related industries, such as adding in row crop or livestock production to FV operations. Further research should consider exploring on-farm diversification for enterprises outside of FV and a variety of different agricultural enterprises within an operation. Further research should also look into the production and marketing expertise across operations with different degrees of diversification, and how diversification influences farm profitability and viability.

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