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Excess Competition among Food Hubs

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Food hubs offer a novel solution to connect small and mid-sized local farms, which individually lack the scale to profitably market their products. Because many food hubs rely on grants and philanthropy to provide services and are not necessarily profit-driven, markets may unintentionally oversaturate due to overinvestment. We use a firm-entry model to estimate the average U.S. county population necessary for one, two, and three food hubs to break even. Our findings suggest that policy makers and philanthropists need to consider the carrying capacity of the local food environment and population prior to supporting additional food hubs.

Key words: food hub location, local food, local food systems, social capital

Introduction

Farmers selling only via intermediated channels reported more than three times the local food sales compared to farms selling only via direct channels in 2008 (Low and Vogel, 2011). Growth in local food sales via direct-marketing channels has stalled (Thilmany McFadden, 2015), creating a challenging environment for farmers who lack the scale to reach wholesale buyers. Food hubs (FH) aggregate, distribute, and market source-identified food products from multiple farms, providing more cost-effective and dependable solutions for farmers seeking to sell in intermediated markets (Woods et al., 2013; Barham et al., 2012).

Recognizing this potential, public and nonprofit sectors have increasingly focused their efforts and funding on developing local food infrastructure (Jablonski, Schmit, and Kay, 2016). Most food hubs have some non-sales revenue, up to 18% of their gross revenue (Hardy et al., 2016), indicating that FH management may not necessarily react to market signals in the same way a purely profit-driven firm would. The grant, programming, and philanthropic support targeted to this sector could unintentionally be detrimental if it only defers exit and does not encourage firms to adapt to market forces or threshold sizes. If the intention is to support market access for small and mid-sized farms, this over-competition may be disruptive and leave producers uncertain of which distribution option will provide stable, fair access to intermediated markets.

This paper explores the effects of increased competition on existing food hubs and determines the optimal number of food hubs in a county by estimating breakeven market sizes for one, two, and three firms. We also identify community characteristics (e.g., economic activity,

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population, complementary food businesses, and social capital) associated with FH profitability. To contextualize our results in terms of the industry, we compare results for food hubs to those estimated for a more-established, for-profit industry sector: fruit and vegetable merchant wholesalers (MW), conventional aggregators of produce that may rely on global suppliers and may not be limited by the supply of source-identified foods.

As these establishments' profits are not directly observable, our empirical approach follows Bresnahan and Reiss's (1991, hereafter BR) seminal firm entry model, in which breakeven profits are inferred from the observed number of firms. Our empirical results provide evidence of potential market cannibalization by a community's second and third food hubs, suggesting that market conditions with little to no competition are more favorable to FH sustainability. We also find that food hubs and merchant wholesalers are influenced differently by community characteristics. For example, while fewer and larger farms with sales via direct channels are associated with higher profits for conventional merchant wholesalers, the presence of food hubs is directly related to numerous and smaller direct market farms. Counties with relatively higher social capital scores are also linked with more profitable food hubs; for-profit merchant wholesalers did not show a similar relationship.

Previous research evaluating the sustainability of food hubs has been based on case studies (e.g., Franklin, Newton, and McEntee, 2011; Krejci et al., 2016), which may not be generalizable, or theoretical exercises (e.g., Winfree and Watson, 2017). Franklin, Newton, and McEntee use the case of one food hub in the United Kingdom to examine challenges faced by local food systems initiatives and suggest that in order to be financially viable once established, a food hub may have to limit the scope of its original social or environmental goals. In contrast, Krejci et al., examining one Midwestern food hub, find that social factors may be more important to FH sustainability than financial factors. Neither study examines the role of over-competition. Using a theoretical model of competitive advantage and externalities, Winfree and Watson find that "buying local" can lead to welfare enhancements in the presence of little to no competition and externalities.

Other research on food hubs has mainly focused on the value they can bring to local or regional food systems and communities, with the majority directed at the relationship between food hubs and small to mid-sized farms (e.g., Hardesty et al., 2014; Newman et al., 2012; Barham et al., 2012).

We contribute to the developing literature on FH sustainability by estimating the number of food hubs an area can sustain and the current degree of over-competition in this sector. To our knowledge, an analysis of this nature—which can help policy makers and philanthropists discern whether and where food hubs should be funded—has not been attempted previously. We also use national data and adapt a theoretically consistent model of profits to uncover factors associated with FH profitability, adding context to the case-study approaches discussed previously.

We also update the literature on location conditions for food manufacturing growth (see, e.g., Goetz, 1997), and complement (Dunne et al., 2013) by exploring how firm entry and survival may vary by differentiation strategy. We also contribute to the understanding of the importance of social capital to food hubs, finding that social capital is positively associated with FH profitability. Our findings also contribute to the vast literature on local foods and intermediated marketing channels.

Local Food Hubs and Conventional Merchant Wholesalers

Food hubs are relatively equally dispersed across the United States (Table 1), but conventional food distribution channels, such as merchant wholesalers, are primarily concentrated in the West and South, with the smallest percentage in the Midwest. Food hubs are relatively more dispersed across urban and rural areas. Although most are established in metro areas, they also have a relatively stronger presence in non-metro, non-metro-adjacent areas than merchant wholesalers. Importantly, food hubs have a greater rural presence than conventional channels, while conventional merchant

Table 1. U.S. Fruit and Vegetable Merchant Wholesalers and Food Hubs by Location

Description	Merchant Wholesalers[a] Number	Merchant Wholesalers[a] Percent	Aggregate of Food Hubs Number	Aggregate of Food Hubs Percent	NGFN Food Hubs[b] Number	NGFN Food Hubs[b] Percent	AMS Food Hubs[c] Number	AMS Food Hubs[c] Percent
All establishments	4,797	100.00%	369	100.00%	296	100.00%	169	100.00%
Northeast	1,082	22.56%	84	22.76%	72	24.32%	38	22.49%
Midwest	585	12.20%	86	23.31%	71	23.99%	38	22.49%
West	1,673	34.88%	78	21.14%	64	21.62%	34	20.12%
South	1,451	30.25%	119	32.25%	89	30.07%	57	33.73%
Metro areas	4,347	90.62%	259	70.19%	204	68.92%	124	73.37%
Counties in metro areas of 1 million population or more	3,042	63.41%	140	37.94%	112	37.84%	76	44.97%
Counties in metro areas of 250,000 to 1 million population	998	20.80%	78	21.14%	61	20.61%	34	20.12%
Counties in metro areas of fewer than 250,000 population	307	6.40%	41	11.11%	31	10.47%	14	8.28%
Non-metro, metro adjacent	321	6.69%	86	23.31%	72	24.32%	35	20.71%
Urban population of 20,000 or more, adjacent to a metro area	173	3.61%	30	8.13%	28	9.46%	12	7.10%
Urban population of 2,500 to 19,999, adjacent to a metro area	135	2.81%	46	12.47%	36	12.16%	19	11.24%
Completely rural or less than 2,500 urban population, adjacent to a metro area	13	0.27%	10	2.71%	8	2.70%	4	2.37%
Non-metro, non-metro adjacent	129	2.69%	24	6.50%	20	6.76%	10	5.92%
Urban population of 20,000 or more, not adjacent to a metro area	44	0.92%	6	1.63%	5	1.69%	1	0.59%
Urban population of 2,500 to 19,999, not adjacent to a metro area	69	1.44%	16	4.34%	14	4.73%	8	4.73%
Completely rural or less than 2,500 urban population, not adjacent to a metro area	16	0.33%	2	0.54%	1	0.34%	1	0.59%

Notes: The aggregate of food hubs combines the number of NGFN food hubs and AMS food hubs in the following manner: by county, it takes the value of whichever is larger.
Sources: [a] U.S. Census Bureau (2012b), NAICS Code "424480."
[b] National Good Food Network, "US Food Hubs - Map." Available online at http://ngfn.org/resources/food-hubs/food-hubs#section-10 [31 Aug. 2016].
[c] U.S. Department of Agriculture (2016).

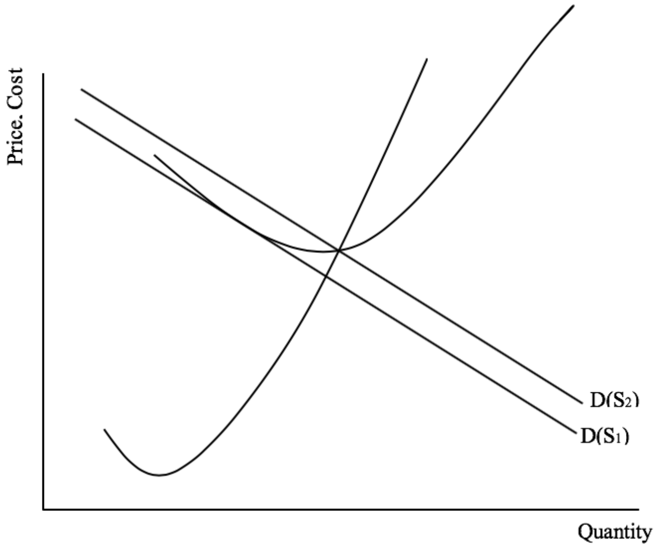

Figure 1. Breakeven Firm Demand and Margins
Source: Adapted from Bresnahan and Reiss (1991).

wholesalers target metro areas.[1] In short, food hubs create more spatially uniform market access for all U.S. farms than merchant wholesalers do.

In 2013, there were 220 self-reported food hubs across the United States, an increase of two-thirds from 2008 (Jablonski, Schmit, and Kay, 2016; U.S. Department of Agriculture, 2016). While food hubs saw mostly steady growth from 2008 to a peak in 2012, their numbers appear to have declined since 2013 (U.S. Department of Agriculture, 2016), although current data quality make this uncertain.[2]

A Model of Food Hub Location and Profits

We estimate breakeven market sizes for food hubs and measure potential sales cannibalization associated with a higher number of firms. To this end, we adapt BR's entry-threshold model to estimate FH profits and uncover conditions favorable to profitability, including local business presence and size, social capital, and other characteristics that may influence FH viability. We also estimate profits of conventional merchant wholesalers to contextualize the niche FH contribution to the food system.

Figure 1 illustrates the model's intuition. Demand for FH produce is given by $D(S_1)$; average cost is given by AC and includes any government grants applied to operations to offset variable costs; MC depicts marginal cost. In this figure, a monopolist pricing at P_M would break even given the market size, S_1, supporting $D(S_1)$. Subsequent entry would push price down; an oligopoly structure would lead to a price between P_M and P_C, with P_C the perfectly competitive price. Subsequent entry would also require additional firm incentives: Any firm pricing below P_M suffers a loss. If, for example, a second firm were to enter with additional government discounts or volunteers, its price would drop

[1] This is comparable to the findings of a national FH survey of 107 food hubs (Fischer et al., 2013). The survey found that 75% of food hubs were located in metro areas, 16% in non-metro, metro-adjacent areas, 9% in non-metro, non-metro-adjacent areas, and 2% in completely rural areas.

[2] This could be a lagged response to the 2011 passage of the Food Safety and Modernization Act (FSMA), which called for broad, diverse changes to the U.S. food safety system, including a higher burden for food handling and regulatory compliance (Low et al., 2015). However, according to a national survey, only 3% of food hubs listed "meeting food safety requirements" as their greatest challenge (Fischer et al., 2013). It could also be that more recently established food hubs have yet to list themselves in the searchable directories.

below P_M and the second firm would lure customers away from the first. To remain viable at the new price, the incumbent must also seek out similar ways to reduce average cost. In contrast, given a market with a larger size, $D(S_2)$, additional firms could be supported without receiving additional government aid.

The breakeven market size is the population necessary for each establishment to at least cover variable costs. The breakeven market size for N establishments operating under business model i (i = FH or MW), S_{Ni}, is determined by both demand and cost factors. We assume that demand factors can be divided into those determining the size of the market, $\boldsymbol{Y_i}$, and those—such as demographics (including income)—influencing per capita demand, $\boldsymbol{X_i}$. Following BR, we assume that total demand is given by $Q_i = d(\boldsymbol{X_i}, P_i)S(\boldsymbol{Y_i})$, where $d(\boldsymbol{X_i}, P_i)$ is the representative consumer's demand and $S(\boldsymbol{Y_i})$ the number of potential consumers for each business model. On the cost side, we assume that food hubs and merchant wholesalers incur different fixed costs, $F(\boldsymbol{Z_i})$, since many food hubs use outside funding or grants. We also allow average variable costs, $c(qi, \boldsymbol{W_i})$, to vary across i as food hubs and merchant wholesalers face different operating cost structures because they buy from farms with different marketing capacities (Jablonski and Schmit, 2016). $\boldsymbol{Z_i}$ and $\boldsymbol{W_i}$ contain variables affecting fixed and variable costs for each i, and q_i represents output for each business model. N_i is the expected equilibrium number of firms operating under each business model.

Even though food hubs may not be motivated by profits, both food hubs and merchant wholesalers must at least break even to remain operating in a given location. Entry into a county occurs if total variable profits at least cover fixed costs. N firms of each business model, i, earn per firm profits given by

$$\pi_{Ni} = S_{Ni}d_{Ni}[P_{Ni} - c_{Ni}(q_{Ni}, \boldsymbol{W}_i)] - F_{Ni} = S_{Ni}V_{Ni}(P_{Ni}, q_{Ni}, \boldsymbol{X}_i, \boldsymbol{W}_i) - F_{Ni}(\boldsymbol{Z}_i), \tag{1}$$

where $P_{Ni} - c_{Ni}(q_{Ni}, \boldsymbol{W}_i)$ is the per unit profit margin, $F_{Ni}(\boldsymbol{Z}_i)$ is fixed cost, and $d_{Ni}[P_{Ni} - c(q_{Ni}, \boldsymbol{W}_i)] = V_{Ni}(P_{Ni}, q_{Ni}, \boldsymbol{X}_i, \boldsymbol{W}_i)$ is the per unit variable profit for each of the N_i firms operating in an area.

As more firms enter, the portion of the market that each serves shrinks, so that variable profits decline with N_i. Unless the industry is perfectly competitive, later entrants may also face increased costs. For example, there are costs associated with acquiring customers who already have longstanding business relationships with incumbent firms. Firms unable to at least recapture costs do not enter; entries cease when $\pi_{Ni} \geq 0$ and $\pi_{Ni+1} < 0$. Because our profit equation depends on market size, the breakeven condition provides the expected threshold population needed to support N_i firms. To construct breakeven population thresholds, we set profits in equation (1) to 0 and solve for S_{Ni}. The solution is

$$S_{Ni} = \frac{F_{Ni}(\boldsymbol{Z}_i)}{V_{Ni}(P_{Ni}, q_{Ni}, \boldsymbol{X}_i, \boldsymbol{W}_i)}, \tag{2}$$

which is the population required for N_i firms remain viable.

A ratio of threshold market sizes needed to support successive entrants can be used to measure market cannibalization. BR calculate competitive effects of successive firms on monopoly profits using the per firm population threshold ratio; we use the same ratio to examine how successive establishments affect profits of all firms in the location:[3]

$$R_{Ni} = \frac{S_{Ni+1}/(N_i + 1)}{S_{Ni}/N_i} \tag{3}$$

measures the per firm, relative population necessary to support an additional establishment. When this ratio is 1, an additional firm requires the same population as the first, which means that sales of

[3] Here we measure cannibalization in the same way that BR measure competition. The key difference between cannibalization and competition is firm ownership: Competition among firms or products with the same parent/owner is cannibalization. While not all food hubs are owned by the same entity, many are funded using government resources and are often an investment for public benefits (Woods et al., 2013).

existing firms are not being "eaten away" by entrants and a greater population is served. When this ratio is less than 1, industries face positive location externalities, as conceptualized in the industry cluster literature (see, e.g., Legun and Bell, 2016). When this ratio is greater than 1, each firm has to serve more than the population that one establishment needs to serve to be profitable; this can occur for a variety of reasons, one of which is when additional firms cannibalize inputs, resources, or existing sales.[4]

Social capital, defined as "norms and networks to facilitate collective action," is associated with economic growth (Rupasingha, Goetz, and Freshwater, 2000, p. 566) and may be particularly important for food hubs (Krejci et al., 2016; Hardesty et al., 2014), which often rely on philanthropy and volunteerism (Fischer et al., 2013). Let k be a measure of social capital in a location. We allow social capital to affect both fixed costs and variable profits because it can contribute to the relative availability of philanthropy (e.g., reducing start-up costs) or volunteerism (e.g., reducing labor costs; Rupasingha, Goetz, and Freshwater, 2006). The effect of social capital on population threshold, S_{Ni}, is given by

$$\frac{\partial S_{Ni}}{\partial k} = S_{Ni}\left(\frac{\partial F_{Ni}/F_{Ni}}{\partial k} - \frac{\partial V_{Ni}/V_{Ni}}{\partial k}\right). \tag{4}$$

The local food system, including local businesses, can also have an important and related impact on FH thresholds. Unlike social capital, we have no conceptual link or expectations about the relationship between local businesses and fixed costs. Therefore, we allow local business to influence profits only through variable costs and per capita demand. The effect of local business, b, on breakeven population thresholds is given by

$$\frac{\partial S_{Ni}}{\partial b} = -\frac{\partial V_{Ni}}{\partial b}\frac{F_{Ni}}{V_{Ni}^2}, \tag{5}$$

so that although the magnitude of the effect of b is gradated by F_{Ni}/V_{Ni}^2, the sign is completely determined by its effect on variable profits.

The Empirical Model

Ideally, we would estimate profits using data on prices and quantities. Despite extensive data collection efforts by the Agricultural Marketing Service (AMS) and the National Good Food Network (NGFN), consistent and reliable data on FH prices paid and quantities sold are not available. Instead, we use the number of establishments in a location, N_i, to infer profitability, which limits our dependent variable to discrete and finite values. As we are using limited dependent variables, we can only estimate profits up to an arbitrary scale factor. We assume that profits are additively separable in a deterministic component and the unobservable error following BR, among others.

As mentioned above, both social capital, k, and local businesses, b, can influence variable profits. We assume that social capital enters V_{Ni} linearly to examine whether there is evidence of at least a first-order effect; however, this assumption may be too restrictive for local food businesses that influence both FH and/or MW profits through number and size of firms. For instance, the number of small farms selling directly may have different influences on FH and MW profits than the number of large farms selling directly if the business models of these two types of firms are more conducive to a certain type of supplier. Therefore, we allow both the number of local businesses, b_{1j}, and their sizes (determined by number of employees), b_{2j}, to influence profits in a location, where j indicates the type of local business and ranges from 1 to J. We assume that V_{Ni} and F_{Ni} are linear in parameters

[4] Another is when successive firms face increasing fixed costs, such as the cost of acquiring customers served by incumbents, as previously discussed.

and that all other elements of $\boldsymbol{X_i}$ and $\boldsymbol{W_i}$ (excluding k, b_1, and b_2) belong to $\boldsymbol{U_i}$, so that

$$V_{Ni} = \alpha_{1i} + \beta_{ki}k_i + \boldsymbol{U}_i'\boldsymbol{\beta}_i + \sum_{j=1}^{J}\phi_{1ji}b_{1ji} + \phi_{2ji}b_{1ji}b_{2ji} - \sum_{n=2}^{N}\alpha_{ni}, \tag{6}$$

where α_i and $\boldsymbol{\beta}_i$ are parameters to be estimated and α_{ni} $(n \geq 2)$ have negative signs when per establishment variable profits are lower for successive entrants. F_{Ni} is given by

$$F_{Ni} = \gamma_{1i} + \lambda_{ki}k_i + \boldsymbol{Z}_i'\boldsymbol{\lambda}_i + \sum_{n=2}^{N}\gamma_{ni}, \tag{7}$$

where $\boldsymbol{\lambda}_i$, ϕ_i, and γ_i are parameters to be estimated and the γ_{ni} capture the differences in fixed costs faced by successive firms. If barriers to entry or inefficiencies increase the costs of additional establishments, these parameters will be positive. We also add an error term so that combining equations (6) and (7) above yields

$$\pi_{Ni}^{*} = S_{Ni}V_{Ni}(\boldsymbol{X}_i, \boldsymbol{W}_i, \alpha_{ni}, \boldsymbol{\beta}_i, \beta_{ki}, \phi_{1ji}, \phi_{2ji}) - F_{Ni}(\boldsymbol{Z}_i, \boldsymbol{\lambda}_i, \lambda_{ki}, \gamma_{ni}) + \varepsilon_i, \tag{8}$$

where the ε_i are assumed to be independent and identically distributed. Since π_{Ni} are per firm profits, all terms (including those representing unobservables) are the same for each establishment belonging to the same business model in the market.

FH and MW profits are latent variables, and we use the observed number of firms for each business model to infer the relative profitability of different locations, following BR. If a location has no firm, we assume that the location is not profitable for any number of firms. Similarly, if we observe one firm in a location, we assume that it can be profitable for one firm but not for two; and we continue this logic for two, three, and four firms.

We assume that the unobservable portion of profit is distributed standard normal and we can use an ordered probit for the estimation. In these ordered probit models, the dependent variable is N_i and the likelihood functions are constructed by calculating probability statements for each N_i, following BR. The probability that no firms will establish in a location is equal to

$$P(\pi_{1i} < 0) = 1 - \Phi(\pi_{1i}^{*}), \tag{9}$$

where $\Phi(\bullet)$ is the normal cumulative density function and π_{1i}^{*} is the profit, as described by equation (8), of a single firm (i.e., when $N_i = 1$). The probability that a monopolist will establish is equal to

$$P(\phi_{1i} \geq 0 \;\&\; \pi_{2i} < 0) = \Phi(\pi_{1i}^{*}) - \Phi\pi_{2i}^{*}), \tag{10}$$

and, likewise, the probability that N_i establishments will locate in an area is

$$P(\phi_{Ni} \geq 0 \;\&\; \pi_{Ni+1} < 0) = \Phi(\pi_{Ni}^{*}) - \Phi\pi_{Ni+1}^{*}), \tag{11}$$

Using equations (6) and (7) for equation (8), as already noted, we can estimate the empirical counterparts of equations (2)–(5).

Data and Methods

We estimate equation (8) separately and jointly for food hubs and merchant wholesalers using county-level data collected from publicly available sources for one year, which encompasses the 3,106 counties in the contiguous United States. To our knowledge, there is no complete database on food hubs, and we rely on self-reported data from two sources to construct three measures of the number of food hubs per county as of August 2016. We use AMS and NGFN data to construct the number of i) AMS food hubs, ii) NGFN food hubs, and iii) composite food hubs. The AMS collects extensive data on food hubs, including county and state Federal Information Processing Standard (FIPS) codes and the ZIP code of their location. As of August 2016, the AMS included information on 170 food hubs. The NGFN provides information on the name of the food hub, a link to its website (if available), and the city and state names of its location (National Good Food Network, 2016, p. 12). As of August 2016, it included information on 296 food hubs. We matched this information to county data by mapping city and state names and recovering the FIPS code of the county to which the combination belonged. If the combination did not belong to a unique county FIPS, only one of the county FIPS was assigned.

Either source may underreport the number of food hubs, especially if FH managers or owners are not aware of both directories or choose to self-report only to one. Our third measure is constructed using both of these measures: composite food hubs takes the value of whichever is larger, the AMS number of food hubs or the NGFN number of food hubs, by county. In this way, we expect to have a more comprehensive FH measure without the potential hazard of double counting food hubs that may be captured by both sources. The composite FH measure yields 369 food hubs across all counties.

Our model assumes that food hubs enter only when they know they will at least break even. Food hubs that are at least partially funded by grants or philanthropy may not complete a breakeven analysis prior to entry. To overcome this potential limitation, we examine the 2012 demographic landscape but use the number of viable food hubs as of 2016.

For merchant wholesalers, we use the number of NAICS 424480 "fresh fruit and vegetable merchant wholesalers" from the County Business Patterns Database (U.S. Census Bureau, 2012b), which provides the most relevant comparison to food hubs and is consistent with the approach used by Wholesome Waves (2014).[5] According to a national survey (Fischer et al., 2013), 93% of food hubs carry fresh produce, which makes up, on average, 68% of total gross sales, the highest grossing category by a large margin (the second-highest, "meat and poultry," accounts for 21%).

The number of merchant wholesalers per county, N_{MW} can reach large values, whereas the number of food hubs, N_{FH}, is concentrated between 0 and 3. For our baseline specification, we set the dependent variables N_i^* equal to the number of establishments if $0 < N_i < 3$ and equal to 4 for all counties with four or more establishments. This allows us to measure market sizes for one, two, and three establishments. In a subsequent specification, we restrict the values of N_i^* further to equal the actual number of establishments for values between 0 and 2 and to take the value of 3 for all counties with three or more establishments. This allows us to investigate FH locations relying solely on AMS data; however, we can only calculate market sizes for one and two establishments with this model because of the limited number of food hubs in locations with a greater number of firms.

A key independent variable is total county population, from the U.S. Census Bureau Population Estimates Program (PEP), which is a proxy for market size and is multiplied by all variables in the variable profit equation (8). The number of local farms already participating in local sales is likely important for food hubs that want to build their markets on an existing consumer base. To proxy for the size of farms selling directly, we include the per capita number of farms selling directly per county and the per capita value of products sold directly from farms (U.S. Department of Agriculture, 2014).[6] We hypothesize that a larger number of smaller local farms selling directly raises FH variable profits as they likely seek wholesale market access, while larger farms may have a greater variety of cost-effective distribution options to deliver produce to final consumers.

[5] The County Business Patterns Database provides information on nine groups of grocery and related product MWs (NAICS 4244): general line grocery, packaged frozen food, dairy product, poultry and poultry product, confectionery, fish and seafood, meat and meat product, fresh fruit and vegetable, and other grocery and related product.

[6] The Census of Agriculture suppresses direct sales data for some counties where they could lead to disclosure of private information. We estimate these suppressed data by summing all direct sales across all counties in a state, comparing this sum to the state total, and then dividing the excess state sales equally among all farms for each county with suppressed data.

To capture social capital differences across counties, we use the 2009 social capital index developed by Rupasingha, Goetz, and Freshwater (2006). Using principal component analysis, this variable is constructed from four indicators of social capital: an aggregate of community involvement, voter turnout, census response rate, and number of nonprofit organizations (excluding those with international approaches). We rescaled social capital to range from 0 (the county with the least social capital) to 100 (the county with the highest social capital observed in the data).

In our baseline specification, we include the per capita number of establishments and per capita number of employees to proxy for establishment size of several local businesses collected from the County Business Patterns Database: supermarkets and other grocery stores (NAICS 445110); colleges, universities, and professional schools (NAICS 6113); community food services (NAICS 624210); full-service restaurants (NAICS 722511); and mobile food services (NAICS 722330). We also include the number of supercenters and club stores (NAICS 452910) but do not add a size proxy for these, because these stores are generally all similarly large-scale.

To control for other demand-side factors that may influence variable profits, we also included median per capita income (in $thousands) and share of Supplemental Nutrition Assistance Program (SNAP) participants from the U.S. Bureau of Census Small Area Income and Poverty Estimates (2012a) and share of black population, share of Hispanic population, share of population over the age of 25 with some college, and share of population over the age of 25 with at least a bachelor's degree from PEP. To account for varying operational costs, we used state-level commercial electricity price in cents/kwh (U.S. Department of Energy, 2012).

Variables included to proxy for fixed costs are fruit and vegetable production and imports as well as the home price index (HPI). We rely on data collected and estimated by Ge et al. (2018) to proxy for fruit and vegetable production and imports per county.[7] The HPI from the Lincoln Institute of Land Policy () is based on adjusted Federal Housing Finance Agency (FHFA) quarterly repeat-sales (constant quality) house prices and provides a proxy for building and real estate costs.

We allow our model to capture differences in variable profits and fixed costs across areas, showing different levels of urbanization by using indicator variables for counties that are classified as metropolitan and non-metro, metro adjacent, obtained using a clustering of categories from the Economic Research Service's 2013 Rural–Urban Continuum Codes (U.S. Department of Agriculture, 2013). Lastly, we capture regional variation via fixed effects for the Northeast, Midwest, and West in equations (6) and (7). Table 2 summarizes the variables used in the estimation, along with the distribution of our dependent variable across the United States and for counties with at least one merchant wholesaler, composite food hub, NGFN food hub, or AMS food hub.

While nearly 25% of counties have a MW, FHs are only identified in about 5%–10% of counties, depending upon the data source used to measure the number of FHs. Also, even though FHs have a greater relative presence in non-metro counties than MWs, the mean population in counties with at least one FH is larger than those in counties with a MW.

The social capital index ranges from 0 to 100, with a mean across all counties of 18.33, signifying that counties with very high levels of social capital are uncommon. Counties with at least one merchant wholesaler have a mean social capital index of 16.24, while those with at least one food hub have a higher mean social capital index than counties; however, both are lower than the average social capital across all counties. Coupled with food hubs' relatively larger presence (compared to merchant wholesalers) in non-metro areas, this may point to food hubs being positioned to increase fruit and vegetable availability in rural areas by leveraging the relatively high social capital.

[7] These authors use data from the National Agricultural Statistics Service USDA 2007 Census of Agriculture for 37 (43) states and 21 (34) fresh market vegetable commodities (fresh fruit and berry crops). They overcome data suppressions using a constrained maximum likelihood mathematical programming model, which is estimated simultaneously for state and county to produce maximum likelihood estimates of all suppressed county harvested acreage statistics. Fruit and vegetables are summed after conversion to a common unit (1,000 lb).

Table 2. Summary Statistics for Counties with Fruit and Vegetable Merchant Wholesalers and Food Hubs

Variable Description	Across U.S. ($N = 3,106$ counties)		Merchant Wholesalers ($N = 753$ counties)		Aggregate Hubs ($N = 281$ counties)		NGFN Hubs ($N = 221$ counties)		AMS Hubs ($N = 139$ counties)	
Counties with zero establishments			2,353		2,825		2,885		2,967	
Counties with one establishments			361		222		172		118	
Counties with two establishments			117		41		32		18	
Counties with three establishments			66		12		11		1	
	Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
Population (in thousands)	99.53	317.82	306.65	594.64	401.04	847.65	443.14	930.82	404.27	682.30
Income, per capita	44.71	11.32	49.44	13.23	50.14	12.49	50.62	12.70	50.14	12.44
Income, per capita squared	2,126.78	1,233.46	2,619.35	1,581.32	2,669.81	1,562.04	2,723.21	1,619.15	2,667.51	1,496.19
SNAP participants, share	16.06	8.03	16.02	6.74	15.15	5.95	14.95	5.91	15.48	5.94
Black, population share	9.22	14.55	11.13	13.55	11.13	14.52	10.71	13.76	11.58	15.28
Hispanic, population share	8.68	13.38	12.16	14.63	10.24	12.78	10.21	12.81	10.60	12.52
Some college, population share 25+	30.05	5.21	30.13	4.81	29.48	4.74	29.27	4.64	29.50	5.06
Bachelor's or higher, population share 25+	20.06	8.91	25.64	10.34	28.40	10.60	29.12	10.55	28.23	10.69
Commercial electricity price	9.06	1.64	9.94	2.22	10.20	2.40	10.30	2.47	10.08	2.36
Social capital index	18.34	6.25	16.24	4.04	17.50	4.05	17.50	3.77	17.60	4.22
Direct sales from farms, per capita	8.39	14.01	7.76	13.47	10.61	15.62	11.44	16.06	10.20	16.89
Farms selling direct, per capita	1.34	1.33	0.82	0.94	1.14	1.36	1.19	1.41	1.15	1.48
Supermarkets and other grocery stores, per capita	0.25	0.20	0.20	0.11	0.21	0.11	0.22	0.11	0.22	0.11
Employees of supermarkets and other grocery, per capita	8.15	4.54	9.04	3.88	9.74	3.78	9.97	3.97	9.55	3.55
Assisted living facilities for the elderly, per capita	0.06	0.08	0.06	0.06	0.07	0.06	0.07	0.06	0.07	0.06
Employees of assisted living facilities for the elderly, per capita	1.14	1.61	1.48	1.14	1.62	1.19	1.65	1.22	1.54	1.07
Community food services, per capita	0.04	0.12	0.02	0.03	0.02	0.04	0.02	0.04	0.02	0.03
Employees of community food services, per capita	0.23	1.00	0.16	0.33	0.19	0.28	0.19	0.26	0.19	0.32
Full-service restaurants, per capita	0.79	0.59	0.76	0.37	0.85	0.43	0.87	0.46	0.81	0.30
Employees of full-service restaurants, per capita	12.16	9.38	16.24	8.77	17.43	10.14	17.61	10.56	16.98	7.61
Mobile food services, per capita	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Employees of mobile food services, per capita	0.02	0.08	0.04	0.06	0.04	0.06	0.04	0.06	0.04	0.06
Supercenters and club stores, per capita	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02
Fruit and vegetable production and imports	48.34	329.50	180.02	649.87	173.45	715.46	173.73	757.88	217.62	911.33
Home price index	1.45	0.20	1.44	0.21	1.46	0.20	1.46	0.19	1.47	0.22
Metro county indicator	0.37	0.48	0.70	0.46	0.66	0.48	0.64	0.48	0.70	0.46
Non-metro, metro adjacent county indicator	0.33	0.47	0.21	0.41	0.27	0.44	0.29	0.45	0.23	0.42
Northeast region indicator	0.07	0.25	0.18	0.38	0.21	0.41	0.24	0.43	0.19	0.39
Midwest region indicator	0.34	0.47	0.23	0.42	0.24	0.43	0.24	0.43	0.22	0.42
Western region indicator	0.13	0.34	0.18	0.39	0.19	0.39	0.19	0.39	0.23	0.42

Notes: N = number of counties with at least one establishment.

The average per capita number of farms selling directly and average per capita direct sales from farms are greater in counties with at least one food hub versus counties with at least one merchant wholesaler; however, both are lower than the national average. Conversely, fruit and vegetable production and imports are larger than average in counties a merchant wholesaler or food hub; however, in counties with merchant wholesalers, this value is relatively larger than it is in counties with food hubs.

Per capita income in counties with at least one food hub is greater and the share of SNAP participants lower than the average across all counties. Food hubs and merchant wholesalers are located in counties with more diversity (higher black and Hispanic shares) than the average U.S. county, although this could be due to the fact that most merchant wholesalers and food hubs are located in more metro areas, where populations are generally more diverse.

Equation (8) is estimated by maximum likelihood, using the likelihood equations of the ordered probit described previously. Due to the high number of counties with zero food hubs and/or zero merchant wholesalers, we estimate a first-stage equation determining the likelihood of observing any type of wholesale food distribution establishment in a county; from this we generate an inverse Mills ratio to be included in the second stage (equation 8) as an additional control to accommodate selection bias (Greene and Hensher, 2010), following Van de Ven and Van Praag (1981), among others. Appendix A reports results of the first-stage regressions. In an Online Supplement (available at www.jareonline.org), we also estimate the model without correcting for potential selection bias. Tests for equivalence of the two models' thresholds and threshold ratios reveal some differences in the results of the two approaches.

Empirical Results and Discussion

Model Validation

As discussed previously, we cannot rule out that some of the food hubs collected via NGFN and AMS are not also represented in the County Business Patterns data on merchant wholesalers. To test whether conventional merchant wholesalers and food hubs are profit-dependent, we estimate equation (8) for each establishment type in a system using bivariate ordered probit and then test for independence. The likelihood ratio test of independent equations fails to reject the null hypothesis that the profits of each establishment type are independent with a χ^2, 1 degree of freedom, test value of 1.03 and a p-value of 0.3099. Therefore, each is properly estimated independently and the remaining discussion will refer to the statistically preferred, independent specification.

Results

Table 3 presents the estimated parameters of equation (8) for the baseline model (i.e., $N_i^* = 1, 2, 3, 4$) as well as standard errors and Maddala's pseudo-R^2. The model fits the data relatively well for a cross-section model, with a pseudo-R^2 of 32.4% for the composite FH measure and 39.8% for MWs. Table 4 reports the results of the model using a restricted N_i^*.

We first compare the coefficients of the MW and composite FH profit equations to address our objective of comparing FH and MW profit drivers. From equation (8), the estimated parameters can be directly interpreted as each variable's relationship with profits, although these are arbitrarily scaled. Then we discuss estimated population thresholds and population threshold ratios to address our primary objectives of determining the optimal number of food hubs in a county and uncovering effects of increased competition on incumbent food hubs. Lastly, we identify community characteristics associated with FH profitably, namely the relationship of social capital and the presence of complementary local food businesses with FH population thresholds.

Table 3. Parameter Estimates and Standard Errors for the Baseline Model

Variable Description	Parameter	Merchant Wholesalers	Food Hub Composite	NGFN Food Hubs
Variable Profits				
Per capita income ($thousands)	β_{1i}	−0.00049***	−0.00033***	−0.00032***
		(0.00011)	(0.00007)	(0.00008)
Per capita income ($thousands), squared	β_{2i}	3.55E-06***	1.88E-06***	1.74E-06***
		(7.29E-07)	(4.72E-07)	(5.30E-07)
Share of SNAP recipients	β_{3i}	−0.00003	−0.00012***	−0.00010**
		(0.00007)	(0.00004)	(0.00004)
Share of black population	β_{4i}	0.00004	0.00006***	0.00006***
		(0.00002)	(0.00002)	(0.00002)
Share of Hispanic population	β_{5i}	0.00007***	0.00004***	0.00006***
		(0.00003)	(0.00001)	(0.00002)
Share of 25+ with some college	β_{6i}	0.00005	0.00023***	0.00022***
		(0.00007)	(0.00006)	(0.00006)
Share of 25+ with at least a bachelor's	β_{7i}	−0.00003	0.00011***	0.00014***
		(0.00004)	(0.00003)	(0.00004)
Social capital index	β_{ki}	0.00010	0.00017**	0.00016**
		(0.00009)	(0.00007)	(0.00007)
Electricity price	β_{8i}	−0.00044***	−0.00016**	−0.00021**
		(0.00014)	(0.00008)	(0.00010)
Metro county indicator (RUCCs 1–3)	β_{9i}	−0.01662***	−0.01388***	−0.01395***
		(0.00318)	(0.00416)	(0.00447)
Metro-adjacent county indicator (RUCCs 4, 6, 8)	β_{10i}	−0.01227***	−0.00936**	−0.00895*
		(0.00356)	(0.00459)	(0.00491)
Northeast region indicator	β_{11i}	0.00292***	0.00041	0.00039
		(0.00109)	(0.00065)	(0.00071)
Midwest region indicator	β_{12i}	−0.00017	0.00049	0.00113**
		(0.00065)	(0.00043)	(0.00050)
West region indicator	β_{13i}	0.00037	−0.00040	−0.00035
		(0.00088)	(0.00054)	(0.00062)
Per capita value of direct sales from farms ($thousands)	β_{14i}	0.00019***	0.00002	0.00005
		(0.00005)	(0.00004)	(0.00004)
Per capita number of farms selling direct	β_{15i}	0.00071	0.00409***	0.00432***
		(0.00077)	(0.00073)	(0.00078)
Per capita number of grocery supermarkets	ϕ_{11i}	0.01932***	−0.00122	0.00012
		(0.00514)	(0.00149)	(0.00145)
Per capita number of employees in grocery supermarkets	ϕ_{21i}	−0.00008	0.00005	0.00010
		(0.00010)	(0.00007)	(0.00008)
Per capita number of assisted living facilities for the elderly	ϕ_{12i}	−0.00762	−0.00994*	−0.01176*
		(0.00776)	(0.00575)	(0.00633)
Per capita number of employees in assisted living facilities for the elderly	ϕ_{22i}	0.00068**	−0.00004	−0.00002
		(0.00034)	(0.00026)	(0.00028)
Per capita number of community food services	ϕ_{13i}	0.01438	0.02891	0.02137
		(0.01889)	(0.01785)	(0.01963)
Per capita number of employees in community food services	ϕ_{23i}	0.00077	−0.00124	−0.00173
		(0.00132)	(0.00106)	(0.00122)
Per capita number of full-service restaurants	ϕ_{14i}	0.00184	0.00451***	0.00458***
		(0.00170)	(0.00106)	(0.00109)
Per capita number of employees in full-service restaurants	ϕ_{24i}	0.00002	−0.00014***	−0.00016***
		(0.00007)	(0.00004)	(0.00004)
Per capita number of mobile food services	ϕ_{15i}	0.01263	0.09508***	0.08108***
		(0.03218)	(0.02343)	(0.02743)
Per capita number of employees in mobile food services	ϕ_{25i}	−0.00243	−0.01560***	−0.01049**
		(0.00406)	(0.00457)	(0.00501)
Per capita number of supercenters and club stores	ϕ_{16i}	0.00780	−0.03973	−0.02910
		(0.02973)	(0.02524)	(0.02759)
V2 − V1	α_{2i}	0.00161***	0.00294***	0.00302***
		(0.00050)	(0.00035)	(0.00039)

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Table 3. – continued from previous page

Variable Description	Parameter	Merchant Wholesalers	Food Hub Composite	NGFN Food Hubs
V3 − V2	α_{3i}	0.00080*	0.00355***	0.00463***
		(0.00048)	(0.00059)	(0.00081)
V4 − V3	α_{4i}	0.28533	0.15549	0.23777
		(5.72164)	(1.58942)	(1.62150)
Population (in thousands)	α_{1i}	0.03303***	0.01558***	0.01407**
		(0.00593)	(0.00527)	(0.00569)
Fixed costs				
Fruit and vegetable production and imports	λ_{1i}	0.00138***	0.00021**	0.00015*
		(0.00016)	(0.00009)	(0.00009)
Home price index	λ_{2i}	−0.59138***	0.21514	0.19795
		(0.16299)	(0.21488)	(0.24226)
Social capital index	λ_{ki}	−0.00296	0.01812**	0.01662*
		(0.00777)	(0.00820)	(0.00897)
Metro county indicator (RUCCs 1–3)	λ_{3i}	0.84851***	0.91169***	0.80421***
		(0.13030)	(0.17865)	(0.19898)
Metro-adjacent county indicator (RUCCs 4, 6, 8)	λ_{4i}	0.46142***	0.68894***	0.66538***
		(0.13513)	(0.18422)	(0.20403)
Northeast region indicator	λ_{5i}	0.20540	0.27838*	0.31394*
		(0.15872)	(0.15230)	(0.16202)
Midwest region indicator	λ_{6i}	−0.12317	−0.10816	−0.15293
		(0.09389)	(0.11029)	(0.12476)
West region indicator	λ_{7i}	0.23059**	−0.05051	−0.13733
		(0.11369)	(0.13838)	(0.15726)
F1	γ_{1i}	1.14622***	3.19890***	3.23000***
		(0.28432)	(0.39107)	(0.43700)
F2 − F1	γ_{2i}	2.06076***	4.52743***	4.53929***
		(0.28690)	(0.40489)	(0.45218)
F3 − F2	γ_{3i}	2.67546***	5.77579***	5.71103***
		(0.29102)	(0.44578)	(0.49270)
F4 − F3	γ_{4i}	3.24068***	8.13891***	13.08008***
		(0.29629)	(1.00826)	(2.67247)
Pseudo-R^2		39.103%	30.336%	32.853%

Notes: Single, double, and triple asterisks (*,**,***) indicate statistical difference at the 10%, 5%, and 1% level. Numbers in parentheses are standard errors.

One of the key variables underlying variable profits is population. The coefficient on population reflects the relationship between population and profitability; it can also be structurally interpreted via its role as α_1, which is a component of the variable profits when a single establishment locates in a county, independent of other demand and cost considerations. For merchant wholesalers and food hubs, the coefficient on population is positive and significant. Additionally, α_{i2} and α_{i3} show how variable profits change with the entry of subsequent firms. For food hubs, α_{i2} and $\alpha_{i3}$are positive and significant at the 1% level, indicating that the establishment of successive food hubs is associated with a reduction in each food hub's profits, all else constant.

Social capital is associated with increases in FH variable profits, but we find no such relationship with MW profits. It could be that counties with higher social capital also have residents who value food hubs or shop with the food businesses their area food hub supplies, thus strengthening variable profits. However, it could also be that counties with a higher social capital index have a population more likely to engage in volunteer work, which would decrease FH variable costs (thus increasing variable profits). In a national FH survey, 49% of FH managers responded that the inability to increase their paid staff was a barrier to growth (Fischer et al., 2013). The coefficient on social capital for composite food hubs is 0.014 and is not significant at the 10% level, indicating that social capital may have little effect on initial FH investments.

Table 4. Parameter Estimates and Standard Errors, Up to Three Establishments

Variable Description	Parameter	Merchant Wholesalers	Food Hub Composite	NGFN Food Hubs	AMS Food Hubs
Variable Profits					
Per capita income ($thousands)	β_{1i}	−0.00052***	−0.00029***	−0.00032***	−0.00019**
		(0.00012)	(0.00007)	(0.00008)	(0.00009)
Per capita income ($thousands), squared	β_{2i}	3.29E-06***	1.65E-06***	1.80E-06***	1.25E-06**
		(8.04E-07)	(4.85E-07)	(5.19E-07)	(5.77E-07)
Share of SNAP recipients	β_{3i}	−0.00008	−0.00010**	−0.00010**	−0.00005
		(0.00009)	(0.00004)	(0.00004)	(0.00005)
Share of black population	β_{4i}	0.00004	0.00004**	0.00005***	0.00006***
		(0.00003)	(0.00002)	(0.00002)	(0.00002)
Share of Hispanic population	β_{5i}	0.00008***	0.00005***	0.00006***	0.00003*
		(0.00003)	(0.00001)	(0.00002)	(0.00002)
Share of 25+ with some college	β_{6i}	0.00003	0.00018***	0.00017***	0.00012**
		(0.00008)	(0.00005)	(0.00005)	(0.00006)
Share of 25+ with at least a bachelor's	β_{7i}	0.00004	0.00010***	0.00012***	0.00004
		(0.00005)	(0.00004)	(0.00004)	(0.00004)
Social capital index	β_{ki}	0.00012	0.00021***	0.00020***	0.00016**
		(0.00011)	(0.00007)	(0.00007)	(0.00007)
Electricity price	β_{8i}	−0.00056***	−0.00023***	−0.00026***	−0.00025***
		(0.00017)	(0.00008)	(0.00009)	(0.00008)
Metro county indicator (RUCCs 1–3)	β_{9i}	−0.01549***	−0.00980**	−0.00965*	−0.00776
		(0.00345)	(0.00452)	(0.00494)	(0.00543)
Metro-adjacent county indicator (RUCCs 4, 6, 8)	β_{10i}	−0.01127***	−0.00481	−0.00431	−0.00246
		(0.00383)	(0.00489)	(0.00531)	(0.00596)
Northeast region indicator	β_{11i}	0.00430***	0.00036	0.00072	0.00053
		(0.00129)	(0.00064)	(0.00068)	(0.00074)
Midwest region indicator	β_{12i}	0.00056	0.00029	0.00089*	0.00055
		(0.00078)	(0.00046)	(0.00053)	(0.00051)
West region indicator	β_{13i}	−0.00023	0.00017	0.00030	0.00142***
		(0.00096)	(0.00051)	(0.00055)	(0.00053)
Per capita value of direct sales from farms ($thousands)	β_{14i}	0.00021***	−0.00005	−0.00001	−0.00002
		(0.00005)	(0.00004)	(0.00004)	(0.00005)
Per capita number of farms selling direct	β_{15i}	0.00062	0.00418***	0.00444***	0.00205**
		(0.00082)	(0.00076)	(0.00081)	(0.00085)
Per capita number of grocery supermarkets	ϕ_{11i}	0.02649***	0.00048	0.00076	−0.00019
		(0.00655)	(0.00144)	(0.00142)	(0.00198)
Per capita number of employees in grocery supermarkets	ϕ_{21i}	−0.00009	0.00011	0.00014*	0.00018*
		(0.00012)	(0.00008)	(0.00008)	(0.00009)
Per capita number of assisted living facilities for the elderly	ϕ_{12i}	−0.00156	−0.00370	−0.00293	−0.00860
		(0.00837)	(0.00551)	(0.00593)	(0.00603)
Per capita number of employees in assisted living facilities for the elderly	ϕ_{22i}	0.00040	−0.00026	−0.00029	0.00003
		(0.00036)	(0.00028)	(0.00029)	(0.00033)
Per capita number of community food services	ϕ_{13i}	0.02173	0.02566	0.01786	0.02254
		(0.02136)	(0.01809)	(0.02002)	(0.02148)
Per capita number of employees in community food services	ϕ_{23i}	−0.00186	−0.00069	−0.00103	0.00023
		(0.00185)	(0.00117)	(0.00128)	(0.00119)
Per capita number of full-service restaurants	ϕ_{14i}	0.00230	0.00308***	0.00327***	0.00114
		(0.00201)	(0.00112)	(0.00117)	(0.00128)
Per capita number of employees in full-service restaurants	ϕ_{24i}	−0.00003	−0.00014***	−0.00015***	−0.00006
		(0.00008)	(0.00004)	(0.00004)	(0.00004)
Per capita number of mobile food services	ϕ_{15i}	0.02698	0.02229	0.03246	0.02610
		(0.03677)	(0.02139)	(0.02237)	(0.02348)
Per capita number of employees in mobile food services	ϕ_{25i}	−0.00440	0.00497*	0.00446	−0.00145
		(0.00510)	(0.00270)	(0.00275)	(0.00325)
Per capita number of supercenters and club stores	ϕ_{16i}	0.02814	−0.00757	0.00206	0.00215
		(0.03283)	(0.02646)	(0.02876)	(0.02570)
V2 − V1	α_{2i}	0.00177***	0.00361***	0.00364***	0.00468***
		(0.00052)	(0.00042)	(0.00045)	(0.00074)

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Table 4. – continued from previous page

Variable Description	Parameter	Merchant Wholesalers	Food Hub Composite	NGFN Food Hubs	AMS Food Hubs
V3 − V2	α_{3i}	1.20478	0.52442	0.52438	0.01024
		(15.86752)	(6.94029)	(8.98664)	(0.14281)
Population (in thousands)	α_{1i}	0.03396***	0.01163**	0.01176**	0.00743
		(0.00675)	(0.00545)	(0.00587)	(0.00664)
Fixed costs					
Fruit and vegetable production and imports	λ_{1i}	0.00134***	0.00020**	0.00016*	0.00027***
		(0.00017)	(8.46E-05)	(8.96E-05)	(8.94E-05)
Home price index	λ_{2i}	−0.60222***	−0.00302	−0.06586	0.23637
		(0.17114)	(0.22009)	(0.24831)	(0.26304)
Social capital index	λ_{ki}	−0.00880	0.02122***	0.01974**	0.01588
		(0.00839)	(0.00821)	(0.00896)	(0.00963)
Metro county indicator (RUCCs 1–3)	λ_{3i}	0.79600***	0.86881***	0.75872***	0.79365***
		(0.13731)	(0.18524)	(0.20883)	(0.21856)
Metro-adjacent county indicator (RUCCs 4, 6, 8)	λ_{4i}	0.44325***	0.65876***	0.64539***	0.45608**
		(0.14149)	(0.18971)	(0.21294)	(0.23014)
Northeast region indicator	λ_{5i}	0.09543	0.43539***	0.44738***	0.39334**
		(0.17281)	(0.15349)	(0.16295)	(0.18991)
Midwest region indicator	λ_{6i}	−0.15898	−0.17215	−0.21737*	−0.04739
		(0.09952)	(0.11279)	(0.12736)	(0.13799)
West region indicator	λ_{7i}	0.23965**	−0.14902	−0.25868	0.09313
		(0.11726)	(0.14228)	(0.16237)	(0.16243)
F1	γ_{1i}	1.04351***	2.89388***	2.86904***	3.31300***
		(0.30111)	(0.39987)	(0.44758)	(0.48257)
F2 − F1	γ_{2i}	2.02824***	4.36704***	4.35308***	4.66799***
		(0.30383)	(0.41674)	(0.46699)	(0.50714)
F3 − F2	γ_{3i}	2.79363***	7.25281***	6.98837***	8.34339***
		(0.30941)	(0.61766)	(0.65226)	(1.06778)
Pseudo-R^2		0.42877	0.34006	0.36656	0.26875

Notes: Single, double, and triple asterisks (*,**,***) indicate statistical difference at the 10%, 5%, and 1% level. Numbers in parentheses are standard errors.

County per capita income is negatively associated with FH and MW profits. It could be that operating resources (including average labor wages) for these establishments are relatively lower in lower-income locations so opportunity costs are less. For food hubs, this could also reflect the fact that food hubs locate in relatively poorer areas to fulfill their missions, which include a common nonprofit mission of expanding access to fresh foods in underserved areas (Barham et al., 2012). In a national survey, 22% of food hubs reported “food access,” 20% included “local economy,” and 14% included “justice and/or equity” among their value themes (Fischer et al., 2013).

The coefficient on the share of SNAP recipients is negative and significant for food hubs and not significant for merchant wholesalers. This, again, could point to the different missions pursued by profit-seeking merchant wholesalers compared to value-driven food hubs (Barham et al., 2012). Yet as the share of SNAP recipients in a county increases, FH profits may still decrease, presenting challenges to those entities (and justifying grant funds intended to support their missions).

The value of direct sales does not have a statistically significant effect on FH profits, but the number of farms selling directly (and options for supply sources) is positively associated with FH variable profits. The opposite pattern is found for merchant wholesalers, which are positively associated with the value of direct sales from farms and not significantly influenced by the number of farms selling directly. Barham et al. (2012, p. 6) note that “[traditional] wholesale buyers often find it too costly to purchase products directly from numerous farms.” As such, farms that have large direct sales can fill a relatively larger set of produce needs, thus lowering merchant wholesalers’ variable transaction costs (and increasing variable profits).

Neither the number nor the size of full-service restaurants has a significant impact on MW profitability, but both are significantly related to FH profitability. The coefficient on the per capita

Table 5. Population (in thousands) Needed to Support One, Two, and Three Establishments

	Merchant Wholesalers	Food Hub Composite	NGFN Food Hubs	AMS Food Hubs
Estimated with up to three establishments				
To support one establishment	105.38***	182.66***	191.37***	
	(10.59)	(25.49)	(27.69)	
To support two establishments	188.40***	502.88***	507.41***	
	(31.86)	(103.90)	(111.67)	
To support three establishments	342.44***	1669.27**	1867.85**	
	(71.53)	(658.09)	(924.93)	
Estimated with up to two establishments				
To support one establishment	101.81***	206.15***	218.95***	381.90***
	(10.29)	(34.74)	(39.13)	(138.46)
To support two establishments	182.15***	608.45***	603.08***	3534.62
	(31.42)	(171.62)	(184.06)	(7,937.11)

Notes: Single, double, and triple asterisks (*,**,***) indicate statistical difference at the 10%, 5%, and 1% level. Numbers in parentheses are standard errors.

number of full-service restaurants is positive, while the coefficient on the per capita number of employees in full-service restaurants is negative (larger entities may not see FH supply volumes as sufficient to meet their buying needs). This signifies that full-service restaurants have a positive relationship with FH profits that decreases with the size of the restaurant. We find similar results for mobile food services.

We also look at the effect of the number and size of community food services. The County Business Patterns Database classifies businesses like food banks and “meals on wheels” as community food services. In this case, the evidence of a relationship between community food services and MW or FH profits is inconclusive. There is also inconclusive evidence on the relationship between the presence or size of traditional supermarkets or other grocery stores and FH profits. The presence of supercenters and club stores is also not statistically significant for either food hubs or merchant wholesalers. However, we do find a positive and statistically significant coefficient on the number of grocery stores for merchant wholersalers.

The share of the population that is black has a positive and significant relationship with FH profits, but there is inconclusive evidence for the effect on MW profits. A recent ERS report found that non-Hispanic blacks were the only racial/ethnic group to increase whole fruit and total fruit consumption between 1994–1998 and 2007–2008 (Lin and Morrison, 2016). Perhaps this group is also increasingly consuming fruit from local sources if underserved markets now have better options (a demand effect). While education level has no effect on MW profits, locating in counties with more educated individuals is positively related with variable FH profits, likely through heightened awareness, interest, and demand for local, fresh offerings among educated households. The share of the population that is Hispanic is positively associated with both MW and FH profits, which may confirm the profound importance of Hispanic workers in the U.S. agricultural and food industry labor force (a supply or cost effect).

Given that most produce needs to be refrigerated, we also included the electricity price as a variable cost. The coefficient on electricity price is negative and significant, as expected, for both merchant wholesalers and food hubs.

In addition to social capital, the fixed cost variables also include the HPI as a proxy for relative building and real estate costs. The HPI negatively influences MW profits (by increasing fixed costs) but has only a marginally significant effect on FH profits. Approximately 70% of food hubs use some sort of physical space or assets to conduct business (e.g., office space, warehouse, processing facilities, retail space, etc.) but may participate in more cooperative ownership or shared access models that mitigate the role of real estate costs (Fischer et al., 2013). An indicator of the price of these spaces, HPI, did not have a negative effect on FH profits.

To determine the robustness of these results, we also used only NGFN food hubs and AMS food hubs as dependent variables. Although we find quantitative differences, the qualitative results remain the same. As an additional robustness check, we also estimated the model without accounting for the first-stage decision (see the Online Supplement).

Breakeven Market Sizes

A central goal of this paper is to understand the minimum county population required to support a viable food hub. We estimate this measure using the empirical equivalent of equation (2). Table 5 reports the market sizes (in thousands of people) necessary for composite food hubs, NGFN food hubs, AMS food hubs, and merchant wholesalers to break even in a county. Population thresholds are measured using the results from the base line model for 1–3 establishments and using the restricted dependent variable model for 1 and 2 establishments.

We estimate that a county seeking to establish its first food hub needs a population of about 182,660, which is significantly higher than the average county population of about 99,530. For a county to sustain two food hubs, 2.75 times as many, about 502,880 residents, are required for each to at least break even. There are few counties of this size (about 129), suggesting that zero or one food hub is optimal for most counties from a viability perspective. This may suggest that smaller counties seeking to establish a food hub collaboratively may better achieve the population to sustain it. When the third food hub enters the area, the threshold increases to a little over 3 times that for two food hubs. These findings are qualitatively similar when only food hubs collected from the NGFN are used to estimate the breakeven populations.

In contrast, the first merchant wholesaler requires only 105,380 people in a county, and the second requires about 1.8 times that population for both to be viable. To support three merchant wholesalers, a county requires a population less than that needed to support only two food hubs: 342,440. These lower thresholds suggest that there is higher market penetration for the MW food distribution strategy, which is more likely based on relatively large volume transactions driven by price competition and product assortment rather than food hubs' diverse social missions, which may appeal to only a subset of buyers.

We conducted another robustness check using a model that further restricts the dependent variable, which yields slightly higher breakeven market sizes for merchant wholesalers, composite food hubs, and NGFN food hubs. Estimates of breakeven market sizes using only the AMS FH data are substantially larger than those using the composite or NGFN food hubs: 206,150. The estimate for the population needed to support two food hubs is about 608,450.

Population Threshold Ratios

Table 6 presents the per firm population threshold ratios described in equation (3), which are statistically different from 0 at the 1% level, excluding those from the AMS FH regression. Consistent with our aim to determine whether food hubs cannibalize sales, we also test threshold ratios against the competitive and "no cannibalization" benchmark of 1. The ratio comparing the population needed for two versus one food hubs is 1.38, which is statistically different from 1 at the 5% level, indicating that a second food hub is more likely to diffuse the incumbent's revenue compared to the MW threshold ratio of 0.89 (and we fail to reject the hypothesis that it is equal to 1). These results suggest that merchant wholesalers operate in a more competitive market environment and that food hubs operate in an environment that is more conducive to cannibalism.

A third food hub also increases the required population per firm for food hubs to break even. The three-to-two establishment population threshold for food hubs is 2.21, which is statistically different from competitive behavior (i.e., 1) at the 5% level. Three firms require 121% more residents per firm

Table 6. Ratios of per Firm Population Thresholds

	Merchant Wholesalers	Food Hub Composite	NGFN Food Hubs	AMS Food Hubs
Estimated with up to three establishments				
Two establishments to one	0.89***	1.38***	1.33***	
	(0.15)	(0.20)	(0.21)	
Three establishments to two	1.21***	2.21***	2.45***	
	(0.07)	(0.51)	(0.80)	
Estimated with up to two establishments				
Two establishments to one	0.89***	1.48***	1.38***	4.63
	(0.15)	(0.26)	(0.27)	(8.85)

Notes: Single, double, and triple asterisks (*,**,***) indicate statistical difference at the 10%, 5%, and 1% level. Numbers in parentheses are standard errors.

Table 7. Changes in Break-Even Population Thresholds (in thousands) Linked with Social Capital

	Merchant Wholesalers	Food Hub Composite	NGFN Food Hubs	AMS Food Hubs
Estimated with up to three establishments				
For one establishment	−0.59	−3.74***	−3.47**	
	(0.78)	(1.35)	(1.44)	
For two establishments	−0.94	−10.84**	−10.56*	
	(1.41)	(5.14)	(5.45)	
For three establishments	−1.57	−57.89	−74.06	
	(2.78)	(50.23)	(77.39)	
Estimated with up to two establishments				
For one establishment	−0.12	−6.00***	−5.57**	−12.49
	(0.83)	(2.18)	(2.26)	(9.53)
For two establishments	−0.35	−22.93*	−21.08	−574.79
	(1.58)	(13.27)	(13.30)	(2,613.52)

Notes: Single, double, and triple asterisks (*,**,***) indicate statistical difference at the 10%, 5%, and 1% level. Numbers in parentheses are standard errors.

relative to two food hubs, signaling that successive food hubs are more likely to further cannibalize sales and/or resources from existing firms. In contrast, the 3-to-2 MW establishment population threshold is 1.21, even though it too is statistically different from 1 at the 5% level, it is meaningfully smaller than the FH threshold.

Social Capital

As discussed previously, social capital can be important for food hubs, but there is no statistical evidence that it is important to merchant wholesalers. Table 7 shows the changes in the breakeven population thresholds with no statistically significant effect of social capital for merchant wholesalers. However, a 1-percentage-point increase in social capital is associated with a 3,740, or 2.05%, decrease in the population threshold for the first food hub. Its relationship with the population to sustain two food hubs is similar, reducing the threshold by about 2.15%; however, there is no statistically significant relationship with the threshold for the third firm.

Table 8. Changes in Break-Even Population Thresholds (in thousands) Linked with Local Business Presence

	Supporting a Single Merchant Wholesaler			Supporting a Single Food Hub		
Local Business	Average Size	Smallest Firm	Largest Firm	Average Size	Smallest Firm	Largest Firm
Farms selling direct	−0.15***	−0.04	−2.85***	−0.70***	−0.71***	−0.49
	(0.06)	(0.06)	(1.02)	(0.21)	(0.22)	(1.32)
Grocery stores and supermarkets	−1.60***	−1.69***	−1.03*	0.27	0.23	0.53
	(0.52)	(0.54)	(0.63)	(0.31)	(0.27)	(0.85)
Assisted living for the elderly	0.48	0.54	−0.47	2.05*	2.04*	2.18**
	(0.61)	(0.63)	(0.52)	(1.11)	(1.14)	(1.04)
Community food services	−1.66	−1.65	−3.72	−5.06	−5.11*	4.38
	(1.55)	(1.56)	(4.08)	(3.07)	(3.09)	(7.18)
Full-service restaurants	−0.13	−0.12	−0.19	−0.44**	−0.69***	2.02**
	(0.11)	(0.14)	(0.63)	(0.18)	(0.26)	(0.90)
Mobile food services	−0.92	−0.93	−0.81	−15.35**	−15.40**	−12.05**
	(2.70)	(2.71)	(2.37)	(6.25)	(6.27)	(5.11)

Notes: Single, double, and triple asterisks (*,**,***) indicate statistical difference at the 10%, 5%, and 1% level. Numbers in parentheses are standard errors.

Local Food Businesses

We find different types and sizes of business more commonly linked with profitable food hubs and MWs. Table 8 reports the effect of local food businesses on population thresholds. We find that large farms selling directly to consumers are linked with lower MW population thresholds of about 2,850 but have no statistically significant effect on food hubs. Conversely, small farms selling directly are linked with lower population thresholds for food hubs, of about 700 people, but have no statistical effect on merchant wholesalers. This aligns with policy intentions to use food hubs as a strategy to ensure market access for smaller producers. In 2008, small farms accounted for 81% of all farms reporting local food sales (Low and Vogel, 2011). While food hubs buy local produce from farms (among other channels), they can also supply community supported agriculture efforts, farmers' markets, and mobile retail units (Fischer et al., 2013; Angelo, Jablonski, and Thilmany, 2016), all of which can be counted as farms' direct sales (Census of Agriculture, 2012, Appendix B). Viewed from this perspective, the number of farms selling directly would be expected to have a positive effect on FH variable profits by increasing their customer base (or signaling where that customer base is strongest).

Grocery stores and supermarkets of any size are linked with lower thresholds for merchant wholesalers but are not statistically significant for food hubs. Average and small grocery stores and supermarkets have a larger effect than large ones when considering effects on MW thresholds, perhaps due to large retail food chains transition to self-distribution. Among food hubs, 27% sell to traditional grocery stores or supercenters, making up, on average, 29% of total gross sales (Fischer et al., 2013); however, we find that food hubs in counties with these stores may not necessarily be more profitable.

Some food hubs believe there are expansion opportunities in elder care programs such as, for example, retirement communities (Fischer et al., 2013). However, our estimates suggest that assisted living facilities for the elderly increase population thresholds. Food hubs locating in counties with assisted living facilities require a larger population to be economically viable, which may not be surprising given those institutions' current practices of managing food costs by buying from commodity programs and price-competitive food suppliers.

Community food services such as "meals on wheels" were also listed as growth opportunities for food hubs (Fischer et al., 2013). We find the smallest and average-size community food services are associated with profitable food hubs, but the largest have no statistically significant effect.

We find that small and average-sized full-service restaurants are associated with lower population thresholds for food hubs but have no statistical link with merchant wholesalers. In contrast, we find food hubs in counties with large full-service restaurants require a larger population to remain viable. Consequently, 58% of Food hubs sell to restaurants, caterers, or bakeries, to generate, on average, 33% of their total gross sales (Fischer et al., 2013), which provides evidence of a potential causal mechanism for our finding.

While a majority of food hubs already sell to restaurants, only 6% sell to mobile retail units, comprising, on average, 14% of their total gross sales (Fischer et al., 2013). Mobile food services of all sizes are positively linked with FH profitability; however, smaller and average-sized mobile food services are associated with lower population thresholds than larger ones. Moreover, the threshold effects of the mobile food services are about 33 times larger than those of full-service restaurants, indicating that they may offer a promising growth opportunity for food hubs.

Conclusions

Food hubs can add significant value to the food system by acting as aggregators and distributors (Barham et al., 2012), helping to address some supply channel disadvantages smaller producers encounter when seeking to create a network focused on conventional food retail and service markets. However, there have been concerns about oversaturation of local foods markets and overinvestment in food hubs.

We adapted an entry-threshold model to determine the optimal number of food hubs, the extent of over-competition, and the profit drivers for food hubs and merchant wholesalers. We used publicly available data from 2012 to determine the landscape of opportunity and the number of food hubs as of 2016, to limit the influence of food hubs that fail within an initial period. We find that populations of about 182,000 can support the first food hub and that subsequent FH entries diffuse revenue (more than the industry benchmark), making viability more challenging for all. Support for food hubs in any location should consider this potential, unintended implication of funding or support for additional start-ups. Most counties are able to sustain zero or one food hubs, depending on their specific community characteristics; less than 4% have the population necessary to support two or more.

We found that social capital plays a unique role for food hubs (but does not have a similar influence for merchant wholesaler) and thus may provide an advantage for long-run FH success. Social capital is positively associated with FH profitability and can significantly reduce the population necessary for viability, suggesting that the entry of new or additional food hubs should be more strongly considered where there is evidence that social capital (and public support) is more aligned with the food hub's varied social missions. One of those missions may be business development, networking, and supply chain opportunities for new, small, and young producers. Smaller farms selling directly, smaller full-service restaurants, and mobile food services can likewise reduce the population required to sustain the initial food hub. Counties without the population necessary for a food hub but that would like to support one may consider investing in the above community characteristics to lower their thresholds.

Policies and funding programs supporting new FH establishments may seek to fund successive entrants that are differentiated from incumbents. To this end, there has been growing interest in branding to help consumers know where their food comes from by using producer profiles to accurately identify local foods; however, as product volumes increase and originate from a greater number of farms, accurate identification may be intractable (Woods et al., 2013). Food hubs may be positioned to address this information barrier by developing their own brand, which could also increase differentiation and mitigate the threat of over-competition.

To our knowledge, this is the first analysis of FH sustainability on a national scale. Our analysis is limited by the self-reported nature of the data; in our comparison of sources, we found evidence that no single source is comprehensive or complete. Our results will reflect the bias, if any, of the underlying data. Also, some food hubs may be included among the number merchant wholesalers, which may bias the comparisons made. We also do not capture wages or numbers of employees (as they may be endogenous), but these encompass some of the greatest FH expenditures and may represent important costs excluded from our direct analysis. Finally, on the demand side, food hubs may serve more than the population solely in the county in which they are located, which our current analysis does not account for. Future work should explored this possibility using spatial interactions within regional systems, but such analysis is beyond the scope of the current study.

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Online Supplement: Ordered Probit Results (without Controlling for Possible Selection Bias)

Here we present the results of equation (8) using the ordered probit technique and do not control for the possible selection bias with a first-stage regression. Although an argument has been made in the manuscript for selection, as there are many counties without FHs, it is possible that these 'zero' observations are a result of the same data generating process that led to counties with positive FH numbers. If this is indeed the case, then controlling for selection will introduce bias. Tables S1 and S2 correspond to Tables 4 & 5 in the manuscript and present estimated coefficients and standard errors for the ordered probit. Tables S3 to S6 correspond to Tables 6 to 9 in the manuscript.

Table S7 presents tests for equivalence of results of the model controlling for selection and the model not controlling for selection. We test the estimate from the model controlling for selection against the null hypothesis that it is equivalent to the number estimated without controlling for selection. In most cases, we fail to reject equivalence, however, there are some notable exceptions. All tests of 2 to 1 population threshold ratios reject equivalence between the two models, so that the two results are statistically different. That said, the qualitative results remain: the 2 to 1 threshold for MW is not statistically different from 1 while the same for FHs is statistically different from 1. We also find a slightly different threshold for 1 MW: the baseline model finds 105.38, the robustness check discussed herein finds 86.08, and the test of the baseline's equivalence to 86.08 is marginally rejected with a *p*-value of 0.07.

Table S1. Parameter Estimates and Standard Errors for the Baseline Model

Variable Description	Parameter	Merchant Wholesalers	Food Hub Composite	NGFN Food Hubs
Variable Profits				
Per capita income ($thousands)	β_{1i}	−0.00049***	−0.00033***	−0.00032***
		(0.00011)	(0.00007)	(0.00008)
Per capita income ($thousands), squared	β_{2i}	3.55E-06***	1.88E-06***	1.74E-06***
		(7.29E-07)	(4.72E-07)	(5.30E-07)
Share of SNAP recipients	β_{3i}	−0.00003	−0.00012***	−0.00010**
		(0.00007)	(0.00004)	(0.00004)
Share of black population	β_{4i}	0.00004	0.00006***	0.00006***
		(0.00002)	(0.00002)	(0.00002)
Share of Hispanic population	β_{5i}	0.00007***	0.00004***	0.00006***
		(0.00003)	(0.00001)	(0.00002)
Share of 25+ with some college	β_{6i}	0.00005	0.00023***	0.00022***
		(0.00007)	(0.00006)	(0.00006)
Share of 25+ with at least a bachelor's	β_{7i}	−0.00003	0.00011***	0.00014***
		(0.00004)	(0.00003)	(0.00004)
Social capital index	β_{ki}	0.00010	0.00017**	0.00016**
		(0.00009)	(0.00007)	(0.00007)
Electricity price	β_{8i}	−0.00044***	−0.00016**	−0.00021**
		(0.00014)	(0.00008)	(0.00010)
Metro county indicator (RUCCs 1-3)	β_{9i}	−0.01662***	−0.01388***	−0.01395***
		(0.00318)	(0.00416)	(0.00447)
Metro-adjacent county indicator (RUCCs 4, 6, 8)	β_{10i}	−0.01227***	−0.00936**	−0.00895*
		(0.00356)	(0.00459)	(0.00491)
Northeast region indicator	β_{11i}	0.00292***	0.00041	0.00039
		(0.00109)	(0.00065)	(0.00071)
Midwest region indicator	β_{12i}	−0.00017	0.00049	0.00113**
		(0.00065)	(0.00043)	(0.00050)
West region indicator	β_{13i}	0.00037	−0.00040	−0.00035
		(0.00088)	(0.00054)	(0.00062)
Per capita value of direct sales from farms ($thousands)	β_{14i}	0.00019***	0.00002	0.00005
		(0.00005)	(0.00004)	(0.00004)
Per capita number of farms selling direct	β_{15i}	0.00071	0.00409***	0.00432***
		(0.00077)	(0.00073)	(0.00078)
Per capita number of grocery supermarkets	ϕ_{11i}	0.01932***	−0.00122	0.00012
		(0.00514)	(0.00149)	(0.00145)
Per capita number of employees in grocery supermarkets	ϕ_{21i}	−0.00008	0.00005	0.00010
		(0.00010)	(0.00007)	(0.00008)
Per capita number of assisted living facilities for the elderly	ϕ_{12i}	−0.00762	−0.00994*	−0.01176*
		(0.00776)	(0.00575)	(0.00633)
Per capita number of employees in assisted living facilities for the elderly	ϕ_{22i}	0.00068**	−0.00004	−0.00002
		(0.00034)	(0.00026)	(0.00028)
Per capita number of community food services	ϕ_{13i}	0.01438	0.02891	0.02137
		(0.01889)	(0.01785)	(0.01963)
Per capita number of employees in community food services	ϕ_{23i}	0.00077	−0.00124	−0.00173
		(0.00132)	(0.00106)	(0.00122)
Per capita number of full-service restaurants	ϕ_{14i}	0.00184	0.00451***	0.00458***
		(0.00170)	(0.00106)	(0.00109)
Per capita number of employees in full-service restaurants	ϕ_{24i}	0.00002	−0.00014***	−0.00016***
		(0.00007)	(0.00004)	(0.00004)
Per capita number of mobile food services	ϕ_{15i}	0.01263	0.09508***	0.08108***
		(0.03218)	(0.02343)	(0.02743)
Per capita number of employees in mobile food services	ϕ_{25i}	−0.00243	−0.01560***	−0.01049**
		(0.00406)	(0.00457)	(0.00501)
Per capita number of supercenters and club stores	ϕ_{16i}	0.00780	−0.03973	−0.02910
		(0.02973)	(0.02524)	(0.02759)
V2 − V1	α_{2i}	0.00161***	0.00294***	0.00302***
		(0.00050)	(0.00035)	(0.00039)

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Table S1. – continued from previous page

Variable Description	Parameter	Merchant Wholesalers	Food Hub Composite	NGFN Food Hubs
V3 − V2	α_{3i}	0.00080*	0.00355***	0.00463***
		(0.00048)	(0.00059)	(0.00081)
V4 − V3	α_{4i}	0.28533	0.15549	0.23777
		(5.72164)	(1.58942)	(1.62150)
Population (in thousands)	α_{1i}	0.03303***	0.01558***	0.01407**
		(0.00593)	(0.00527)	(0.00569)
Fixed Costs				
Fruit and vegetable production and imports	λ_{1i}	0.00138***	0.00021**	0.00015*
		(0.00016)	(0.00009)	(0.00009)
Home price index	λ_{2i}	−0.59138***	0.21514	0.19795
		(0.16299)	(0.21488)	(0.24226)
Social capital index	λ_{ki}	−0.00296	0.01812**	0.01662*
		(0.00777)	(0.00820)	(0.00897)
Metro county indicator (RUCCs 1-3)	λ_{3i}	0.84851***	0.91169***	0.80421***
		(0.13030)	(0.17865)	(0.19898)
Metro-adjacent county indicator (RUCCs 4, 6, 8)	λ_{4i}	0.46142***	0.68894***	0.66538***
		(0.13513)	(0.18422)	(0.20403)
Northeast region indicator	λ_{5i}	0.20540	0.27838*	0.31394*
		(0.15872)	(0.15230)	(0.16202)
Midwest region indicator	λ_{6i}	−0.12317	−0.10816	−0.15293
		(0.09389)	(0.11029)	(0.12476)
West region indicator	λ_{7i}	0.23059**	−0.05051	−0.13733
		(0.11369)	(0.13838)	(0.15726)
F1	γ_{1i}	1.14622***	3.19890***	3.23000***
		(0.28432)	(0.39107)	(0.43700)
F2 − F1	γ_{2i}	2.06076***	4.52743***	4.53929***
		(0.28690)	(0.40489)	(0.45218)
F3 − F2	γ_{3i}	2.67546***	5.77579***	5.71103***
		(0.29102)	(0.44578)	(0.49270)
F4 − F3	γ_{4i}	3.24068***	8.13891***	13.08008***
		(0.29629)	(1.00826)	(2.67247)
Pseudo-R^2		39.103%	30.336%	32.853%

Notes: Single, double, and triple asterisks (*,**,***) indicate statistical difference at the 10%, 5%, and 1% level. Numbers in parentheses are standard errors.

Table S2. Parameter Estimates and Standard Errors, Up to Three Establishments

Variable Description	Parameter	Merchant Wholesalers	Food Hub Composite	NGFN Food Hubs	AMS Food Hubs
Variable Profits					
Per capita income ($thousands)	β_{1i}	−0.00052***	−0.00029***	−0.00032***	−0.00019**
		(0.00012)	(0.00007)	(0.00008)	(0.00009)
Per capita income ($thousands), squared	β_{2i}	3.29E-06***	1.65E-06***	1.80E-06***	1.25E-06**
		(8.04E-07)	(4.85E-07)	(5.19E-07)	(5.77E-07)
Share of SNAP recipients	β_{3i}	−0.00008	−0.00010**	−0.00010**	−0.00005
		(0.00009)	(0.00004)	(0.00004)	(0.00005)
Share of black population	β_{4i}	0.00004	0.00004**	0.00005***	0.00006***
		(0.00003)	(0.00002)	(0.00002)	(0.00002)
Share of Hispanic population	β_{5i}	0.00008***	0.00005***	0.00006***	0.00003*
		(0.00003)	(0.00001)	(0.00002)	(0.00002)
Share of 25+ with some college	β_{6i}	0.00003	0.00018***	0.00017***	0.00012**
		(0.00008)	(0.00005)	(0.00005)	(0.00006)
Share of 25+ with at least a bachelor's	β_{7i}	0.00004	0.00010***	0.00012***	0.00004
		(0.00005)	(0.00004)	(0.00004)	(0.00004)
Social capital index	β_{ki}	0.00012	0.00021***	0.00020***	0.00016**
		(0.00011)	(0.00007)	(0.00007)	(0.00007)
Electricity price	β_{8i}	−0.00056***	−0.00023***	−0.00026***	−0.00025***
		(0.00017)	(0.00008)	(0.00009)	(0.00008)
Metro county indicator (RUCCs 1–3)	β_{9i}	−0.01549***	−0.00980**	−0.00965*	−0.00776
		(0.00345)	(0.00452)	(0.00494)	(0.00543)
Metro-adjacent county indicator (RUCCs 4, 6, 8)	β_{10i}	−0.01127***	−0.00481	−0.00431	−0.00246
		(0.00383)	(0.00489)	(0.00531)	(0.00596)
Northeast region indicator	β_{11i}	0.00430***	0.00036	0.00072	0.00053
		(0.00129)	(0.00064)	(0.00068)	(0.00074)
Midwest region indicator	β_{12i}	0.00056	0.00029	0.00089*	0.00055
		(0.00078)	(0.00046)	(0.00053)	(0.00051)
West region indicator	β_{13i}	−0.00023	0.00017	0.00030	0.00142***
		(0.00096)	(0.00051)	(0.00055)	(0.00053)
Per capita value of direct sales from farms ($thousands)	β_{14i}	0.00021***	−0.00005	−0.00001	−0.00002
		(0.00005)	(0.00004)	(0.00004)	(0.00005)
Per capita number of farms selling direct	β_{15i}	0.00062	0.00418***	0.00444***	0.00205**
		(0.00082)	(0.00076)	(0.00081)	(0.00085)
Per capita number of grocery supermarkets	ϕ_{11i}	0.02649***	0.00048	0.00076	−0.00019
		(0.00655)	(0.00144)	(0.00142)	(0.00198)
Per capita number of employees in grocery supermarkets	ϕ_{21i}	−0.00009	0.00011	0.00014*	0.00018*
		(0.00012)	(0.00008)	(0.00008)	(0.00009)
Per capita number of assisted living facilities for the elderly	ϕ_{12i}	−0.00156	−0.00370	−0.00293	−0.00860
		(0.00837)	(0.00551)	(0.00593)	(0.00603)
Per capita number of employees in assisted living facilities for the elderly	ϕ_{22i}	0.00040	−0.00026	−0.00029	0.00003
		(0.00036)	(0.00028)	(0.00029)	(0.00033)
Per capita number of community food services	ϕ_{13i}	0.02173	0.02566	0.01786	0.02254
		(0.02136)	(0.01809)	(0.02002)	(0.02148)
Per capita number of employees in community food services	ϕ_{23i}	−0.00186	−0.00069	−0.00103	0.00023
		(0.00185)	(0.00117)	(0.00128)	(0.00119)
Per capita number of full-service restaurants	ϕ_{14i}	0.00230	0.00308***	0.00327***	0.00114
		(0.00201)	(0.00112)	(0.00117)	(0.00128)
Per capita number of employees in full-service restaurants	ϕ_{24i}	−0.00003	−0.00014***	−0.00015***	−0.00006
		(0.00008)	(0.00004)	(0.00004)	(0.00004)
Per capita number of mobile food services	ϕ_{15i}	0.02698	0.02229	0.03246	0.02610
		(0.03677)	(0.02139)	(0.02237)	(0.02348)
Per capita number of employees in mobile food services	ϕ_{25i}	−0.00440	0.00497*	0.00446	−0.00145
		(0.00510)	(0.00270)	(0.00275)	(0.00325)
Per capita number of supercenters and club stores	ϕ_{16i}	0.02814	−0.00757	0.00206	0.00215
		(0.03283)	(0.02646)	(0.02876)	(0.02570)
V2 − V1	α_{2i}	0.00177***	0.00361***	0.00364***	0.00468***
		(0.00052)	(0.00042)	(0.00045)	(0.00074)

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Table S2. – continued from previous page

Variable Description	Parameter	Merchant Wholesalers	Food Hub Composite	NGFN Food Hubs	AMS Food Hubs
V3 − V2	α_{3i}	1.20478	0.52442	0.52438	0.01024
		(15.86752)	(6.94029)	(8.98664)	(0.14281)
Population (in thousands)	α_{1i}	0.03396***	0.01163**	0.01176**	0.00743
		(0.00675)	(0.00545)	(0.00587)	(0.00664)
Fixed Costs					
Fruit and vegetable production and imports	λ_{1i}	0.00134***	0.00020**	0.00016*	0.00027***
		(0.00017)	(0.00008)	(0.00009)	(0.00009)
Home price index	λ_{2i}	−0.60222***	−0.00302	−0.06586	0.23637
		(0.17114)	(0.22009)	(0.24831)	(0.26304)
Social capital index	λ_{ki}	−0.00880	0.02122***	0.01974**	0.01588
		(0.00839)	(0.00821)	(0.00896)	(0.00963)
Metro county indicator (RUCCs 1-3)	λ_{3i}	0.79600***	0.86881***	0.75872***	0.79365***
		(0.13731)	(0.18524)	(0.20883)	(0.21856)
Metro-adjacent county indicator (RUCCs 4, 6, 8)	λ_{4i}	0.44325***	0.65876***	0.64539***	0.45608**
		(0.14149)	(0.18971)	(0.21294)	(0.23014)
Northeast region indicator	λ_{5i}	0.09543	0.43539***	0.44738***	0.39334**
		(0.17281)	(0.15349)	(0.16295)	(0.18991)
Midwest region indicator	λ_{6i}	−0.15898	−0.17215	−0.21737*	−0.04739
		(0.09952)	(0.11279)	(0.12736)	(0.13799)
West region indicator	λ_{7i}	0.23965**	−0.14902	−0.25868	0.09313
		(0.11726)	(0.14228)	(0.16237)	(0.16243)
F1	γ_{1i}	1.04351***	2.89388***	2.86904***	3.31300***
		(0.30111)	(0.39987)	(0.44758)	(0.48257)
F2 − F1	γ_{2i}	2.02824***	4.36704***	4.35308***	4.66799***
		(0.30383)	(0.41674)	(0.46699)	(0.50714)
F3 − F2	γ_{3i}	2.79363***	7.25281***	6.98837***	8.34339***
		0.30941	0.61766	0.65226	1.06778
Pseudo-R^2		42.877%	34.006%	36.656%	26.875%

Notes: Single, double, and triple asterisks (*,**,***) indicate statistical difference at the 10%, 5%, and 1% level. Numbers in parentheses are standard errors.

Table S3. Population (in thousands) Needed to Support One, Two, and Three Establishments

	Merchant Wholesalers	Food Hub Composite	NGFN Food Hubs	AMS Food Hubs
Estimated with up to three establishments				
To support one establishment	86.08***	144.74***	155.72***	
	(5.23)	(14.05)	(16.31)	
To support two establishments	223.11***	600.05***	617.88***	
	(22.99)	(84.05)	(94.29)	
To support three establishments	410.30***	1678.27***	1997.76***	
	(50.52)	(377.38)	(601.38)	
Estimated with up to two establishments				
To support one establishment	84.53***	156.88***	169.71***	262.27***
	(5.29)	(17.62)	(20.77)	(58.47)
To support two establishments	212.63***	694.55***	711.15***	1860.74*
	(22.68)	(121.35)	(136.12)	(1,058.49)

Notes: Single, double, and triple asterisks (*,**,***) indicate statistical difference at the 10%, 5%, and 1% level. Numbers in parentheses are standard errors.

Table S4. Ratios of per Firm Population Thresholds

	Merchant Wholesalers	Food Hub Composite	NGFN Food Hubs	AMS Food Hubs
Estimated with up to three establishments				
Two establishments to one	1.30***	2.07***	1.98***	
	(0.11)	(0.15)	(0.16)	
Three establishments to two	1.23***	1.86***	2.16***	
	(0.05)	(0.21)	(0.39)	
Estimated with up to two establishments				
Two establishments to one	1.26***	2.21***	2.10***	3.55***
	(0.11)	(0.20)	(0.21)	(1.33)

Notes: Single, double, and triple asterisks (*,**,***) indicate statistical difference at the 10%, 5%, and 1% level. Numbers in parentheses are standard errors.

Table S5. Changes in Break-Even Population Thresholds (in thousands) Linked with Social Capital

	Merchant Wholesalers	Food Hub Composite	NGFN Food Hubs	AMS Food Hubs
Estimated with up to three establishments				
For one establishment	−0.32	−3.05***	−2.95***	
	(0.50)	(0.84)	(0.94)	
For two establishments	−1.19	−10.81***	−10.44**	
	(1.17)	(4.06)	(4.49)	
For three establishments	−2.47	−40.42*	−52.94	
	(2.28)	(22.44)	(36.84)	
Estimated with up to two establishments				
For one establishment	−0.08	−4.22***	−4.13***	−6.91**
	(0.54)	(1.11)	(1.23)	(3.40)
For two establishments	−1.01	−18.11**	−17.29**	−84.97
	(1.32)	(7.39)	(7.82)	(101.55)

Notes: Single, double, and triple asterisks (*,**,***) indicate statistical difference at the 10%, 5%, and 1% level. Numbers in parentheses are standard errors.

Table S6. Changes in Break-Even Population Thresholds (in thousands) Linked with Local Business Presence

	Supporting a Single Merchant Wholesaler			Supporting a Single Food Hub[a]		
Local Business	**Average Size**	**Smallest Firm**	**Largest Firm**	**Average Size**	**Smallest Firm**	**Largest Firm**
Farms selling direct	−0.11***	−0.03	−1.96***	−0.44***	−0.43***	−0.79
	(0.03)	(0.04)	(0.53)	(0.10)	(0.10)	(0.82)
Grocery stores and supermarkets	−0.91***	−0.94***	−0.73**	0.08	0.13	−0.18
	(0.25)	(0.26)	(0.36)	(0.18)	(0.16)	(0.51)
Assisted living facilities	0.33	0.37	−0.33	1.05*	1.04	1.13**
	(0.37)	(0.38)	(0.31)	(0.61)	(0.63)	(0.57)
Community food services	−0.71	−0.70	−2.24	−3.00*	−3.03*	2.32
	(0.89)	(0.90)	(2.37)	(1.80)	(1.81)	(4.19)
Full-service restaurants	−0.10	−0.09	−0.21	−0.30***	−0.47***	1.42***
	(0.06)	(0.08)	(0.37)	(0.10)	(0.14)	(0.50)
Mobile food services	−0.61	−0.62	−0.43	−9.92***	−9.96***	−7.41***
	(1.57)	(1.58)	(1.37)	(3.35)	(3.36)	(2.69)

Notes: Single, double, and triple asterisks (*,**,***) indicate statistical difference at the 10%, 5%, and 1% level. Numbers in parentheses are standard errors.

Table S7. Testing the Baseline Model against the Null of Estimates from Alternative Model

	Baseline Estimates	Null Hypothesis	*p*-Value of Test	Result
Market thresholds		Baseline estimates are equal to:		
Merchant wholesalers				
To support one establishment	105.38	86.08	0.07	Marginally reject null
To support two establishments	188.40	223.11	0.28	Fail to reject null
To support three establishments	342.44	410.30	0.34	Fail to reject null
Food hub composite				
To support one establishment	182.66	144.74	0.14	Fail to reject null
To support two establishments	502.88	600.05	0.35	Fail to reject null
To support three establishments	1,669.27	1,678.27	0.99	Fail to reject null
NGFN food hubs				
To support one establishment	191.37	155.72	0.20	Fail to reject null
To support two establishments	507.41	617.88	0.32	Fail to reject null
To support three establishments	1,867.85	1,997.76	0.89	Fail to reject null
Threshold ratios				
Merchant wholesalers				
Two establishments to one	0.89	1.30	0.01	Reject null
Three establishments to two	1.21	1.23	0.81	Fail to reject null
Food hub composite				
Two establishments to one	1.38	2.07	0.00	Reject null
Three establishments to two	2.21	1.86	0.49	Fail to reject null
NGFN food hubs				
Two establishments to one	1.33	1.98	0.00	Reject null
Three establishments to two	2.45	2.16	0.71	Fail to reject null

Notes: The null hypothesis is that the estimate from the baseline model is equivalent to the estimate from the alternative model.