Diversification and Resilience of Firms in the Agri-Food Supply Chain

Andrew W. Stevens & Jim Teal

University of Wisconsin–Madison

NC-1177 Annual Meeting (Detroit, MI)
October 17, 2022

Agricultural and Applied Economics
UNIVERSITY OF WISCONSIN-MADISON

Diversified agri-food supply chains

- February, 2021: President Biden issues Executive Order No. 14017:
  - in part directs the USDA to assess the country's agricultural and food supply chains and propose actions to increase their **resilience**
- February, 2022: USDA issues its recommendations, including:
  - "to reduce concentration and **diversify** market participation in U.S. agri-food supply chains"
- Two competing views of diversification:
  1. Diversified supply chains require **diversified firms** (e.g., Hertel et al., 2021)
  2. Specialized firms are fine if there is diversification *across* firms (e.g., FAO, 2021)

Research question

For businesses in the agri-food supply chain, does within-firm diversification increase a firm's resilience to negative market shocks?

More specifically, does producing a broader range of distinct goods or services increase the likelihood a firm will survive a crisis like the COVID-19 pandemic?

Analytic approach

1. Leverage novel survey data to construct measures of firm-level diversification and resilience to the COVID-19 pandemic

2. Use various inverse-probability weighting (IPW) methods to compare more-diversified firms with comparable less-diversified firms

3. Calculate odds ratios to interpret our results

Survey data overview

- Qualtrics survey administered in spring, 2021
- Targeted agri-food supply chain firms in California, Florida, and Minnesota/Wisconsin
- 872 responses received, yielding 380 usable observations for this analysis
- Key questions asked:
  - firm characteristics (location, annual revenue, employees, etc.)
  - revenue distribution across and within supply chain segments
  - COVID-19 impacts (firm closure, labor shortages, layoffs, etc.)

Measuring firm diversification (1)

Firms were asked about how their pre-pandemic revenues were split between the following enterprises:

- Production Agriculture
- Processing/Manufacturing
- Grocery Wholesaling
- Food and Beverage Retailing
- Restaurant Services
- Other

This gives us five different named segments of the agri-food supply chain.

Measuring firm diversification (2)

Within each of the five named segments, firms were then asked about how their segment-specific revenues were split between different activities. For example, within production agriculture, the activities were:

- Sales of unprocessed farm products for food
- Sales of value-added farm products for food
- Sales of farm products not for human food (feed grains, hay, plants, wool)
- Sales of non-food products
- Post-harvest activities for other farms (drying, apple processing, etc.)
- Service to other businesses (pollination, harvesting, etc.)
- Service to customers (such as agritourism)
- Other

Measuring firm diversification (3)

Using the first set of questions, we develop an **index of vertical diversification**:

$$VD = 100 \times \left(1 - \sum_{i=1}^{n} \left(\frac{r_i}{R}\right)^2\right)$$

where r_i is the firm's revenue from each i of the n supply chain segments and R is the firm's total revenue.

Since n has an upper bound in our empirical setting (6 possible segments), we also generate a **normalized index of vertical diversification**:

$$VD^{norm} = 100 \times \left(\frac{1 - \sum_{i=1}^{n} \left(\frac{r_i}{R}\right)^2}{1 - \frac{1}{n}}\right)$$

Measuring firm diversification (4)

Using the second set of questions, we develop an **index of horizontal diversification**:

$$HD = \sum_{j=1}^{5} \left(\frac{r_j}{R} \times 100 \times \left(1 - \sum_{i=1}^{n_j} \left(\frac{r_i}{r_j} \right)^2 \right) \right)$$

where j indexes the five named supply chain segments, 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 also generate a **normalized index of horizontal diversification**:

$$HD^{norm} = \sum_{j=1}^{5} \left(\frac{r_j}{R} \times 100 \times \left(\frac{1 - \sum_{i=1}^{n_j} \left(\frac{r_i}{r_j} \right)^2}{1 - \frac{1}{n_j}} \right) \right)$$

Measuring firm resilience

We analyze **four binary measures of firm resilience** to the COVID-19 pandemic:

1. *EverClosed*: equals one if the firm closed temporarily or permanently due to COVID-19
2. *LayoffsOrClosed*: accounts for whether the firm implemented layoffs due to COVID-19
3. *ShortageOrClosed*: accounts for whether the firm experienced a labor shortage due to COVID-19
4. *NegativeLaborShock*: combines the other three measures

We cannot disentangle firm closure from the other measures since closed firms did not answer the same questions as open firms.

Sample refinement

Using binary measures of firm diversification ($VD = 0$ vs. $VD > 0$ and $HD = 0$ vs. $HD > 0$), we use observable firm characteristics to generate propensity scores that a firm is diversified:

$$logit(\pi_i) = f(\text{firm characteristics}_i) + \varepsilon_i$$

where π_i is the probability that firm i is diversified.

We then "trim" our samples to ensure overlap in the propensity scores between diversified and specialized firms.

This results in a **vertical diversification sample** of 133 firms and a **horizontal diversification sample** of 221 firms.

Summary statistics: dependent variables

	Initial Sample		Vertical Diversification Sample		Horizontal Diversification Sample	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
EverClosed	0.266	0.442	0.353	0.480	0.253	0.436
LayoffsOrClosed	0.511	0.501	0.617	0.488	0.471	0.500
ShortageOrClosed	0.384	0.487	0.466	0.501	0.385	0.488
NegativeLaborShock	0.592	0.492	0.684	0.467	0.570	0.496
Observations	380		133		221	

Summary statistics: treatment variables

	Initial Sample		Vertical Diversification Sample		Horizontal Diversification Sample	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
VerticallyDiversified	0.303	0.460	0.135	0.343	0.208	0.407
HorizontallyDiversified	0.706	0.456	0.692	0.464	0.643	0.480
VD	11.972	20.807	4.800	13.492	8.064	17.483
VD^{norm}	14.366	24.968	5.760	16.191	9.677	20.980
$VD \vert VD > 0$	39.560	18.393	35.468	16.181	38.743	16.714
$VD^{norm} \vert VD^{norm} > 0$	47.472	22.072	42.561	19.417	46.492	20.056
HD	25.113	23.618	26.183	24.305	22.727	23.393
HD^{norm}	28.714	26.629	29.714	27.217	25.901	26.280
$HD \vert HD > 0$	35.565	20.433	37.820	20.265	35.371	20.086
$HD^{norm} \vert HD^{norm} > 0$	40.666	22.744	42.920	22.357	40.310	22.195
Observations	380		133		221	

Summary statistics: control variables

	Initial Sample		Vertical Diversification Sample		Horizontal Diversification Sample	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
SalesRevenue ($1,000)	31,467	335,694	1,236	4,140	1,886	5,546
FullTime	77.068	728.563	7.827	19.241	8.113	16.676
PartTime	24.576	105.445	16.008	25.440	13.348	42.398
ContractLabor	2.957	24.829	1.278	4.020	1.028	5.638
CA	0.526	0.500	0.797	0.404	0.538	0.500
MNWI	0.450	0.498	0.180	0.386	0.448	0.498
ProductionAgriculture	0.303	0.460	0.248	0.434	0.376	0.485
ProcessingManufacturing	0.150	0.358	0	0	0.149	0.357
GroceryWholesaling	0.139	0.347	0.030	0.171	0.118	0.323
FoodRetail	0.316	0.465	0.323	0.470	0.281	0.450
Restaurant	0.403	0.491	0.398	0.491	0.294	0.457
OtherEnterprise	0.150	0.358	0.135	0.343	0.041	0.198
Observations	380		133		221	

Outcome equation

Because our dependent variables (measures of firm resilience) are binary, our outcome equation takes the form of a logit:

$$logit(\rho_i) = \gamma_1 Diversification_i + f(\text{firm characteristics}_i) + \xi_i$$

where ρ_i is the probability that firm i is resilient and *Diversification* is either *VerticallyDiversified*, *HorizontallyDiversified*, *HD*, or HD^{norm}.

We estimate the outcome equation several ways:

- Unweighted observations (likely incorrect)
- IPW using traditional propensity scores (for *VerticallyDiversified* and *HorizontallyDiversified*)
- IPW using CBGPS and npCBGPS methods (for *HD* and HD^{norm})
  - CBGPS = covariate-balancing generalized propensity score
  - npCBGPS = non-parametric CBGPS
  - see Fong et al. (2018)

Identification

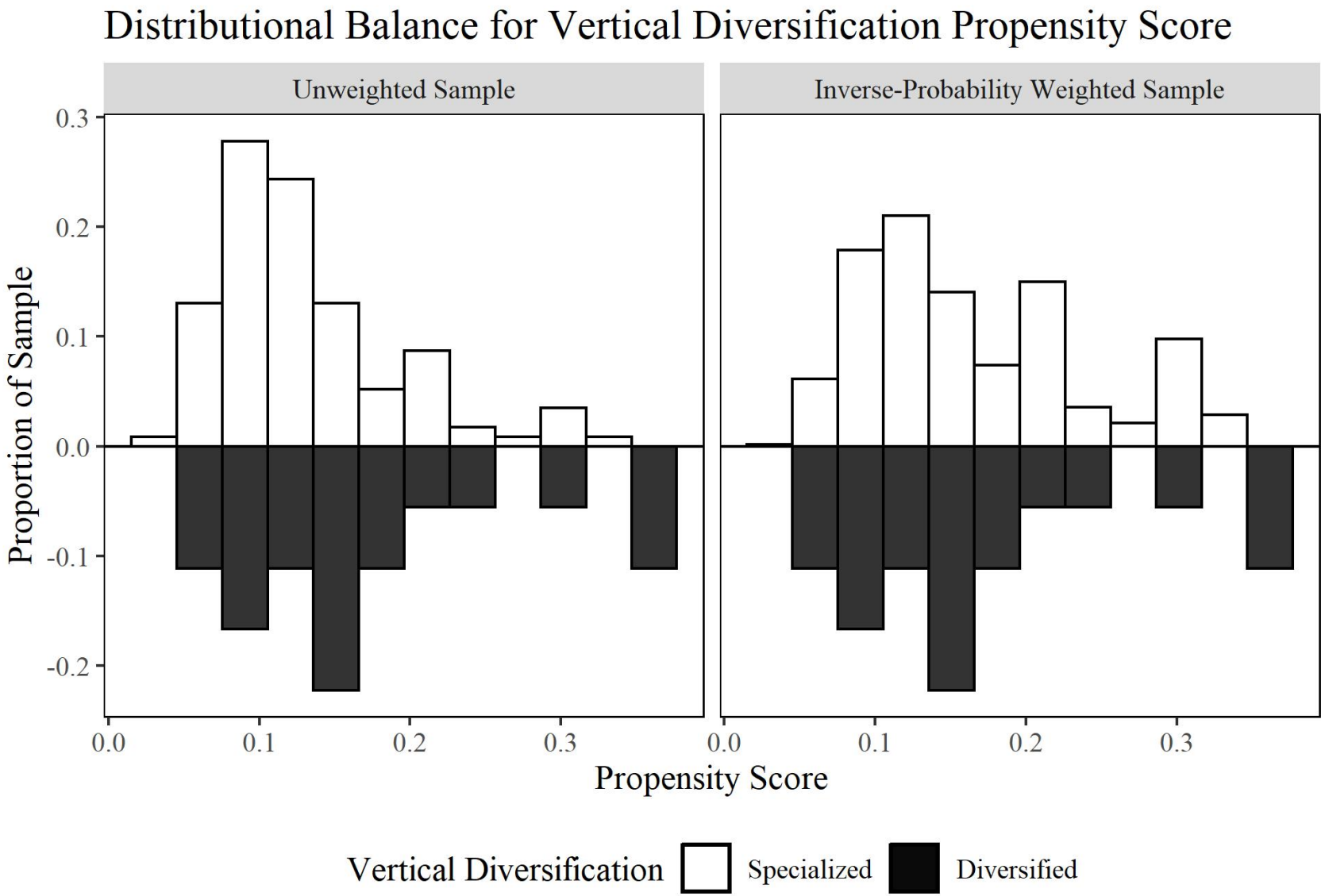
Our identification strategy relies on two arguments:

1. We assume that firms' levels of diversification are as good as random after controlling for observable characteristics
   - IPW methods are doubly-robust and efficient at controlling for observable characteristics
   - enforcing overlap in estimated propensity scores is crucial to compare "apples to apples"

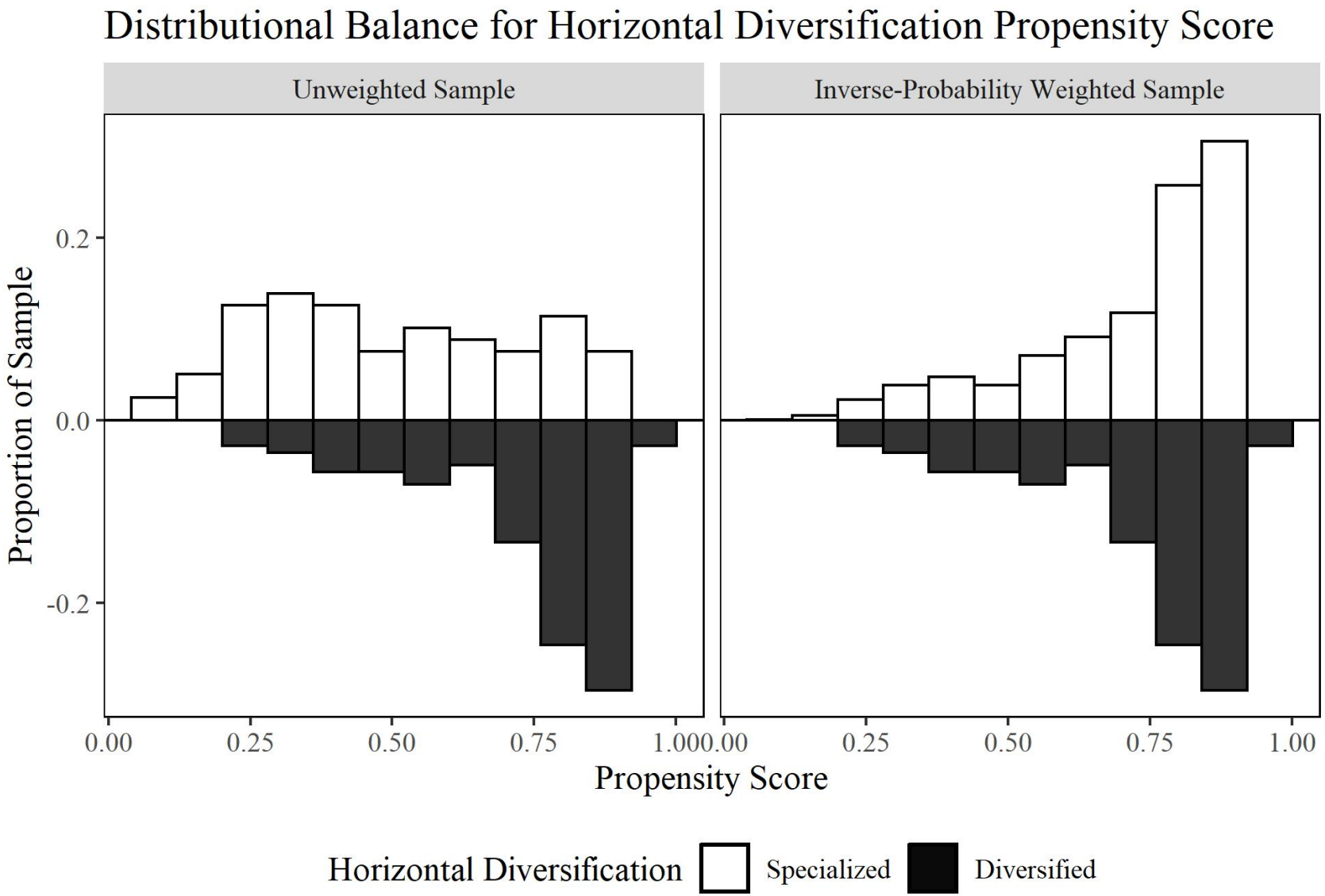
2. We argue the COVID-19 pandemic was unpredictable and disruptive, constituting an exogenous market shock to all firms in our sample

Our results are still threatened by possible omitted variable bias, but we argue our methods improve on the existing approaches in the literature.

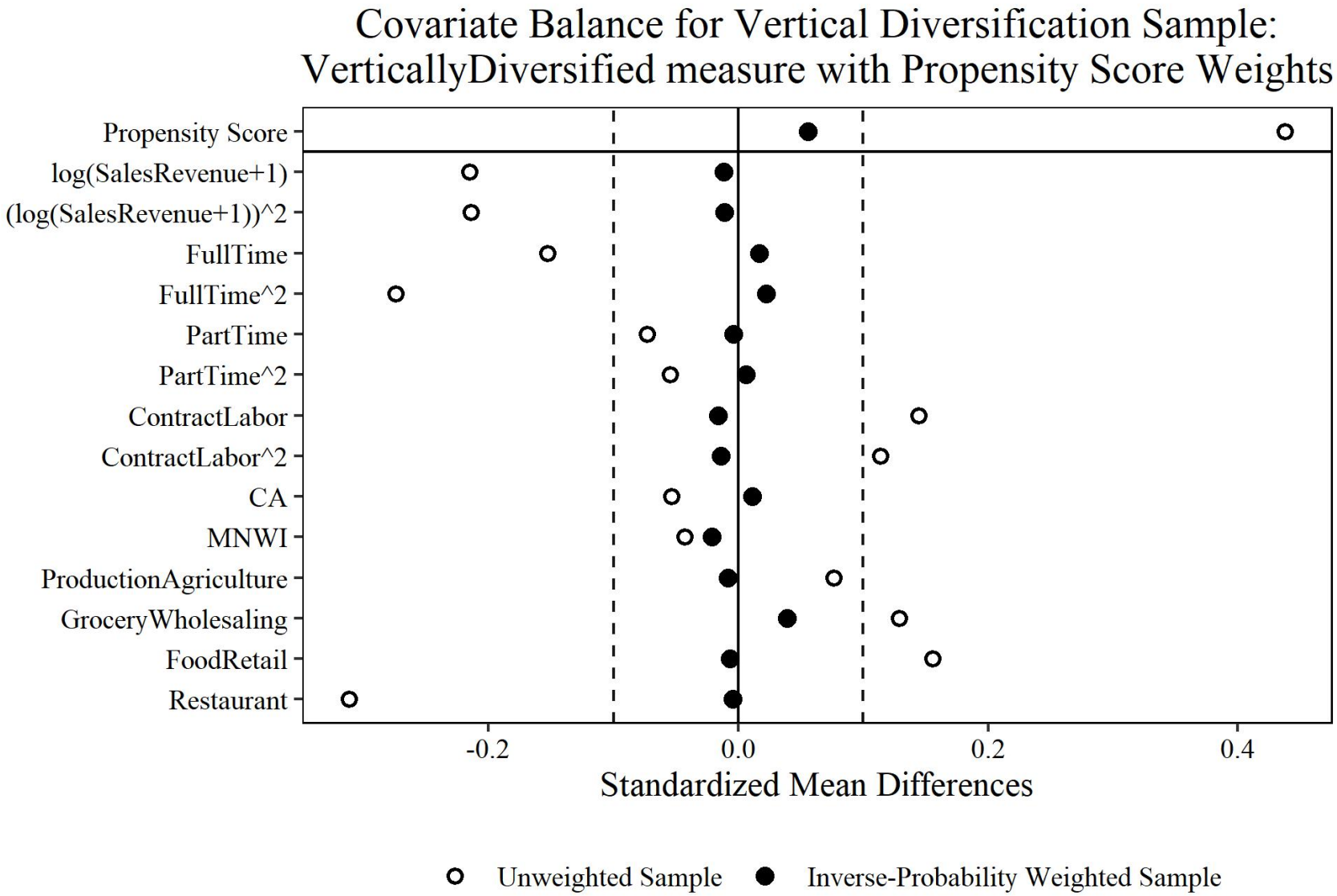
Distributional balance: *VerticallyDiversified* (binary)



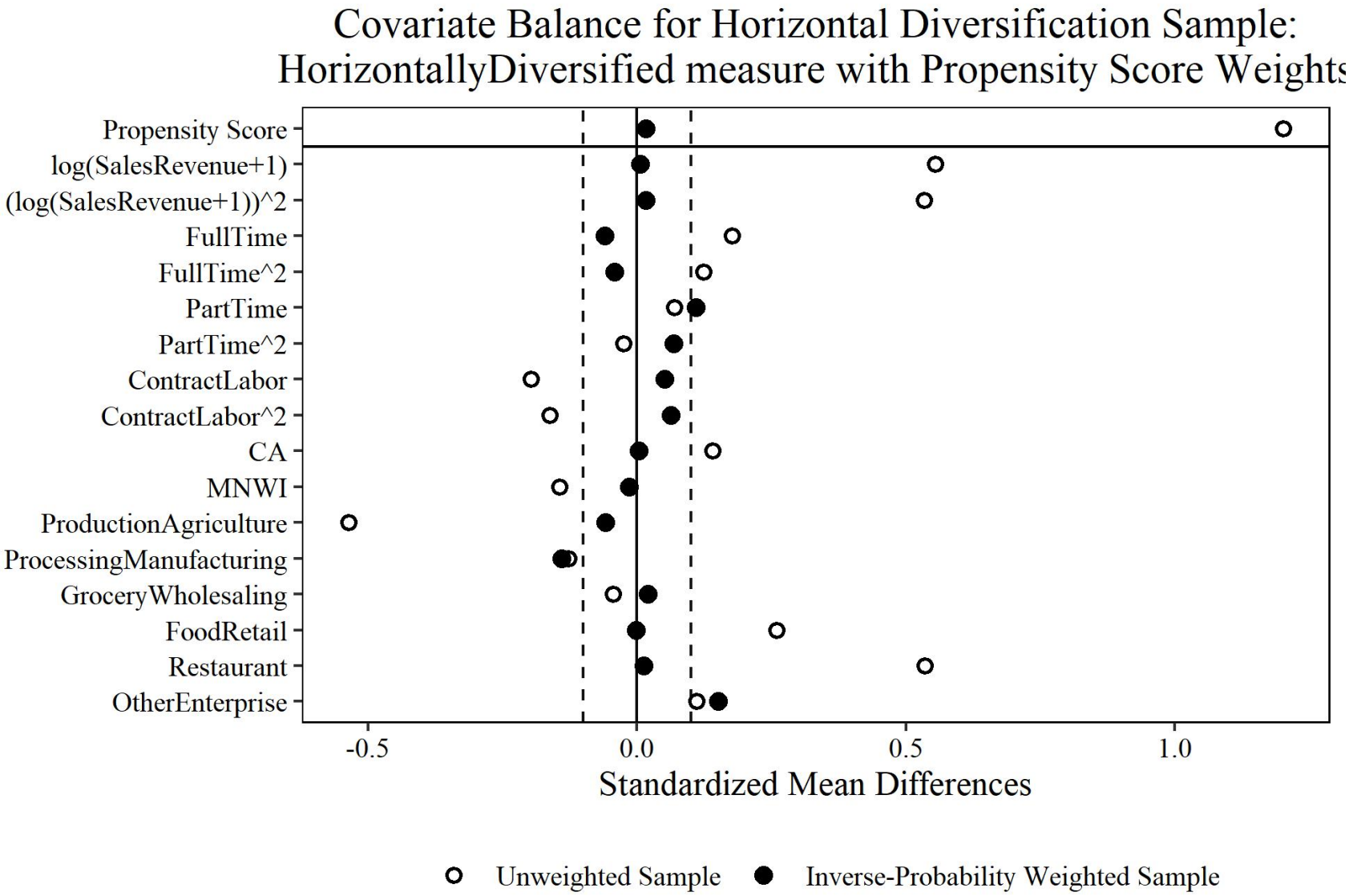
Distributional balance: *HorizontallyDiversified* (binary)



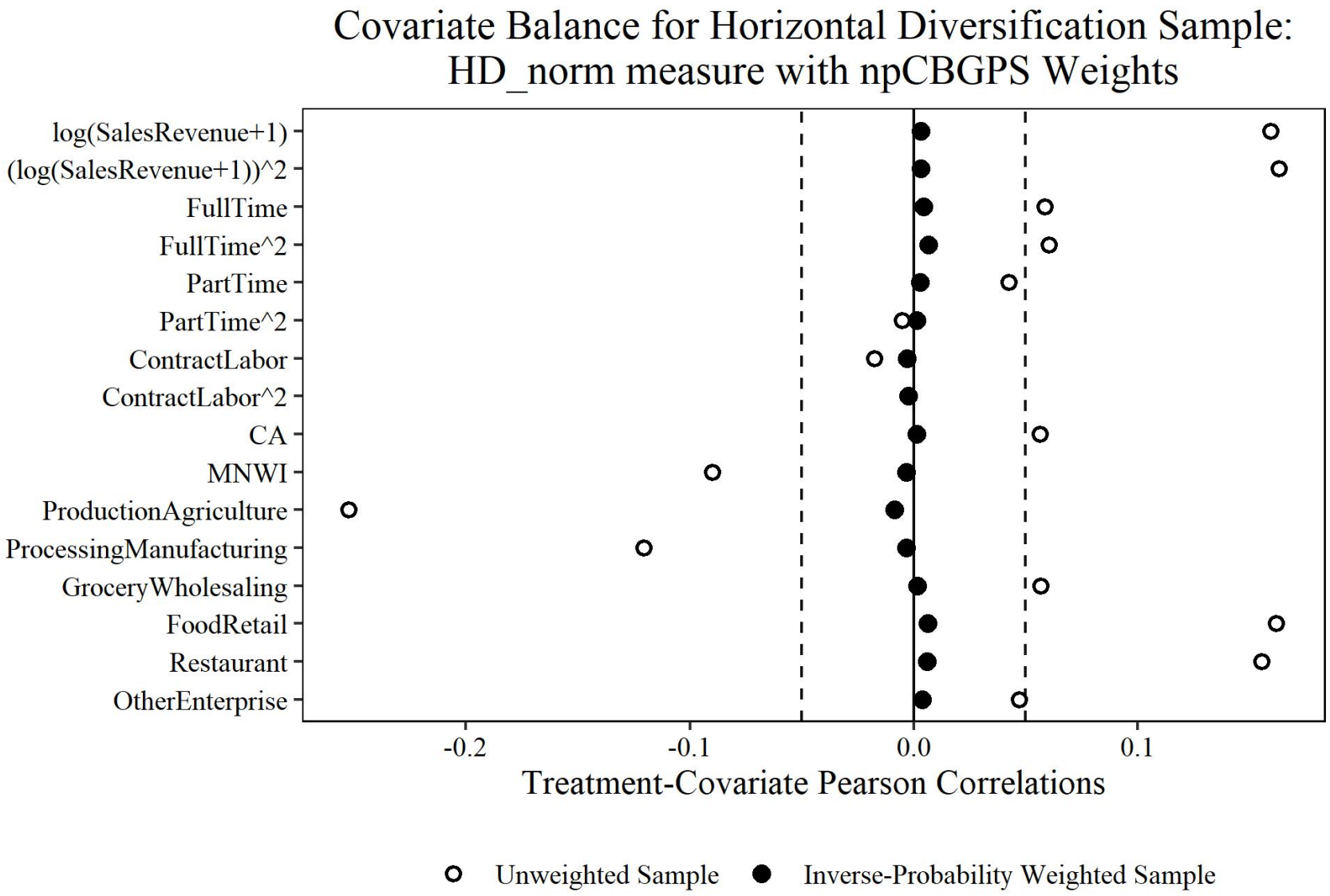
Covariate balance: *VerticallyDiversified* (binary)



Covariate balance: *HorizontallyDiversified* (binary)



Covariate balance: HD^{norm} (continuous) (representative example of continuous measures)



Results (1): Vertical diversification odds ratios

Outcome variable:	*EverClosed*	*LayoffsOrClosed*	*ShortageOrClosed*	*NegativeLaborShock*
VerticallyDiversified				
Unweighted	**3.64**	**3.78**	2.86	**4.47**
	(1.21, 11.92)	**(1.06, 16.8)**	(0.981, 9.31)	**(1.11, 24.52)**
IPW-weighted	**4.73**	5.2	3.43	4.73
	(1.01, 28.45)	(0.866, 50.53)	(0.819, 16.609)	(0.815, 40.077)

Odds ratios are estimated for diversified firms. Parentheses contain 95% confidence intervals. Odds ratios that are statistically different from 1 at a 95% level of confidence are bolded.

Results (2): Horizontal diversification odds ratios

Outcome variable:	*EverClosed*	*LayoffsOrClosed*	*ShortageOrClosed*	*NegativeLaborShock*
HorizontallyDiversified				
Unweighted	0.526	0.824	0.545	0.679
	(0.236, 1.154)	(0.394, 1.683)	(0.266, 1.098)	(0.321, 1.386)
IPW-weighted	0.63	0.85	0.711	0.67
	(0.33, 1.18)	(0.492, 1.465)	(0.41, 1.22)	(0.376, 1.18)
HD				
Unweighted	0.621	0.734	**0.518**	**0.561**
	(0.342, 1.089)	(0.438, 1.211)	**(0.299, 0.866)**	**(0.329, 0.937)**
CBGPS-weighted	**0.529**	0.711	**0.485**	**0.546**
	(0.284, 0.944)	(0.426, 1.173)	**(0.28, 0.809)**	**(0.325, 0.9)**
npCBGPS-weighted	**0.517**	0.656	**0.479**	**0.526**
	(0.282, 0.906)	(0.392, 1.08)	**(0.279, 0.794)**	**(0.312, 0.868)**
HD^{norm}				
Unweighted	0.638	0.714	**0.53**	**0.55**
	(0.351, 1.124)	(0.423, 1.185)	**(0.306, 0.888)**	**(0.32, 0.923)**
CBGPS-weighted	**0.542**	0.689	**0.491**	**0.529**
	(0.29, 0.97)	(0.409, 1.142)	**(0.284, 0.82)**	**(0.314, 0.876)**
npCBGPS-weighted	**0.53**	0.637	**0.486**	**0.513**
	(0.289, 0.933)	(0.378, 1.054)	**(0.283, 0.807)**	**(0.303, 0.849)**

For *HorizontallyDiversified*, odds ratios are estimated for diversified firms. For *HD* and HD^{norm}, odds ratios are estimated at the mean value of either *HD* or HD^{norm} among those firms with *HorizontallyDiversified* = 1. Parentheses contain 95% confidence intervals. Odds ratios that are statistically different from 1 at a 95% level of confidence are bolded.

Interpreting results

- Vertically diversified firms are (almost five times!) more likely to have closed at some point during the COVID-19 pandemic compared to vertically specialized firms
- Horizontally diversified firms are less likely (about half as likely as horizontally specialized firms) to have experienced negative outcomes (closure or labor shortage) during the COVID-19 pandemic
- Accounting for variation in the *extent* of horizontal diversification is important for capturing the second relationship

Additional discussion and conclusion

- Our results are relevant for "small and medium-sized" firms with modest revenues and few employees
- Our results are informative for shocks that are similar to the COVID-19 pandemic: large, unforeseen, and supply-chain-disrupting
- We are uncertain about the specific mechanisms that drive our results, but have various hypotheses:
  - Diseconomies of scope for small firms
  - Sensitivity to supply chain disruptions
  - Substitutability of inputs (especially labor) across outputs