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# Predicting Firm Diversification in Agri-Food Value Chains

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## Abstract

Diversifying agri-food value chains and the firms within them is one proposed strategy for increasing resilience within the global agri-food sector; however, adapting policy to specific firms based on their level of diversification is challenging in practice due to frequent data limitations. We investigate whether more easily observable firm characteristics can predict diversification for firms in the agri-food value chain, thereby facilitating policy targeting. Using regression analysis of survey-based data from roughly 200 agri-food firms in the United States, we find that few firm characteristics reliably predict diversification, but engagement in direct-to-consumer sales is positively correlated with firm diversification.

**Keywords:** diversification, agri-food value chains, policy targeting, direct-to-consumer sales

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## Introduction

In recent years, the global agri-food sector has become increasingly organized around complex and interconnected global agri-food value chains (Barrett et al., 2022; Bellemare, Bloem, and Lim, 2022; Lim and Kim, 2022; Montalbano and Nenci, 2022; Lim, 2023). The COVID-19 pandemic has drawn attention to these value chains and raised questions about their efficiency, sustainability, resilience, and ability to innovate in the face of large market shocks (Coopmans et al., 2021; Hobbs, 2021; Mishra, Singh, and Subramanian, 2021; Nordhagen et al., 2021; Weersink et al., 2021; Arita et al, 2022; Ahn and Steinbach, 2023; Azzam, Gren, and Andersson, 2023; DiGiacomo et al., 2023; Ramsey, Goodwin, and Haley, 2023; Hadachek, Ma, and Sexton, 2024). Policy makers are now particularly interested in how to increase the resilience of food supply networks and the agri-food value chains that comprise them: Should agri-food firms be encouraged to specialize and consolidate? Should they be encouraged to diversify? Should they be encouraged to participate in international trade?

Of the many possible approaches to strengthen agri-food value chain resilience, increasing diversification is a frequently proposed strategy, especially in food systems that are highly specialized and efficient. Previous research has explored diversification at the levels of entire supply networks (Choi, 2023; Karakoc et al., 2023), separate supply chains (Stone and Rahimifard, 2018; Hertel et al., 2021), and individual firms (Dorsey and Boland, 2009; Rawley and Simcoe, 2010). At the firm level, Stevens and Teal (2024) document an important distinction between what they call "vertical diversification" (a firm participating in multiple different segments of the agri-food supply chain) and "horizontal diversification" (a firm participating in multiple different activities within individual segments of the supply chain) (see Figure 1).[1] Specifically, they find that vertical diversification reduces firm resilience among small- and medium-sized agri-food firms whereas horizontal diversification increases resilience.

[1]Vertical diversification and horizontal diversification are related to vertical integration and horizontal integration, respectively, but differ in that diversification does not necessarily imply product-level linkages across different segments of the supply chain. For example, a farm that is both vertically diversified and vertically integrated might grow its own corn that it feeds to its own cattle that it raises for beef. However, a different farm could grow corn that it sells as grain and separately raise cattle using feed it buys from other suppliers. This second farm would be vertically diversified, but not vertically integrated.

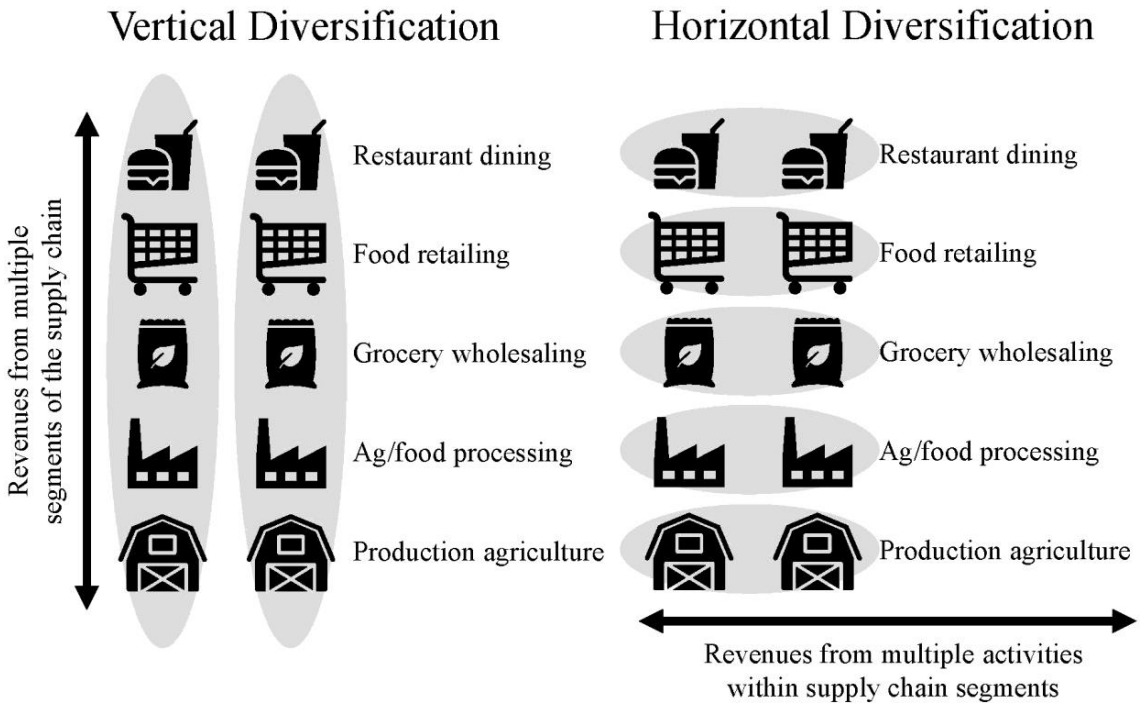


**Figure 1.** Vertical and Horizontal Diversification in the Agri-Food Value Chain

A shortcoming of much of the research on diversification in the agri-food value chain is that diversification is frequently difficult to observe. At the firm level, for instance, measuring diversification frequently requires detailed and proprietary information about firm expenditures, revenues, or activities. Such information is not generally available, especially to policy makers who might want to target their policies to firms based on levels of diversification. To overcome this challenge, we investigate whether other, more easily observable firm characteristics can consistently predict the degree of firm-level diversification in the agri-food sector. If suitable proxy variables exist for firm diversification, they can be leveraged by policy makers to implement targeted policies based on feasibly observable data.

Existing research on the predictors of diversification for firms operating throughout the agri-food sector is scarce. For large corporate firms, the existing literature in the fields of finance and management on diversification focuses on things like market power, principal-agent problems, or financing constraints (Montgomery, 1994). However, many firms in the agri-food value chain are considerably smaller than the corporations studied in this literature. Within the agri-food sector, research has focused largely on farms rather than on processors or manufacturers. In this literature, farm size, ownership structure, and owner characteristics are frequently identified as factors influencing diversification (Mishra, El-Osta, and Sandretto, 2004; Khanal, 2020; Khanal and Ojha, 2023).

We analyze the data from Stevens and Teal (2024) to determine which firm characteristics—if any—can effectively and consistently predict firm-level vertical diversification and horizontal diversification. Among a sample of U.S. agri-food firms from California, Florida, Minnesota, and Wisconsin, we examine many possible predictors of diversification including firm size (sales

revenues, number of employees, etc.), firm ownership (women-owned, veteran-owned, cooperative-owned, etc.), and firm owner characteristics (education level, years of experience, etc.). We analyze potential predictors both individually through unidimensional difference-in-means *t*-tests and collectively through ordinary least squares (OLS) regressions.

Our analyses yield four main findings. First, surprisingly few firm characteristics can consistently predict either vertical or horizontal diversification with any statistical significance. Second, the most consistent predictor of being vertically or horizontally diversified is whether a firm is engaged in direct-to-consumer sales. Third, being located in Florida and being an organic certified firm, respectively, are consistently negatively correlated with firms' levels of vertical diversification. And fourth, engaging in food and beverage retailing is consistently positively correlated with firms' levels of horizontal diversification.

The remainder of the article is organized as follows. First, we briefly describe how we measure firm diversification. Then, we summarize our data. Next, we describe our empirical framework. After that, we present our results and discuss the lessons we can draw from them. We then discuss the policy implications of our findings. Finally, we conclude.

## Measuring Firm Diversification

To measure the extent to which firms are diversified across and within segments of the agri-food supply chain, we adapt Stevens and Teal's (2024) normalized measures of vertical and horizontal diversification. These measures are a generalization of the Herfindahl-Hirschman Index but differ in that small values indicate concentration while large values indicate diversification. In our empirical context, which we share with Stevens and Teal (2024), firms were asked in a survey about how their revenues in a typical year were split between six different segments of the agri-food supply chain: production agriculture, processing/manufacturing, grocery wholesaling, food and beverage retailing, restaurant dining, and other. Then, firms were asked about how their revenues within each segment were split across different activities.

Specifically, we define our vertical diversification index $VD$ as

$$VD = \frac{1 - \sum_{i=1}^{n} \left(\frac{r_i}{R}\right)^2}{1 - \frac{1}{n}} \tag{1}$$

where $r_i$ is a firm's revenue from each $i$ of $n$ supply chain segments, $n$ is taken as given and is strictly greater than 1 (in our application, $n = 6$), and $R$ is the firm's total revenue. A *VD* value of zero signifies a vertically specialized firm whose revenue all comes from a single supply chain segment. A *VD* value of 1 signifies a "maximally diversified" firm whose revenue is equally split across all possible supply chain segments.

We define our horizontal diversification index *HD* as:

$$HD = \sum_{j=1}^{5} \left( \frac{r_j}{R} \times \left( \frac{1 - \sum_{i=1}^{n_j} \left( \frac{r_i}{r_j} \right)^2}{1 - \frac{1}{n_j}} \right) \right) \quad (2)$$

where $j$ indexes the five named supply chain segments in our data, $r_j$ is the revenue generated from segment $j$, $n_j$ is the number of activities in segment $j$, and $r_i$ is the revenue generated from activity $i$ (in segment $j$). We omit the "other" category from our calculation of *HD* because firms were not asked about how their revenues from their "other" supply chain segment(s) were split across different activities. For additional details about the activities $i$ in each segment $j$ in our empirical application, see Stevens and Teal (2024).

Both *VD* and *HD* are ordinal measures of firm diversification, allowing for firm-to-firm comparisons even if firms are active in different markets or supply chain segments. However, these indices are not cardinal; that is, a firm with a *VD* value of 0.5 is not necessarily "twice as diversified" as a firm with a *VD* value of 0.25. The real strength of these measures for our purposes is that they capture the *extent* to which a firm is diversified. For instance, consider two firms (A and B) that are both active in four supply chain segments. Suppose 85% of firm A's revenue comes from one segment, with the remaining 15% of its revenue split among the remaining three. Then suppose firm B's revenues are split evenly among the four segments: 25% each. In this case, firm B would have a higher value of *VD* than firm A, reflecting the more even distribution of its revenues across different segments.

## Data

We analyze firm-level data collected by an online survey conducted in the spring of 2021. The survey targeted firms in four states within the United States—California, Florida, Minnesota, and Wisconsin—and was designed to assess how firms in the agri-food supply chain were impacted by the COVID-19 pandemic. Different firms answered different subsets of questions depending on their business status (closed, temporarily closed, or open) and the supply chain segments in which they operated (production agriculture, processing/manufacturing, grocery wholesaling, food and beverage retailing, restaurant dining, and other). We use information about firms' self-reported pre-pandemic revenue to calculate our measures of *VD* and *HD* as described in equations (1) and (2), respectively. We also observe a variety of other pre-pandemic firm characteristics. A complete list of variables and their definitions can be found in Table 1. For additional information about our data source, see Peterson et al. (2023).

**Table 1.** Variable Descriptions

| Variable | Description |
|---|---|
| Diversification variables | |
| VD | Vertical diversification index, see equation (1) |
| HD | Horizontal diversification index, see equation (2) |
| Supply chain segments | |
| productionAg | Dummy for if the firm was active in production agriculture |
| processing | Dummy for if the firm was active in processing and manufacturing |
| groceryWholesaling | Dummy for if the firm was active in grocery wholesaling |
| foodBeverageRetail | Dummy for if the firm was active in food and beverage retailing |
| restaurant | Dummy for if the firm was active in restaurant dining |
| other | Dummy for if the firm was active in an unlisted agri-food supply chain segment |
| Other binary firm characteristics | |
| WI | Dummy for if the firm is located in Wisconsin |
| MN | Dummy for if the firm is located in Minnesota |
| FL | Dummy for if the firm is located in Florida |
| CA | Dummy for if the firm is located in California |
| womenOwned | Dummy for if the firm is majority-owned by women |
| minorityOwned | Dummy for if the firm is majority-owned by ethnic minorities |
| veteranOwned | Dummy for if the firm is veteran-owned |
| LGBTOwned | Dummy for if the firm is LGBT-owned |
| firstGenOwned | Dummy for if the firm owner is first-generation |
| multiGenOwned | Dummy for if the firm is a multi-generation business |
| familyOwned | Dummy for if the firm is majority-owned by a single family |
| franchised | Dummy for if the firm is franchised |
| cooperative | Dummy for if the firm is a cooperative |
| organic | Dummy for if the firm is certified organic |
| LEED | Dummy for if the firm is LEED-certified |
| BCorp | Dummy for if the firm is a B Corporation |
| hiringVisa | Dummy for if the firm is authorized to hire H-2A visa workers |
| ebtPurchases | Dummy for if the firm allows SNAP, WIC, or EBT purchases[1] |
| onSiteSales | Dummy for if the firm makes on-site sales |
| directSales | Dummy for if the firm makes retail or direct-to-consumer sales |
| exportSales | Dummy for if the firm exports any of its products |
| someCollege | Dummy for if the firm owner (survey respondent) has completed at least some college education |
| associates | Dummy for if the firm owner (survey respondent) has completed at least an associate's degree |
| bachelor | Dummy for if the firm owner (survey respondent) has completed at least a bachelor's degree |

**Table 1. (cont.)**

| Variable | Description |
|---|---|
| Other continuous firm characteristics | |
| salesRevenue | Firm's self-reported sales revenue in 2019, measured in USD |
| lnSalesRevenue | Natural logarithm of *salesRevenue* |
| fullTime | Number of full-time employees employed in 2019 |
| partTime | Number of part-time employees employed in 2019 |
| contractLabor | Number of contract labor employees employed in 2019 |
| ownerAge | Age of firm owner (survey respondent) |
| yearsInOperation | Number of years the firm has been in business |
| yearsInIndustry | Number of years the firm owner (survey respondent) has worked in their industry |

Note: [1]SNAP = supplemental nutrition assistance program, WIC = women, infants, and children program, EBT = electronic benefits transfer.

Although more than 800 firms provided responses to the survey described above, not all responses are usable for our analysis. Specifically, to construct our measures of *VD* and *HD*, a firm must have provided sufficient information about the distribution of its pre-pandemic revenues across different supply chain segments and economic activities. We therefore focus on two samples of our data: our "vertical diversification" sample includes firms for which we can calculate a value for *VD*, and our "horizontal diversification" sample includes firms for which we can calculate a value for *HD*. Although there is considerable overlap between these two samples, they are not identical. We further restrict our sample by omitting firms that: (i) did not report the current status of their business at the time of the survey, (ii) reported a pre-pandemic annual sales revenue of zero dollars or over 98 million U.S. dollars (USD), (iii) were not located in one of the four targeted states (California, Florida, Minnesota, and Wisconsin), (iv) reported having more than 300 full-time employees, (v) reported having more than 200 part-time employees, (vi) reported having more than 40 contract employees, or (vii) reported having zero full-time, part-time, and contract employees. Enforcing these criteria leads us to drop a handful of outlier firms that are not readily comparable to the rest of our sample, which is comprised largely of small- and medium-sized agri-food firms.

After restricting our sample as described above, we are left with 349 firms in our vertical diversification sample and 248 firms in our horizontal diversification sample. However, within each of these samples, not all firms have valid values for all observable characteristics. If we restrict our samples further to only those firms with complete information (as we do in our regression analysis described below), there are 211 firms in the vertical diversification "complete case" sample and 196 firms in the horizontal diversification "complete case" sample representing all six supply chain segments. All firms in the horizontal diversification complete case sample are included in the vertical diversification complete case sample. Summary statistics for both complete case samples are reported in Table 2.

**Table 2.** Summary Statistics

| | ***VD* Complete Case Sample (*n* = 211)** | | | | ***HD* Complete Case Sample (*n* = 196)** | | | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **Mean** | **Std. Dev.** | **Min.** | **Max.** | **Mean** | **Std. Dev.** | **Min.** | **Max.** |
| VD | 0.14 | 0.25 | 0.00 | 0.94 | | | | |
| HD | | | | | 0.29 | 0.27 | 0.00 | 0.94 |
| productionAg | 0.24 | 0.43 | 0.00 | 1.00 | 0.26 | 0.44 | 0.00 | 1.00 |
| processing | 0.16 | 0.36 | 0.00 | 1.00 | 0.17 | 0.38 | 0.00 | 1.00 |
| groceryWholesaling | 0.12 | 0.33 | 0.00 | 1.00 | 0.13 | 0.34 | 0.00 | 1.00 |
| foodBeverageRetail | 0.34 | 0.48 | 0.00 | 1.00 | 0.37 | 0.48 | 0.00 | 1.00 |
| restaurant | 0.42 | 0.49 | 0.00 | 1.00 | 0.45 | 0.50 | 0.00 | 1.00 |
| other | 0.18 | 0.38 | 0.00 | 1.00 | 0.11 | 0.32 | 0.00 | 1.00 |
| WI | 0.08 | 0.27 | 0.00 | 1.00 | 0.08 | 0.27 | 0.00 | 1.00 |
| MN | 0.35 | 0.48 | 0.00 | 1.00 | 0.36 | 0.48 | 0.00 | 1.00 |
| FL | 0.04 | 0.19 | 0.00 | 1.00 | 0.03 | 0.17 | 0.00 | 1.00 |
| CA | 0.54 | 0.50 | 0.00 | 1.00 | 0.54 | 0.50 | 0.00 | 1.00 |
| womenOwned | 0.35 | 0.48 | 0.00 | 1.00 | 0.35 | 0.48 | 0.00 | 1.00 |
| minorityOwned | 0.20 | 0.40 | 0.00 | 1.00 | 0.21 | 0.41 | 0.00 | 1.00 |
| veteranOwned | 0.09 | 0.28 | 0.00 | 1.00 | 0.09 | 0.29 | 0.00 | 1.00 |
| LGBTOwned | 0.05 | 0.21 | 0.00 | 1.00 | 0.05 | 0.22 | 0.00 | 1.00 |
| firstGenOwned | 0.44 | 0.50 | 0.00 | 1.00 | 0.43 | 0.50 | 0.00 | 1.00 |
| multiGenOwned | 0.14 | 0.35 | 0.00 | 1.00 | 0.15 | 0.36 | 0.00 | 1.00 |
| familyOwned | 0.51 | 0.50 | 0.00 | 1.00 | 0.54 | 0.50 | 0.00 | 1.00 |
| franchised | 0.06 | 0.23 | 0.00 | 1.00 | 0.06 | 0.24 | 0.00 | 1.00 |
| cooperative | 0.01 | 0.12 | 0.00 | 1.00 | 0.02 | 0.12 | 0.00 | 1.00 |
| organic | 0.14 | 0.35 | 0.00 | 1.00 | 0.14 | 0.35 | 0.00 | 1.00 |
| LEED | 0.01 | 0.10 | 0.00 | 1.00 | 0.01 | 0.07 | 0.00 | 1.00 |
| BCorp | 0.02 | 0.14 | 0.00 | 1.00 | 0.02 | 0.14 | 0.00 | 1.00 |
| hiringVisa | 0.01 | 0.12 | 0.00 | 1.00 | 0.02 | 0.12 | 0.00 | 1.00 |
| ebtPurchases | 0.11 | 0.32 | 0.00 | 1.00 | 0.11 | 0.31 | 0.00 | 1.00 |
| onSiteSales | 0.55 | 0.50 | 0.00 | 1.00 | 0.55 | 0.50 | 0.00 | 1.00 |
| directSales | 0.72 | 0.45 | 0.00 | 1.00 | 0.73 | 0.45 | 0.00 | 1.00 |
| exportSales | 0.05 | 0.22 | 0.00 | 1.00 | 0.05 | 0.21 | 0.00 | 1.00 |
| someCollege | 0.87 | 0.34 | 0.00 | 1.00 | 0.86 | 0.35 | 0.00 | 1.00 |
| associates | 0.69 | 0.46 | 0.00 | 1.00 | 0.68 | 0.47 | 0.00 | 1.00 |
| bachelor | 0.63 | 0.49 | 0.00 | 1.00 | 0.62 | 0.49 | 0.00 | 1.00 |
| graduate | 0.24 | 0.43 | 0.00 | 1.00 | 0.24 | 0.43 | 0.00 | 1.00 |
| salesRevenue | 2,968,120 | 7,297,821 | 50.00 | 49,000,000 | 3,018,561 | 7,376,485 | 50.00 | 49,000,000 |
| lnSalesRevenue | 13.10 | 2.17 | 3.93 | 17.71 | 13.10 | 2.21 | 3.93 | 17.71 |
| fullTime | 10.34 | 20.93 | 0.00 | 200.00 | 10.82 | 21.58 | 0.00 | 200.00 |
| partTime | 16.82 | 28.51 | 0.00 | 175.00 | 17.63 | 29.26 | 0.00 | 175.00 |
| contractLabor | 0.73 | 2.61 | 0.00 | 20.00 | 0.69 | 2.66 | 0.00 | 20.00 |
| ownerAge | 52.64 | 11.80 | 23.00 | 81.00 | 52.73 | 12.00 | 23.00 | 81.00 |
| yearsInOperation | 22.24 | 19.33 | 2.00 | 106.00 | 22.15 | 19.51 | 2.00 | 106.00 |
| yearsInIndustry | 23.88 | 13.95 | 2.00 | 65.00 | 23.68 | 14.08 | 2.00 | 65.00 |

Notes: "Complete Case Sample" refers to observations in the *VD* and *HD* samples, respectively, for which we observe data for all listed variables. These "complete case" samples of 211 and 196 observations, respectively, are the same samples used in the regression analyses reported in Table 7.

## Empirical Framework

Our objective is to determine which observable firm characteristics—if any—predict a firm's level of vertical or horizontal diversification. We take two different approaches: first, we analyze each firm characteristic in isolation to determine whether it has a statistically significant relationship with either *VD* or *HD* in the relevant sample. Second, we include all observable firm characteristics in a single OLS regression of each index.

In our first approach, we handle binary firm characteristics differently than continuous firm characteristics. For binary characteristics, we compare the mean value of *VD* (or *HD*) among firms that share a particular characteristic to the mean value of *VD* (or *HD*) among firms that do not share the characteristic. We then calculate a *t*-test on the difference in means to determine whether it is statistically significantly different from zero. For continuous characteristics, we compare the mean value of the characteristic among specialized firms (*VD* = 0 or *HD* = 0) to the mean value of the characteristic among diversified firms (*VD* > 0 or *HD* > 0, respectively). We then calculate a *t*-test on the difference in means to determine whether it is statistically significantly different from zero.

In our second approach, we include all binary and continuous firm characteristics in a single OLS regression where the dependent variable is either *VD* or *HD*. Specifically, we estimate equation (3):

$$D_i = \alpha + \boldsymbol{B_i}\boldsymbol{\beta} + \boldsymbol{C_i}\boldsymbol{\gamma} + \varepsilon_i \tag{3}$$

where $D_i$ is either the value of either *VD* or *HD*, as appropriate, for firm *i*, $\boldsymbol{B_i}$ is a vector of binary characteristics for firm *i*, $\boldsymbol{C_i}$ is a vector of continuous characteristics for firm *i*, and $\varepsilon_i$ is an error term. Within $\boldsymbol{C_i}$, we include the level and square of four different variables to capture potential non-linear effects: *lnSalesRevenue*, *fullTime*, *partTime*, and *contractLabor*.

When we estimate equation (3) for our horizontal diversification sample, we include binary variables for the six different supply chain segments: production agriculture, processing/manufacturing, grocery wholesaling, food and beverage retailing, restaurant dining, and other. However, we omit these variables in our analysis of the vertical diversification sample since they enter directly into the construction of *VD*. In a supplemental regression for the vertical diversification sample, we include the variable *numSegments*, which is an integer counting the number of supply chain segments in which a firm is active.

Our coefficients of interest from equation (3) are $\boldsymbol{\beta}$ and $\hat{\boldsymbol{\gamma}}$. If any of these coefficients are statistically significantly different from zero, we conclude that they are effective predictors of firm diversification. Importantly, we do not argue that any of these coefficients capture causal effects; we are merely interested in whether observable firm characteristics can reliably predict a firm's level of diversification—not whether these characteristics are the cause of any such diversification.

## Results

We begin by presenting our unidimensional findings for firms in our vertical diversification sample. Table 3 presents differences-in-means for binary firm characteristics, and Table 4 presents differences-in-means for continuous firm characteristics. Figure 2 further summarizes the results from Table 3 and includes 95% confidence intervals.

**Table 3.** Difference in Means Of Vertical Diversification Index (*VD*) by Binary Firm Characteristics

| Variable | Mean if False | Mean if True | Difference in Means | *p*-Value of Difference | Sample Size | Number True |
|---|---|---|---|---|---|---|
| WI | 0.121 | 0.224 | 0.102 | 0.173 | 349 | 20 |
| MN | 0.127 | 0.128 | 0.000 | 0.988 | 349 | 129 |
| FL | 0.133 | 0.057 | -0.075 | 0.016 | 349 | 24 |
| CA | 0.129 | 0.126 | -0.003 | 0.897 | 349 | 176 |
| womenOwned | 0.105 | 0.164 | 0.059 | 0.079 | 252 | 89 |
| minorityOwned | 0.137 | 0.085 | -0.052 | 0.152 | 252 | 51 |
| veteranOwned | 0.121 | 0.180 | 0.059 | 0.394 | 252 | 20 |
| LGBTOwned | 0.126 | 0.132 | 0.006 | 0.928 | 252 | 13 |
| firstGenOwned | 0.127 | 0.125 | -0.002 | 0.952 | 252 | 111 |
| multiGenOwned | 0.122 | 0.153 | 0.031 | 0.526 | 252 | 35 |
| familyOwned | 0.129 | 0.123 | -0.006 | 0.856 | 252 | 129 |
| franchised | 0.129 | 0.078 | -0.051 | 0.537 | 252 | 12 |
| cooperative | 0.128 | 0.000 | -0.128 | 0.000 | 252 | 4 |
| organic | 0.148 | 0.068 | -0.080 | 0.032 | 217 | 31 |
| hiringVisa | 0.138 | 0.054 | -0.084 | 0.219 | 217 | 4 |
| ebtPurchases | 0.133 | 0.161 | 0.027 | 0.667 | 217 | 25 |
| onSiteSales | 0.108 | 0.160 | 0.052 | 0.125 | 217 | 118 |
| directSales | 0.072 | 0.162 | 0.089 | 0.009 | 217 | 156 |
| exportSales | 0.135 | 0.158 | 0.023 | 0.774 | 217 | 11 |
| someCollege | 0.113 | 0.128 | 0.015 | 0.713 | 252 | 216 |
| associates | 0.155 | 0.113 | -0.042 | 0.211 | 252 | 172 |
| bachelor | 0.167 | 0.101 | -0.067 | 0.042 | 252 | 156 |
| graduate | 0.139 | 0.085 | -0.054 | 0.094 | 252 | 59 |

Notes: "Number True" refers to the number of firms for which the relevant variable is equal to 1. Statistics in this table calculated using the vertical diversification sample.

**Table 4.** Difference in Means of Continuous Firm Characteristics by Vertical Diversification

| Variable | Mean if *VD* = 0 | Mean if *VD* > 0 | Difference in Means | *p*-value of Differences | Sample Size | Number *VD* > 0 |
|---|---|---|---|---|---|---|
| HD | 0.299 | 0.287 | -0.011 | 0.733 | 248 | 72 |
| lnSalesRevenue | 13.238 | 12.873 | -0.365 | 0.143 | 349 | 99 |
| salesRevenue | 3,150,611 | 1,816,560 | -1,334,051 | 0.029 | 349 | 99 |
| fullTime | 14.312 | 11.990 | -2.322 | 0.475 | 349 | 99 |
| partTime | 15.660 | 15.465 | -0.195 | 0.954 | 349 | 99 |
| contractLabor | 0.677 | 0.770 | 0.093 | 0.776 | 349 | 99 |
| ownerAge | 22.135 | 20.963 | -1.172 | 0.688 | 252 | 67 |
| yearsInOperation | 24.651 | 21.500 | -3.151 | 0.102 | 251 | 66 |
| yearsInIndustry | 52.613 | 51.569 | -1.044 | 0.520 | 246 | 65 |

Notes: Statistics in this table calculated using the vertical diversification sample.

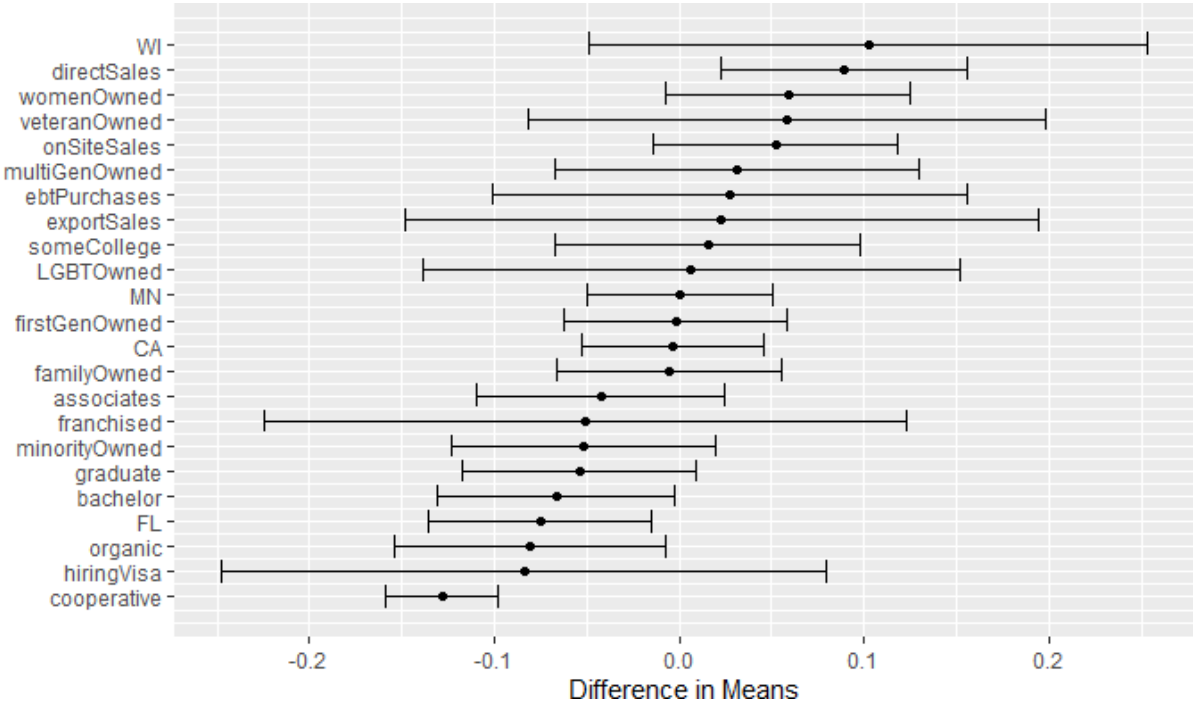


**Figure 2.** Difference in Means of Vertical Diversification Index (*VD*) by Firm Characteristics

Note: Error bars report 95% confidence intervals.

Overall, we find that few binary firm characteristics seem to be statistically significantly correlated with firms' vertical diversification. Only being engaged in direct sales and being woman-owned seem to be positively correlated with a firm's *VD*, while operating in Florida, being a cooperative, being certified organic, and having a firm owner with a bachelor's degree or graduate education seem to be negatively correlated with a firm's *VD.* Among continuous firm characteristics, only

sales revenue (but not its natural logarithm) is statistically significantly correlated with *VD*: Vertically diversified firms have lower sales revenue than vertically specialized firms.

Next, we present our unidimensional findings for firms in our horizontal diversification sample. Table 5 presents differences-in-means for binary firm characteristics, and Table 6 presents differences-in-means for continuous firm characteristics. Figure 3 further summarizes the results from Table 5 and includes 95% confidence intervals.

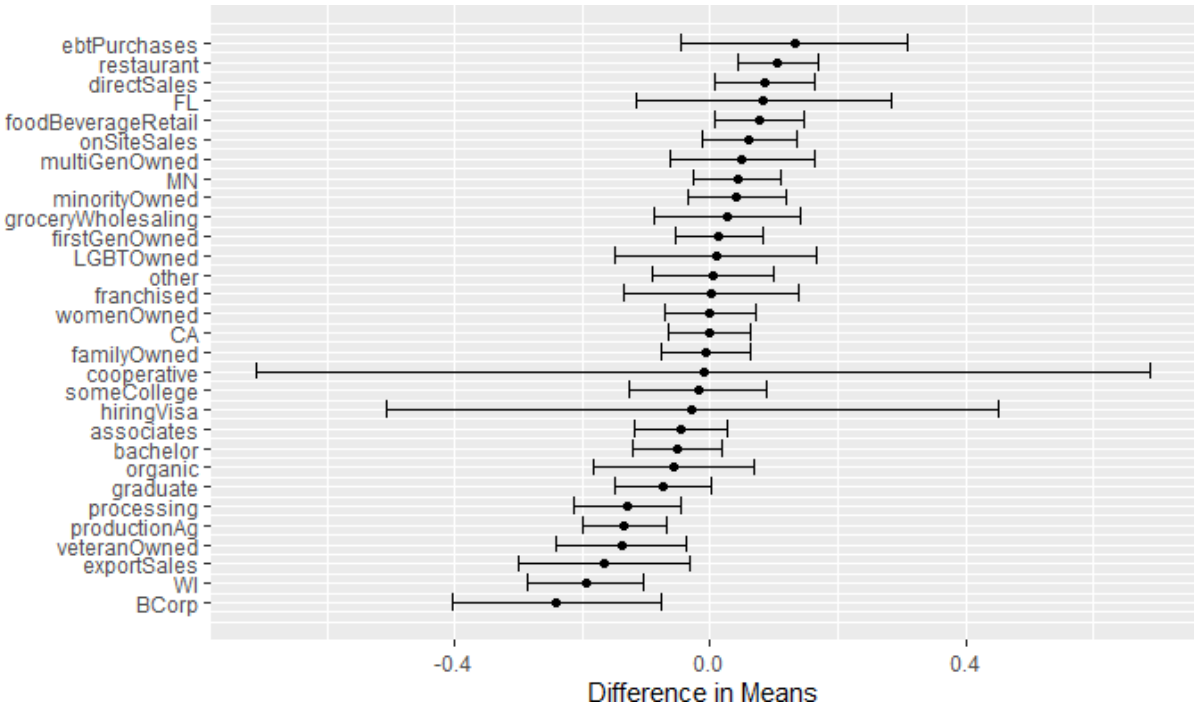


**Figure 3:** Difference in Means of Horizontal Diversification Index (HD) by Firm Characteristics

Note: Error bars report 95% confidence intervals.

Overall, we find that more firm characteristics seem to be statistically significantly correlated with firms' horizontal diversification. Characteristics that are positively correlated with *HD* include being engaged in direct sales, food and beverage retailing, and restaurant services. Characteristics that are negatively correlated with *HD* include operating in Wisconsin, being engaged in production agriculture, being engaged in agri-food processing or manufacturing, being veteran-owned, being a B Corporation,[2] engaging in export sales, and having a firm owner with a graduate-level education.

Among continuous firm characteristics, those that are positively correlated with *HD* include *VD*, the natural logarithm of sales revenue (but not its level), the number of full-time employees, and

[2]B Corporations are businesses that have received a certification for meeting "high standards of verified performance, accountability, and transparency on factors from employee benefits and charitable giving to supply chain practices and input materials." For more information, see https://bcorporation.net/en-us/certification.

the number of part-time employees. Those that are negatively correlated with *HD* include the number of years the firm owner has worked in their industry and the firm owner's age.

**Table 5.** Difference in Means of Horizontal Diversification Index (*HD*) by Binary Firm Characteristics

| Variable | Mean if False | Mean if True | Difference in Means | *p*-value of Differences | Sample Size | Number True |
|---|---|---|---|---|---|---|
| WI | 0.309 | 0.114 | -0.195 | 0.000 | 248 | 17 |
| MN | 0.279 | 0.321 | 0.043 | 0.217 | 248 | 96 |
| FL | 0.293 | 0.376 | 0.083 | 0.363 | 248 | 8 |
| CA | 0.296 | 0.295 | -0.001 | 0.973 | 248 | 127 |
| productionAg | 0.334 | 0.199 | -0.135 | 0.000 | 248 | 71 |
| processing | 0.314 | 0.185 | -0.129 | 0.003 | 248 | 36 |
| groceryWholesaling | 0.292 | 0.318 | 0.026 | 0.648 | 248 | 32 |
| foodBeverageRetail | 0.268 | 0.344 | 0.076 | 0.034 | 248 | 88 |
| restaurant | 0.250 | 0.355 | 0.105 | 0.001 | 248 | 106 |
| other | 0.295 | 0.299 | 0.004 | 0.936 | 248 | 24 |
| womenOwned | 0.294 | 0.294 | 0.000 | 0.997 | 233 | 81 |
| minorityOwned | 0.286 | 0.327 | 0.041 | 0.292 | 233 | 49 |
| veteranOwned | 0.306 | 0.167 | -0.139 | 0.009 | 233 | 20 |
| LGBTOwned | 0.294 | 0.303 | 0.009 | 0.907 | 233 | 13 |
| firstGenOwned | 0.288 | 0.302 | 0.014 | 0.688 | 233 | 101 |
| multiGenOwned | 0.287 | 0.336 | 0.049 | 0.381 | 233 | 35 |
| familyOwned | 0.298 | 0.291 | -0.007 | 0.848 | 233 | 125 |
| franchised | 0.294 | 0.295 | 0.000 | 0.994 | 233 | 12 |
| cooperative | 0.295 | 0.284 | -0.011 | 0.964 | 233 | 4 |
| organic | 0.298 | 0.241 | -0.057 | 0.363 | 201 | 29 |
| BCorp | 0.294 | 0.054 | -0.240 | 0.015 | 201 | 4 |
| hiringVisa | 0.290 | 0.262 | -0.028 | 0.866 | 201 | 4 |
| ebtPurchases | 0.275 | 0.407 | 0.132 | 0.139 | 201 | 22 |
| onSiteSales | 0.256 | 0.317 | 0.061 | 0.108 | 201 | 111 |
| directSales | 0.227 | 0.312 | 0.085 | 0.034 | 201 | 147 |
| exportSales | 0.297 | 0.131 | -0.166 | 0.02 | 201 | 9 |
| someCollege | 0.311 | 0.292 | -0.019 | 0.719 | 233 | 199 |
| associates | 0.325 | 0.279 | -0.046 | 0.212 | 233 | 157 |
| bachelor | 0.326 | 0.274 | -0.051 | 0.149 | 233 | 142 |
| graduate | 0.311 | 0.237 | -0.074 | 0.052 | 233 | 53 |

Notes: "Number True" refers to the number of firms for which the relevant variable is equal to 1. Statistics in this table calculated using the horizontal diversification sample.

**Table 6.** Difference in Means of Continuous Firm Characteristics by Horizontal Diversification

| Variable | Mean if *HD* = 0 | Mean if *HD* > 0 | Difference in Means | *p*-value of Difference | Sample Size | Number *HD* > 0 |
|---|---|---|---|---|---|---|
| VD | 0.0880 | 0.153 | 0.065 | 0.042 | 248 | 182 |
| lnSalesRevenue | 12.332 | 13.322 | 0.990 | 0.005 | 248 | 182 |
| salesRevenue | 3,038,009 | 2,510,552 | -527,456 | 0.667 | 248 | 182 |
| fullTime | 7.955 | 12.945 | 4.991 | 0.058 | 248 | 182 |
| partTime | 8.348 | 19.549 | 11.201 | 0.000 | 248 | 182 |
| contractLabor | 1.000 | 0.507 | -0.493 | 0.243 | 248 | 182 |
| ownerAge | 25.841 | 20.338 | -5.503 | 0.080 | 233 | 170 |
| yearsInOperation | 24.913 | 23.148 | -1.765 | 0.467 | 232 | 169 |
| yearsInIndustry | 55.806 | 51.084 | -4.722 | 0.014 | 228 | 166 |

Notes: Statistics in this table calculated using the horizontal diversification sample.

Figure 4 presents kernel density plots of the natural logarithm of sales revenue for firms in our *HD* sample (top panel) and *VD* sample (bottom panel). In each case, we report separate density plots for specialized firms (*HD* = 0 and *VD* = 0) and diversified firms (*HD* > 0 and *VD* > 0). This figure helps visualize the relationship between sales revenue and firm diversification and emphasizes that horizontally specialized firms tend to have lower revenue than horizontally diversified firms when measured in natural logarithms. It is notable, however, that we do not find the same relationship in levels, highlighting the statistical importance of firms with particularly large sales revenues when analyzing our data in levels.

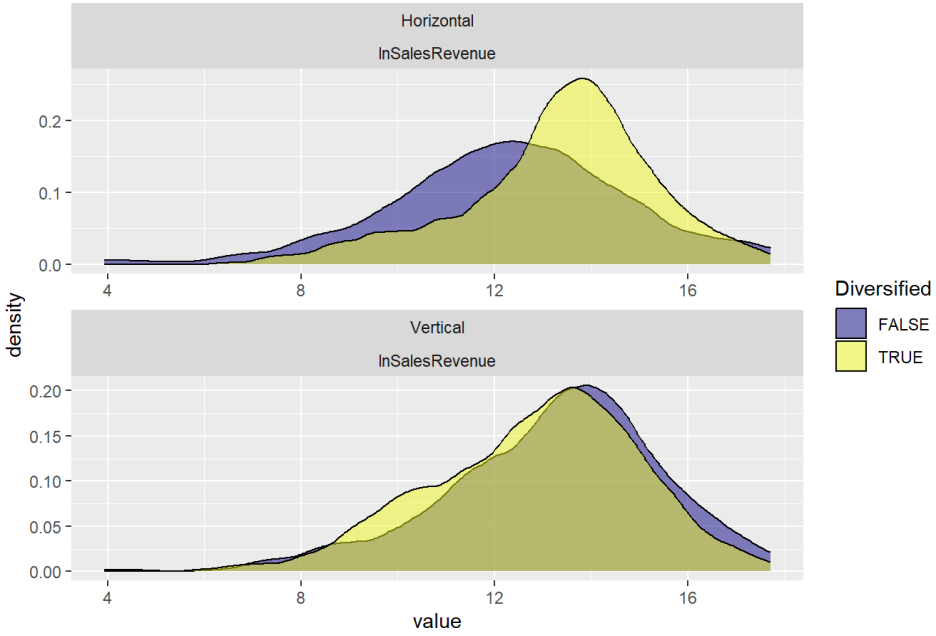


**Figure 4. Kernel Density of Sales Revenue by Diversification Type**

Note: Both panels report the density of firms in our sample measured by the natural logarithm of sales revenue (USD). The top panel includes firms in the horizontal diversification sample and separates firms by whether *HD* = 0 (Diversified = FALSE) or *HD* > 0 (Diversified = TRUE). The bottom panel includes firms in the vertical diversification sample and separates firms by whether *VD* = 0 (Diversified = FALSE) or *VD* > 0 (Diversified = TRUE).

Finally, we present our findings from OLS regressions of *VD* and *HD* on the full set of binary and continuous firm characteristics as described in equation (3). Table 7 contains our results with columns (1) and (2) analyzing *VD* and column (3) analyzing *HD*. Neither column (1) nor column (2) includes the supply chain segment dummy variables because they enter directly into the construction of *VD*: Being active in any particular supply chain segment increases a firm's level of *VD* mechanically. However, in column (2), we include the variable *numSegments* to try and explain more of the variation in *VD* without attributing importance to any segment over another. Unsurprisingly, including *numSegments* dramatically increases our model fit; however, because this variable also enters directly into the construction of *VD* and therefore alters the underlying assumptions of the functional form in our regression model, we are hesitant to over-rely on these results. We therefore present columns (1) and (2) as complementary analyses that should be interpreted together.

In columns (1) and (2) of Table 7, we find that relatively few firm characteristics are statistically significant predictors of firms' vertical diversification. Characteristics that are positively correlated with *VD* include the firm engaging in direct sales, engaging in export sales, and being veteran-owned. Characteristics negatively correlated with *VD* include operating in Florida, being certified organic, and the firm owner having relatively more years of experience in their industry. We also find that the number of contract labor employees is a statistically significant predictor of *VD*: depending on the specification, the relationship is positive when the number of contract labor employees is below seven (column [1]) or nine (column [2]) and negative when the number of contract labor employees is above these respective values.

In column (3) of Table 7, we find that even fewer firm characteristics are statistically significant predictors of firms' horizontal diversification. Characteristics that are positively correlated with *HD* include the firm engaging in direct sales, being active in the food and beverage retailing sector, and allowing for SNAP, WIC, and EBT purchases.[3] The only characteristic that is negatively correlated with *HD* is the number of years the firm has been in operation.

In general, we prefer the regression analyses reported in Table 7 over the unidimensional analyses reported in Tables 3–6 because the regression analyses account for correlations among different firm-level characteristics. Nonetheless, comparing the unidimensional results to the OLS results can help paint a more complete picture of how different firm characteristics relate to one another and firms' diversification levels.

[3]SNAP = supplemental nutrition assistance program, WIC = women, infants, and children program, EBT = electronic benefits transfer.

**Table 7.** Ordinary Least Squares Regression of Diversification Indices on Firm Characteristics

| Variable | *VD* (1) | *VD* (2) | *HD* (3) |
|---|---|---|---|
| (Intercept) | −0.142 | −0.244 | 0.31 |
| | (0.42) | (0.21) | (0.45) |
| WI | 0.03 | 0.02 | −0.059 |
| | (0.07) | (0.04) | (0.08) |
| MN | −0.003 | −0.006 | −0.004 |
| | (0.04) | (0.02) | (0.05) |
| FL | −0.228** | −0.054 | 0.18 |
| | (0.10) | (0.05) | (0.12) |
| lnSalesRevenue | 0.05 | 0.01 | −0.038 |
| | (0.07) | (0.03) | (0.07) |
| lnSalesRevenueSQ | −0.002 | 0.00 | 0.00 |
| | (0.00) | (0.00) | (0.00) |
| fullTime | 0.00 | 0.00 | −0.002 |
| | (0.00) | (0.00) | (0.00) |
| fullTimeSQ | 0.00 | 0.00 | 0.00 |
| | 0.00 | 0.00 | 0.00 |
| partTime | −0.002 | 0.00 | 0.00 |
| | (0.00) | (0.00) | (0.00) |
| partTimeSQ | 0.00 | 0.00 | 0.00 |
| | 0.00 | 0.00 | 0.00 |
| contractLabor | 0.040** | 0.017* | 0.01 |
| | (0.02) | (0.01) | (0.02) |
| contractLaborSQ | −0.003** | −0.001* | −0.001 |
| | (0.00) | (0.00) | (0.00) |
| yearsInOperation | 0.00 | 0.00 | −0.002* |
| | (0.00) | (0.00) | (0.00) |
| yearsInIndustry | −0.003* | −0.001 | 0.00 |
| | (0.00) | (0.00) | (0.00) |
| womenOwned | 0.06 | 0.01 | 0.00 |
| | (0.04) | (0.02) | (0.04) |
| minorityOwned | −0.042 | −0.028 | −0.013 |
| | (0.05) | (0.03) | (0.05) |
| veteranOwned | 0.134* | 0.01 | −0.018 |
| | (0.07) | (0.04) | (0.07) |
| LGBTOwned | 0.05 | 0.04 | −0.079 |
| | (0.09) | (0.04) | (0.09) |
| firstGenOwned | 0.02 | −0.002 | 0.07 |
| | (0.04) | (0.02) | (0.04) |
| multiGenOwned | 0.07 | 0.01 | 0.09 |
| | (0.06) | (0.03) | (0.06) |

**Table 7. (cont.)**

| Variable | *VD* (1) | *VD* (2) | *HD* (3) |
|---|---|---|---|
| familyOwned | −0.015 | 0.01 | −0.044 |
| | (0.04) | (0.02) | (0.04) |
| franchised | −0.022 | −0.001 | −0.118 |
| | (0.08) | (0.04) | (0.08) |
| cooperative | −0.100 | −0.012 | 0.16 |
| | (0.18) | (0.09) | (0.19) |
| ownerAge | 0.00 | 0.00 | −0.002 |
| | (0.00) | (0.00) | (0.00) |
| organic | −0.130** | −0.028 | −0.049 |
| | (0.06) | (0.03) | (0.06) |
| LEED | −0.203 | −0.079 | 0.11 |
| | (0.22) | (0.11) | (0.42) |
| BCorp | −0.010 | 0.01 | −0.059 |
| | (0.15) | (0.07) | (0.16) |
| hiringVisa | −0.045 | −0.001 | −0.129 |
| | (0.17) | (0.08) | (0.19) |
| ebtPurchases | 0.05 | 0.00 | 0.190*** |
| | (0.06) | (0.03) | (0.06) |
| onSiteSales | 0.03 | 0.02 | 0.05 |
| | (0.04) | (0.02) | (0.04) |
| directSales | 0.084** | 0.050** | 0.087* |
| | (0.04) | (0.02) | (0.05) |
| exportSales | 0.15 | 0.092** | −0.094 |
| | (0.09) | (0.05) | (0.11) |
| someCollege | 0.05 | 0.01 | 0.01 |
| | (0.07) | (0.03) | (0.07) |
| associates | 0.02 | −0.013 | −0.045 |
| | (0.09) | (0.04) | (0.09) |
| bachelor | −0.112 | −0.034 | 0.01 |
| | (0.08) | (0.04) | (0.08) |
| graduate | −0.023 | −0.002 | −0.039 |
| | (0.05) | (0.02) | (0.05) |
| numSegments | | 0.233*** | |
| | | (0.01) | |
| productionAg | | | −0.029 |
| | | | (0.06) |
| processing | | | −0.084 |
| | | | (0.06) |
| groceryWholesaling | | | 0.00 |
| | | | (0.06) |
| foodBeverageRetail | | | 0.090* |
| | | | (0.05) |
| restaurant | | | 0.08 |
| | | | (0.05) |
| other | | | −0.086 |
| | | | (0.06) |

**Table 7. (cont.)**

| Variable | *VD* (1) | *VD* (2) | *HD* (3) |
|---|---|---|---|
| Num.Obs. | 211 | 211 | 196 |
| R2 | 0.21 | 0.81 | 0.35 |
| R2 Adj. | 0.05 | 0.77 | 0.17 |
| AIC | 40.00 | −257.9 | 39.00 |
| BIC | 164.10 | −130.5 | 180.00 |
| Log.Lik. | 16.98 | 166.94 | 23.49 |
| RMSE | 0.22 | 0.11 | 0.21 |

Notes: For columns (1) and (2), we use the vertical diversification sample and *VD* is the dependent variable. For column (3), we use the horizontal diversification sample and *HD* is the dependent variable. In column (2), *numSegments* is an integer counting the number of supply chain segments (*productiongAg*, *processing*, etc.) in which a firm is active. OLS standard errors are reported in parentheses. *$p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

## Discussion

Taken together, our results point to four conclusions about the potential for using firm characteristics to predict firm-level diversification in the agri-food supply chain:

*Overall, very few firm characteristics predict firm-level diversification.*

Perhaps surprisingly, we do not find consistent evidence that firms with greater sales revenue or larger workforces are any more or less likely to be diversified than smaller firms. Relatedly, we do not find evidence that being woman-owned, minority-owned, or cooperatively owned consistently predicts a firm's level of diversification. In this sense, many of the variables that would be natural candidates to be proxies for firm diversification in the agri-food supply chain fall short.

More broadly, the general lack of statistical significance among firm characteristics and low measures of model fit from our regression analyses suggest that firm diversification is difficult to predict even with a rich set of firm characteristics. Our results suggest there are few, if any, good ways to assess a firm's level of diversification without measuring it directly.

*Engaging in direct sales is the most consistent predictor of increased firm diversification.*

The only observable firm characteristic that is a statistically significant predictor of both vertical and horizontal diversification in both our unidimensional and regression analyses is whether a firm is engaged in retail or direct-to-consumer sales. This result is perhaps unsurprising, but it highlights how direct sales can be complementary to other activities throughout the agri-food supply chain, such as production or processing. Furthermore, firms engaged in direct sales likely have a sales infrastructure that can be readily adapted to various product categories to take advantage of different market opportunities or to engage consumers in using different sales strategies.

*Geographic location (being located in Florida) and organic certification are consistently negatively correlated with firms' levels of vertical diversification.*

Beyond being engaged in direct sales, the only two firm characteristics that are statistically significant in both the unidimensional and regression analyses of VD are whether a firm is located in Florida and whether a firm is certified organic. Although these results might not be very generalizable (our dataset only includes firms from four U.S. states and is certainly not nationally representative), they suggest that some specialization in the agri-food supply chain might be predictable. Florida agri-food firms and organic firms—both more likely focused on production agriculture of specialty crops—are less likely to expand to other segments of the supply chain, perhaps due to inefficiencies of scope (Rawley and Simcoe, 2010; Court et al., 2023) or restrictive growing contracts for specific crops.

*Being engaged in food and beverage retailing is consistently positively correlated with firms' levels of horizontal diversification.*

Beyond being engaged in direct sales, being engaged in food and beverage retailing is the only other firm characteristic that is a statistically significant predictor of horizontal diversification in both our unidimensional and regression analyses. Although this result is not terribly surprising—it is easy to imagine food retailers leveraging their experience and infrastructure to sell a variety of different goods—it is notable that food and beverage retailing is such a strong predictor of horizontal diversification apart from and in addition to the effects of being engaged in direct sales.

## Conclusion

Understanding how firms' diversification decisions impact their resilience and the resilience of their supply chains is important for understanding how global agri-food value chains function. We extend the analysis in Stevens and Teal (2024) to investigate which observable firm characteristics—if any—can consistently predict firms' levels of vertical and horizontal diversification. In the U.S. context, we find that surprisingly few characteristics have strong predictive power. The most consistent predictor is whether a firm engages in direct-to-consumer sales. Firms that do tend to be more vertically diversified and more horizontally diversified.

Our findings suggest that conditions or policies that increase the number of firms engaged in direct-to-consumer sales might also increase firm diversification both across and within supply chain segments, thereby increasing value chain resilience. It is important to note that our empirical results are not causal, meaning we cannot conclude that increasing firms' adoption of direct-to-consumer sales will necessarily increase their diversity; however, direct-to-consumer sales are the single most consistent predictor of firm diversification across all our analyses. We also emphasize that our findings may be limited in their external validity given the limited geographic and temporal scope of our data.

Nonetheless, the over-arching implication of our analysis is that there are no good proxy variables for diversification among firms in the agri-food sector. Policies that intend to target diversified or

specialized firms will need to consider strategies for observing and analyzing firms' levels of diversification. Given the necessity of detailed and proprietary information in such analyses, the feasibility of such policies is questionable.

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