Assessing Values-based Sourcing Strategies in Regional Food Supply Networks: An Agent-based Approach

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Keywords
local food distribution, food hubs, empirical agent-based modeling, values-based organizations, socially responsible supply chain management, sustainability

Disciplines
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Abstract

The recent increase in demand for regionally produced food has resulted in a need for more efficient distribution methods. To connect regional food producers and consumers, intermediated regional food supply networks have developed. The intermediary, known as a regional food hub, serves as an aggregation point for products and information. It may also act as a filter to ensure that the requirements of both producers and consumers are consistently met. This paper describes an empirically based agent-based model of a regional food network in central Iowa that is intermediated by a food hub. The model was used to test a variety of sourcing policies that could be implemented by the food hub manager to improve operations. Results indicate that policies that protect producers from competition may have negative consequences for consumer satisfaction.

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Introduction

A supply chain’s ability to effectively and efficiently convey and provide value to customers is critical to its success. However, traditional assumptions about consumers’ values may no longer be valid. In particular, consumers are increasingly prioritizing environmental and social sustainability as non-negotiable criteria when making purchasing decisions. Many consumers no longer view “green” or socially responsible sourcing as a competitive advantage or a differentiating feature that they are willing to pay more for; it is expected. To meet these new customer expectations, many organizations have worked to adapt their existing practices and structure, often by mandating certifications (e.g., fair trade, organic, cruelty-free) throughout their supply chains. Some organizations have gone further and have incorporated new sustainability and values-focused components in their mission statements. For example, the “triple bottom line” emphasizes environmental and social sustainability, as well as traditional economic objectives (Elkington, 1998). However, current approaches to social responsibility are often fragmented and disconnected from organizations’ primary business strategies, such that the greatest opportunities to benefit society may remain unrealized (Porter & Kramer, 2006).

As existing organizations grapple with these new requirements, new organizations have emerged that are leveraging consumers’ changed preferences and turning this challenge into an opportunity. These types of organizations are known as values-based organizations (VBOs). Rather than viewing sustainability as a secondary consideration, these organizations are strategically focused on providing consumers with products and services that are socially and environmentally responsible. A key component of this strategy is offering transparency and traceability throughout the entire supply chain and communicating product and process characteristics to the end customers (Pullman & Dillard, 2010).

Food supply chains, which directly influence human health and well-being, have been the target of consumer demands for environmental and social responsibility and transparency. This has led to significant increases in demand for food that is produced regionally, that is, in the same geographic region in which the consumer is located. Consumers are increasingly choosing food that is produced locally and sustainably over food from the conventional food system. Their reasons vary widely, from saving money to wanting to ensure food nutrition, quality, freshness, and safety, to concerns over environmental implications, to concerns over the treatment of farm workers, to a desire to support the local economy, to having a connection with the person who produced their food (Bloom & Hinrichs, 2011. Interest in supporting local food systems is also rising among policymakers, who are incorporating local foods into programs designed to reduce food insecurity, support small farmers and rural economies, encourage more healthful eating habits, and foster closer connections between farmers and consumers (King et al., 2010).
Regional food hubs are an example of an emerging type of VBO that can facilitate the fulfillment of this increasing demand for local food. The United States Department of Agriculture (USDA) working definition of a food hub is “a centrally located facility with a business management structure facilitating the aggregation, storage, processing, distribution, and/or marketing of locally/regionally produced food products” (Barham, 2010). Food hubs act as intermediaries between small-scale food producers (e.g., farmers) and customers, providing connections and infrastructure in support of regional and local food systems. A primary objective for regional food hubs is to support local economies by providing market opportunities for small-scale producers and treating them as valued business partners, rather than interchangeable suppliers (Barham, Tropp, Enterline, Farbman, Fisk, & Kiraly, 2012). However, these producers must also possess attributes that are valued by the food hub’s customers (e.g., reasonable prices, high quality). Thus, the food hub’s process of determining which producers to work with should carefully balance these requirements. However, in practice, food hubs tend to follow ad hoc sourcing and supplier management methods, which can lead to suboptimal performance and often business failure.

This paper describes an agent-based model (ABM) that was developed using empirical data from a regional Iowa food system. The model was used to assess the value of having a food hub manager agent act as a centralized control for the system by exploring the impacts of different management strategies on the food hub’s performance. In particular, the Iowa food hub manager would like to know what types of producer selection policies should be employed (if any). The manager’s current policy is to allow any producer in Iowa who wishes to sell food through the food hub to do so. The manager then relies on consumers to determine whether a producer may continue to participate: if a producer’s prices are too high, or if their products are of poor quality, or if there is insufficient demand for their product, they will make few sales. Such producers will typically either try to improve their offerings or they will cancel their membership. Thus, producer selection at the food hub is a decentralized process, in which the overall makeup of food hub’s producers at any point in time is an emergent property resulting from competition among the producers.

However, the food hub manager suspects that if he intervenes via appropriate producer selection policies, he may be able to increase his consumers’ satisfaction by only allowing in those producers that are most likely to meet their needs. The food hub manager may also be able to improve the well-being of his producers by preventing an oversupply of any given type of food, thereby keeping competition among producers reasonable and prices sufficiently high. The question addressed in this paper is: What producer selection policies should the manager implement to best support the food hub’s objectives?
Background and Literature Review

In this section, sourcing strategies that are common to traditional organizations are described, and the strengths and weaknesses associated with these strategies are reviewed. This is followed by a description of the sourcing strategies that have been used by VBOs, as well as the unique challenges that VBOs face with respect to supplier selection.

Traditional Sourcing Strategies

Traditionally, supply chain management strategies have focused strictly on financial objectives, such as maximizing profit/market share or minimizing exposure to risk. With these objectives in mind, a supply chain manager must decide on an appropriate sourcing strategy, which includes the size of the organization's supply base, as well as the criteria by which suppliers are selected. The question of how many suppliers an organization should use and how business should be allocated to these suppliers is an ongoing topic of debate, and the answer depends on many factors. One strategy involves single sourcing, which is the process of selecting and using only one source of supply for all inputs of a particular type. By contrast, with a dual or multiple sourcing strategy, two or more suppliers are used as sources of the same commodity. Determining which of these sourcing alternatives is best involves difficult tradeoffs and requires a careful multi-objective analysis of the buying organization's preferences, with respect to short- and long-term costs and risk management, and an assessment of the industry environment in which the organization operates. Although much of the supply chain management literature treats these sourcing strategies as mutually exclusive, in reality, this is not necessarily true. In fact, Gadde and Snehota (2000) argue that a balanced combination of single and multiple sourcing is often a practical strategy.

Traditionally, multiple sourcing has been used in supply chain management as a means of encouraging competition among multiple suppliers, wherein a buyer plays suppliers against one another to obtain the best terms, including price, delivery, and quality (Treleven & Schweikhart, 1988). This competition increases a buyer’s negotiating power through the perceived threat of giving its business to another supplier (Ramsay & Wilson, 1990). Also, supplier power over a buyer is weakened when the buyer splits its total requirements among multiple sources (Newman, 1989). Li and Debo (2009) provide several examples of organizations that follow this strategy for sourcing components, including Apple and Microsoft, in order to maintain power over suppliers and keep prices low.

Multiple sourcing also allows a buyer to spread risk across several suppliers. Supply chain risks can be classified as either operational risks, which are inherent to the supply chain and its participants (e.g., insufficient supplier capacity, quality
problems, suppliers reneging on contracts), or disruption risks, which are related to natural and man-made disasters, including earthquakes, hurricanes, fires, and terrorist attacks (Tang, 2006). By having multiple redundant suppliers, organizations can reduce their exposure to both operational and disruption risks, since it is unlikely that all suppliers would be disrupted simultaneously (Chopra & Sodhi, 2004). Because of this, multiple sourcing is one of the most commonly employed supply chain risk mitigation strategies (Hallikas & Lintukangas, 2016).

However, there are disadvantages associated with multiple sourcing. Because multiple sourcing typically involves short-term contracts and frequent rebidding, managing a large number of suppliers increases a buyer’s transaction and supply handling costs (Dyer, Cho, & Chu, 1998). Multiple sourcing may also increase supply chain costs by preventing suppliers from achieving economies of scale (Hahn, Kim, & Kim, 1986). Treleven (1987) argues that multiple sourcing can reduce overall quality as a consequence of the increased variation in incoming quality among suppliers.

In response to these concerns, organizations have increasingly adopted single sourcing as a strategy for some or all of their purchased inputs. Single sourcing strategies strive for the development of partnerships between buyers and suppliers, with an aim to increase cooperation and achieve shared benefits (Burke, Carrillo, & Vakharia, 2007). In these arrangements, buyers and suppliers have jointly aligned goals to accomplish mutually beneficial ends, resulting in collaborative relationships that yield greater benefits than the “transaction-based” relationships that characterize multiple sourcing. Such relationships rely on the development of trust between the buyer and supplier, the willingness to coordinate activities and share information, and the ability to convey a sense of commitment to the relationship (Mohr & Spekman, 1994). Single sourcing can yield higher quality and lower total supply chain costs, but only if the supplier is very carefully selected, ideally through a rigorous certification process (Larson & Kulchitsky, 1998). In particular, concentrating purchase volumes with a single supplier can reduce logistics costs, which is important when suppliers are geographically distant from the buyer (Bozarth, Handfield, & Das, 1998). Additionally, reducing the supplier base tends to substantially reduce the volume of communication that is required for supply chain coordination (Dumond & Newman, 1990).

However, when an organization reduces its supplier base, it relies on fewer suppliers for critical materials, and this increased dependency increases the risk of a supply interruption (Cousins, 1999; Smeltzer & Siferd, 1998). Also, the amount of trust that is required to support a strong strategic relationship with a supplier is significant, and true long-term strategic alliances between buyers and suppliers are uncommon in practice (McCutcheon & Stuart, 2000).

Once an organization has decided whether or not to have redundancies in its supply base, a method of evaluating and selecting candidate suppliers is needed. Because there are almost always multiple critically important criteria that
managers must consider in the supplier selection decision (e.g., price, quality, flexibility), and no single sourcing option will always perform best with respect to all criteria, it is not possible for a buyer to simply rank different options using a single attribute (Elmaghraby, 2000). As a result, a wide variety of decision-making methodologies have been applied to the problem of supplier selection, including multicriteria decision analysis (MCDA) methods and mathematical programming models. For comprehensive reviews of these methods, see de Boer, Labro, and Morlacchi (2001) and Ho, Xu, and Dey (2010).

VBO Sourcing Strategies

Sourcing strategies and decisions for VBOs are not entirely different from those of traditional organizations. To remain financially viable, VBOs must consider economic objectives and risks when designing their supply chains. However, the emphasis that traditional organizations place on these factors is typically inappropriate for VBOs, which tend to focus on elements that impact nature and society (Shrivastava, 1995). The relative importance of these objectives may differ among different organizations. For some VBOs, the social/environmental sustainability imperative outweighs or eclipses the profit motive, whereas in other organizations, financial considerations are the main driver of decision-making. For example, Koch and Hamm (2015) interviewed the managers of 11 Midwestern food hubs to assess the degree to which they focus on increasing access to underserved consumers. They found that, while the managers were interested in increasing food accessibility, in all cases, their main objective was to run a viable business, with access as a secondary priority.

The debate over single and multiple sourcing strategies is not widely discussed in the literature on VBOs. However, there is a clear emphasis on the importance of viewing suppliers as collaborative strategic partners, rather than the more traditional view in which they are leveraged through power imbalances. Stevenson and Pirog (2008) described the concept of a values-based supply chain (VBSC) framework, in which the objective of supporting the well-being of all participants is incorporated into traditional supply chain management strategies. VBOs and VBSCs are typically characterized as “flat” (i.e., nonhierarchical) organizations whose participants work collectively to achieve a common aim, and they tend to allocate decision-making power to individuals and local communities (Pullman & Dillard, 2010). This focus on long-term and egalitarian supply chain relationships suggests that VBOs might prefer single sourcing over multiple sourcing. However, when buyers specifically target sustainable and/or local suppliers as part of their social mission, working with multiple small-scale suppliers may be necessary to satisfy demand (Feenstra, Allen, Hardesty, Ohmart, & Perez, 2011). A VBO may also use multiple sourcing as a strategy by which it can provide financial support to
as many suppliers as possible. For a regional food hub, having a large and diverse set of suppliers is recommended to hedge against the many disruptive risks (e.g., weather, pests) that are inherent to food production (Moragham & Vanderbergh-Wertz, 2014).

Because of their emphasis on transparency and traceability, VBOs should be especially rigorous in evaluating and selecting suppliers—they must ensure that suppliers’ practices are consistent with the values of the VBO and its customers. Methods for including environmental criteria in supplier selection decision are well established (Handfield, Walton, Sroufe, & Melnyk, 2002; Humphreys, Wong, & Chan, 2003). However, incorporating social concerns into sourcing decisions has proven challenging, and there is little existing research that investigates how consumer values can be translated into principles and rules to guide sourcing decisions (Zorzini, Hendry, Huq, & Stevenson, 2015). A case study by Pullman and Dillard (2010) provides one example, in which a natural beef producers’ cooperative has developed specific values-based requirements for membership in the cooperative, including a codified set of sustainable land and water management principles, a detailed list of mandatory production standards (e.g., prohibitions on hormone/antibiotic usage), quality and capacity criteria, and connection to the land (i.e., ownership and plans for future ranch management). Trust, egalitarian values, and freely shared information and ideas characterize the cooperative’s supply system.

For VBOs and VBSCs, a natural tension often exists between the often opposing objectives of profitability and social/environmental responsibility. Organizations that do not go far enough to meet consumers’ values-based requirements may be in danger of accusations of “green-washing” and lose legitimacy, whereas those that focus on social and environmental aspects at the expense of financial sustainability will struggle to remain viable (Walker & Wan, 2012). Thus, maintaining an appropriate balance is challenging but critical to a VBO’s organizational success. Accomplishing this requires that organizations have a clear understanding of their customers’ values and provide products and services that are aligned with these values.

Empirical Data Elicitation and Analysis of a Regional Food Hub

The food hub described in this paper is a VBO that operates as an online grocery store, using its website to broker sales between small-scale Iowa food producers and the food hub’s consumer members. The food hub operates a small warehouse to facilitate sorting, short-term storage, and distribution, but it does not actually take ownership of any inventory, and there is no comingling of different producers’ products—every item that passes through the food hub is
source-identified via producer labels. The only absolute requirement for a producer to become a member of the food hub cooperative is that its operations must be located within the state of Iowa.

Upon joining the food hub, each new producer member develops a descriptive profile that he/she uploads to the food hub’s website. These producer profiles are visible to consumer members and are intended to help inform their decisions regarding from which producers to purchase. The food hub manager gives new producers suggestions about the types of information that are appropriate for their profiles, but these are merely guidelines, and there is no formal certification required. At a minimum, most producers provide the following information: farm/production facility location, types of products offered, and production practices used (e.g., certified organic, chemical-free, free-range, grass-fed). Many producers also include photos of their farms and their families, as well as links to their websites, and they may volunteer additional information, including the histories of their farms and statements about their values and personal beliefs with respect to sustainability and food production. In this way, the profiles give consumers a sense of connection with the producers, although they may never actually meet. An effective profile can make a producer more competitive and increase his/her sales to consumers. None of the information in the profiles is formally verified by the food hub’s manager; the system relies on consumer trust.

At the beginning of each biweekly distribution cycle, each participating producer uploads information about his/her current product offerings (i.e., product types/descriptions, prices, and available quantities) onto the food hub’s website. This information is made available to the consumer members, who select and order items from the producers whose products and profiles best meet their own personal preferences. The producers then package and label these items and deliver them to the food hub’s central distribution center, where products are sorted for transport to various secondary distribution sites throughout central Iowa. Consumers then travel to the site nearest to them to pick up their orders.

To remain economically viable, the food hub charges its members a fee for this service. However, supporting small-scale Iowa producers is also a critical component of the hub’s mission. Therefore, the food hub manager encourages small producers to participate, although this increases the number of transactions the hub must broker. The manager is also mindful of the number of producers in each product category, with an aim toward avoiding too much competition and unsustainable prices. The food hub also tries to promote greater consumer access to regional food by seeking to provide a range of price points. There are often tradeoffs between supporting producer and consumer members, which can be challenging for the food hub to successfully manage.

This regional food system is a complex sociotechnical system, composed of multiple autonomous and interacting actors. The individual decisions and adaptations of the consumers, producers, and the food hub manager yield complex
and unpredictable system-level behavior and outcomes (e.g., food hub success/failure) that cannot be predicted by examining the motivations and behaviors of the individual participants (Meter, 2006; Pathak, Day, Nair, Sawaya, & Kristal, 2007). Agent-based modeling (ABM) is a tool that is well-suited to capturing the complexity of such supply networks (Choi, Dooley, & Rungtusanatham, 2001). For example, Krejci and Beamon (2015) developed a theoretical ABM to study the impact of farmer coordination on the development of regional food system structures and social sustainability outcomes. To gain an increased understanding of the preferences, drivers, attributes, and behaviors of food hub participants, as well as the factors that encourage/discourage consumers and producers to participate in the system over time, Krejci, Stone, Dorneich, and Gilbert (2016) developed an ABM of a regional food system in Iowa using NetLogo (v. 5.0.2). The model was based on empirically derived inputs, which enabled a more realistic representation of the system and its constituent actors. This empirical ABM provides the basis for the study presented in this paper, in which the food hub manager’s sourcing strategy is investigated.

To collect the data for this study, a structured interview with consumer and producer members of an Iowa food hub was conducted to provide a scientific profile of both groups. These profiles would then be used to help identify critical variables and ultimately provide more accurate information to be used in modeling consumer and producer behavior. The interviews were conducted onsite at the food hub’s distribution center in Des Moines, Iowa. Interviewees first signed IRB-approved consent forms and then began a structured interview with a researcher for a period of 1 hour. Interviewers followed a strict interaction protocol so as to avoid influencing participants’ responses. After completing all of the interview questions, participants were given the opportunity to ask questions of the researchers. Upon completion of the interviews, survey questions were transcribed into a spreadsheet and then categorized.

Data Analysis

In total, 33 individuals participated in the interview process (22 consumers and 11 producers). The typical consumer was 48.5 years of age (range 28–78), had a median household income of $100,000 (range $40,000–$300,000), and lived 6.5 miles (SD = 3.2) from the food hub (or associated distribution center). They tended to be very comfortable with technology and were typically the primary shoppers for their family, which averaged 2.5 (SD = 1) individuals. Consumers were also likely to have a college education. The typical producer was 49.1 years of age (range 28–67), had a median household income of $78,000 (range $13,000–$175,000), and lived 39.8 miles (SD = 22.7) from the food hub. Producers were very comfortable with technology, had a family which averaged 3.4 individuals
(SD = 1), and were nearly half as likely as consumers to have a college education. Consumers were largely motivated to interact with the food hub for health, environmental, and sustainability issues, whereas producers were somewhat motivated by similar issues but much more so by classical economic motivators related to profit and entity survival. Nearly all of the consumers interviewed (19 of 22) reported that the producers’ online profiles were important to their purchasing decisions, and they rated their level of trust in the information provided as very high, with a mean of 4.7 on a Likert rating scale of 1–5 (SD = 0.5). As a typical example, one consumer participant, when asked whether or not she trusted the information in the producers’ profiles, commented that she had “no reason not to.”

For each of 14 different values (price, convenience of food preparation, nutrition, freshness, familiarity, novelty, convenience, variety, supporting of local economy, relationship with producers, communicate with vendors, food production practices, food safety, and treatment of animals), consumers responded on a 5-point Likert scale to describe the level of importance of each of the values in determining their participation with the food hub. The average Likert value for each of the 14 values was scaled from 0 to 1, where 1 indicates a strong preference for the given value, and 0 indicates very little interest in that particular value (see Table 1.)

Table 1. Consumer agent persona preference values for food hub and producer parameters

<table>
<thead>
<tr>
<th>Value</th>
<th>Locavore</th>
<th>Pragmatist</th>
<th>Frugalist</th>
<th>Idealist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety</td>
<td>0.700</td>
<td>0.720</td>
<td>0.200</td>
<td>1.00</td>
</tr>
<tr>
<td>Buy</td>
<td>0.700</td>
<td>0.580</td>
<td>0.600</td>
<td>0.860</td>
</tr>
<tr>
<td>Convenience</td>
<td>0.633</td>
<td>0.640</td>
<td>1.00</td>
<td>0.700</td>
</tr>
<tr>
<td>Price</td>
<td>0.367</td>
<td>0.840</td>
<td>0.800</td>
<td>1.00</td>
</tr>
<tr>
<td>Preparation</td>
<td>0.917</td>
<td>0.480</td>
<td>0.400</td>
<td>1.00</td>
</tr>
<tr>
<td>Convenience</td>
<td>1.00</td>
<td>0.560</td>
<td>0.400</td>
<td>1.00</td>
</tr>
<tr>
<td>Nutrition</td>
<td>0.650</td>
<td>0.720</td>
<td>0.800</td>
<td>0.950</td>
</tr>
<tr>
<td>Familiarity</td>
<td>0.467</td>
<td>0.480</td>
<td>0.800</td>
<td>0.950</td>
</tr>
<tr>
<td>Novelty</td>
<td>1.00</td>
<td>0.720</td>
<td>0.600</td>
<td>1.00</td>
</tr>
<tr>
<td>Distance</td>
<td>0.717</td>
<td>0.480</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Relationship</td>
<td>0.817</td>
<td>0.560</td>
<td>0.800</td>
<td>1.00</td>
</tr>
<tr>
<td>Reliability</td>
<td>0.950</td>
<td>0.720</td>
<td>0.600</td>
<td>1.00</td>
</tr>
<tr>
<td>Production</td>
<td>0.950</td>
<td>1.00</td>
<td>0.400</td>
<td>1.00</td>
</tr>
<tr>
<td>Safety</td>
<td>0.983</td>
<td>1.00</td>
<td>0.600</td>
<td>1.00</td>
</tr>
<tr>
<td>Treatment Of Animals</td>
<td>0.917</td>
<td>0.800</td>
<td>0.400</td>
<td>1.00</td>
</tr>
</tbody>
</table>

The participants’ responses to these questions were statistically analyzed (using a hierarchical cluster analysis) to enable the categorization of consumers into different personas (Everitt, Landau, Leese, & Stahl, 2011). This method for interviewee selection and persona development has been widely used (Adler, 2005; Aquino & Filgueiras, 2005). The output of this analysis resulted in the development of four distinct personas: Locavores, Pragmatists, Frugalists, and Idealists (Krejci et al., 2016). The Locavore is a consumer who feels strongly about supporting the local economy and obtaining the freshest foods possible. The Pragmatist is a consumer who values food safety, freshness, and nutritional content, but tends to take a moderate view on other attributes associated with food purchase. The Frugalist is a highly price-conscious consumer, and the Idealist represents a consumer who feels strongly about all sustainable values and is motivated by serving
those values. For an in-depth analysis of the interview findings and the personas developed from them see Krejci et al. (2016).

Modeling Methodology

In this section, the agents that inhabit the empirically based ABM of the central Iowa regional food system (producers, consumers, food hub manager) are described, and an overview of the model and its constituent submodels is provided.

Agents

The consumer agents in the model are described by three parameters: their persona, their demand category, and their food familiarity level. Based on the results of the interviews with food hub consumer members, the probability of the generation of a consumer agent having a given persona in the model was 54%, 23%, 5%, and 18% for being Locavores, Pragmatists, Frugalists, and Idealists, respectively. Each consumer agent is assigned a demand category, which describes its level of demand (low, medium, or high) for each of six product categories in each distribution cycle. The probability that the model generates a consumer agent in any given demand category was determined via food hub historical data, which indicated that many (47%) of its participating consumer members were relatively low-volume customers. Each consumer is also assigned to categories that represent its likelihood of being familiar with a food or finding a food to be “novel” in a given interaction with a producer: 50% of consumers will find 5% of food interactions to yield foods that are unfamiliar/particularly novel to them, and the other 50% will encounter unfamiliar/novel foods in 10% of their interactions. For consumers who prefer familiar foods, the encounters with unfamiliar food will reduce their overall appraisal of the producer who provides it. In contrast, for consumers who prefer novel foods, this type of encounter will increase its rating of a producer.

Consumer agents are also characterized by a utility value, which is a measure of the consumer’s satisfaction at any point in time. The higher a consumer’s overall utility value is, the more likely he/she is to engage in commerce with the food hub in a given cycle, which influences his membership status. Utility values are scaled from 0 to 1, with 0 being the least preferred value and 1 the most preferred. The direction of preference for these utility distributions tends to be intuitive; for example, consumers prefer low prices and highly nutritious/fresh/safe food.

Producer agents are characterized by 11 parameters, each of which governs how the agent is evaluated by consumers and/or how it makes its decisions. Table
2 lists these parameters, the possible values that they can take on, the associated probability of each value being assigned to a given agent, and the source of information/data that provides the basis for the probability distribution. The values that are assigned to a producer for each of these parameters represent innate characteristics that are fixed throughout the duration of the simulation run.

Table 2. The 11 parameters/values that characterize producer agents

<table>
<thead>
<tr>
<th>Producer Parameter</th>
<th>Possible Values</th>
<th>Probability</th>
<th>Distribution Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Production Capacity</td>
<td>50 units/cycle</td>
<td>0.50</td>
<td>System Data</td>
</tr>
<tr>
<td></td>
<td>100 units/cycle</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>150 units/cycle</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Remaining Inventory Threshold</td>
<td>70%</td>
<td>0.33</td>
<td>Assumption</td>
</tr>
<tr>
<td></td>
<td>80%</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>90%</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td>Low</td>
<td>Varies based on food category</td>
<td>System Data</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of Food Preparation</td>
<td>Low</td>
<td>0.25 or 0.50: based on food category</td>
<td>Assumption</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food Nutritional Content</td>
<td>Low</td>
<td>0.25 or 0.50: based on food category</td>
<td>Assumption</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food Freshness Issues</td>
<td>1% chance</td>
<td>0.75</td>
<td>Assumption</td>
</tr>
<tr>
<td></td>
<td>5% chance</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Distance From Food Hub</td>
<td>≤ 20 miles</td>
<td>0.70</td>
<td>System Data</td>
</tr>
<tr>
<td></td>
<td>20–40 miles</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 40 miles</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>Reliability Issues</td>
<td>1% chance</td>
<td>0.90</td>
<td>Assumption</td>
</tr>
<tr>
<td></td>
<td>5% chance</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>Production Practices</td>
<td>Insufficient information</td>
<td>Varies based on input data</td>
<td>System Data</td>
</tr>
<tr>
<td></td>
<td>Conventional</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chemical-free</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Certified organic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food Safety Issues</td>
<td>0.1% chance</td>
<td>0.75</td>
<td>Assumption</td>
</tr>
<tr>
<td></td>
<td>0.5% chance</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Treatment of Animals</td>
<td>No certification</td>
<td>Varies based on input data</td>
<td>System Data</td>
</tr>
<tr>
<td></td>
<td>certified humane</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The model also contains a single food hub manager agent that assesses relative supply and demand levels at the end of each distribution cycle. The manager
A
t  
  
agent then uses this information to determine whether or not to allow new producer agents to become members of the hub.

Model Overview

The producer and consumer agents trade six different categories of food, using the food hub as an intermediary. Each producer agent produces and sells one of the six product categories to consumers through the food hub. The categories and percentage of producers supplying them were: meat (25%), dairy (5%), eggs (9%), fresh produce (36%), ingredients (3%), and processed convenience foods (22%). Each time the model generates a producer agent, there is a fixed probability that the agent will be assigned to particular category (e.g., there is a 25% chance that it will be a meat producer), based on historical data from a real-life food hub. It is assumed that a producer agent may only provide items in a single category, which is typically true in the real regional food system (Krejci et al., 2016).

Each simulated time step represents a distribution cycle by the food hub, which occurs approximately every two weeks throughout the year, for a total of 22 cycles per year. Producers and consumers can be in one of three different membership states with respect to the food hub: nonmember, member, or canceled member. Agent interactions are confined to producer–consumer transactions. It is assumed that consumers do not interact with one another directly, and neither do producers.

The model consists of five major submodels: initialization, consumer purchase decisions, consumer evaluation and status update, producer evaluation and status update, and food hub membership update. The initialization submodel is only run once, at the start of each simulation run. The other four submodels are executed sequentially in every time step.

Initialization. In each simulation run, the model is initialized with 30 producer agents, each of which is randomly assigned parameter values based on the probabilities determined from the interview data, system data, and assumptions. Different random number streams and seeds are used for each run, such that the outputs of each run are statistically independent. Each producer is initialized with 100% of its yield available for sale through the food hub. Fifty consumer agents are created, each of which is randomly assigned a demand category (i.e., low, medium, high), a food familiarity category, and a persona. Each consumer’s producer rating matrix is initialized with producer attribute values for each of the producer agents in the model. A consumer’s overall utility is initialized to 1.00 (the maximum value), and food hub membership status for all consumers and producers is set to “member.”

Consumer purchase decisions. Each consumer who is currently a food hub
member checks its overall utility value: if the value is greater than 0.70, then the consumer decides to participate in purchasing; if the value is less than 0.70, the probability that the consumer decides to participate corresponds to its utility value. If the consumer decides to purchase from the food hub, it is assumed that he/she will try to fill as much as his/her demand as possible via the food hub. Consumers who have decided to participate are selected in random order to make their purchases from participating producers. Each consumer first assesses his/her demand in each product category. Then, he/she seeks out producers that have inventory available in each product category. As a consumer successfully purchases items from producers in each cycle, the consumer’s demand for that item is reduced. It is assumed that demand that goes unfilled by the food hub will be filled by other exogenous sources (i.e., there is no demand backlog from one time-step to the next). After a consumer completes a transaction with a producer, he/she will update the parameter values in his/her producer ratings vector for that producer. If the consumer is unable to find any producers with inventory in a product category, his/her overall utility will be reduced by 0.05, and he/she will move on to the next category. If the consumer finds a producer(s) with inventory, but this inventory is insufficient to completely fill his/her demand, then his/her utility will be reduced by 0.01. If the consumer’s demand is completely satisfied, his/her utility will increase by 0.01.

The consumer will then assess each of the available producers with respect to its values, using the producer’s ratings vectors. Then the consumer ranks each of these producers by the total value he/she gives. He/she then selects the producer with the highest rank and purchases either enough of the producer’s inventory to fill his/her demand or all of the producer’s inventory (whichever is larger). If the consumer has any unfilled demand, he/she will move on to the next ranked producer and will purchase as much as available/needed from that producer, and so on. After each interaction with a producer, the consumer will update his/her producer ratings vector for that producer. The consumer will continue this process for each of the remaining five product categories.

Consumer evaluation and status update. After all consumer agents are finished purchasing food, each consumer will evaluate his/her overall utility with the food hub, which is based on his/her previous transactions. If a consumer’s overall utility falls below a threshold value of 0.10 (out of 1.00), or if the consumer observes that he/she has participated with the food hub fewer than four times out of the previous 11 distribution cycles, he/she will change his/her membership status to “canceled member” and will no longer participate in transactions with the food hub.

Producer evaluation and status update. A producer makes one key decision in each distribution cycle: what percentage of its production capacity to sell to consumers via the food hub. Throughout the simulation, the percentage of production capacity that a producer allocates to the food hub (rather than to other
market channels, such as farmers’ markets) may vary over time, according to how well the producer’s products have sold through the food hub in previous distribution cycles. This update defines the producer’s degree of participation with the food hub and depends on the producer’s upper threshold for unsold inventory ratios. The unsold inventory ratio is simply the amount of inventory (in food units) that a producer has left at the end of a cycle, divided by the total number of units that he/she offered to consumers through the food hub at the beginning of the cycle. If this ratio is equal to zero (i.e., he/she sold the entire available inventory), then in the next cycle, the producer will increase his/her offerings by 10% (up to its capacity). If this ratio is greater than the producer’s upper threshold for unsold inventory, he/she will calculate a weighted average of the ratio of number of items sold to capacity, over the three most recent cycles and will change the percentage of capacity that he/she offers through the food hub in the next time step to that average value. If the ratio is greater than zero but less than the upper threshold value, the number of units that the producer offers through the food hub in the next time step will remain unchanged. It is assumed that if a producer’s participation drops to less than 10% of his/her capacity at any point in time, that producer will no longer participate with the food hub for the duration of the simulation run (i.e., its status will become “canceled member”).

Food hub membership update. At the end of each distribution cycle, new producer and consumer agents are generated, and they are randomly assigned parameter values based on probabilities that were determined from the empirical food hub data. It is assumed that new consumer agents are created at a constant rate of two consumers per cycle. A new producer agent is created on average. These rates approximate the actual rates at which new producer and consumer members joined the real-life food hub, based on food hub historical data.

Producer Selection Policies: Experimental Method

To assess the value of implementing various different producer selection policies, the food hub manager agent may choose to intervene during the “Food Hub Membership Update” submodel execution. To execute a given selection policy, when a producer agent is created and attempts to join the food hub, the manager will determine the producer’s attributes, assess how well these attributes fit the needs of the food hub and its consumers, and based on this assessment, decide whether or not to allow the producer to join the food hub.

Five different producer selection policies were tested to assess the impact of having the food hub manager intervene in the selection of producers:

1. No centralized management of supplier selection: This policy represents the status quo—any producers who wish to join the food hub are allowed to join.
2. **Balance supply and demand**: Following this policy, when a producer attempts to join the food hub, the manager will assess total system supply and demand levels from the previous distribution cycle for the candidate producer’s product type. If the supply of that food type in the previous cycle is less than 120% of the demand (allowing for future growth), then the manager will allow the producer to join; otherwise, the producer is removed from the system.

3. **Account for producer size**: The manager evaluates a producer in terms of system supply and demand (as in Policy 2) but makes exceptions for small-sized producers. That is, if a small dairy producer requests membership, even if the food hub’s supply of dairy items from other producers is already much greater than existing demand, the manager will make an exception to the policy and will allow that producer to join. This policy reflects the food hub’s socially responsible imperative to support small-scale regional producers.

4. **Account for producer price level**: This policy is similar to Policy 3, but here the manager will make an exception for producers who are at a low price level; that is, such producers will be allowed to join even if the supply–demand ratio of their food type is greater than 120%. This policy does not reflect current practices at the Iowa food hub but serves as a “what-if” scenario to determine what would happen to the system if the food hub decided to place a greater emphasis on improving access for low-income consumers.

5. **Account for producer size and price**: This policy combines Policies 2, 3, and 4, such that the manager’s selection policy is very generous—producer membership is only restricted if the candidate producer is medium/large size and/or medium/high price, and the supply for that producer’s product type is greater than 120% of demand.

The model was run for 1000 replications for each of the five policies. The length of each model run was 110 time steps (i.e., distribution cycles), which represents five years of system operation at 22 distribution cycles per year. The food hub manager has two primary objectives: maximizing food hub revenues while providing support and economic opportunities for regional producers. To reflect this, the following output metrics were captured at the end of each replication:

- Total volume of food units traded through the food hub
- Total number of consumer and producer agents participating
- Average “age” (i.e., length of participation) of participating producer and consumer agents
- Number of small-, medium-, and large-sized participating producer agents
- Number of low-, medium-, and high-priced participating producer agents
Results

All quantitative metrics were analyzed with analysis of variance (ANOVA) tests. The results are reported as significant for a significance level alpha \( \alpha < 0.05 \). Post-hoc Tukey’s test with adjusted \( p \)-values was used to test for a significant difference in the means for pairwise comparison, for which no \textit{a priori} hypotheses had been developed. Additionally, Cohen’s \( d \) was calculated to check the effect size to provide a standard measure to express the differences in means between two groups in standard deviation units. The Cohen’s \( d \) results are reported as small effects for \( 0.20 < d < 0.50 \), medium effects for \( 0.50 < d < 0.80 \), and large effects for \( d > 0.80 \). Pairwise differences in means will only be discussed if the effect size was greater than 0.20.

Volume of Food Units Traded

illustrates the means and standard deviations of the volume of food units traded. The volume of food units traded was significant \( (F (4,4995) = 10.17, p < 0.001) \) across the five different policies. In the figure, means that do not share a letter are significantly different, as calculated by post-hoc analysis. There was a small \( (d = 0.24) \) difference between Policy 1 (No Management) and Policy 2 (Supply & Demand). There was also a small \( (d = -0.22) \) difference between Policy 2 and Policy 5 (Size & Price).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{volume_of_food_units_traded.png}
\caption{The volume of food traded under each policy option. The bars represent standard deviation. Means that do not share a letter are significantly different.}
\end{figure}
Number of Participating Consumers

Figure 2. Number of consumers participating under each policy option. The bars represent standard deviation. Means that do not share a letter are significantly different. Illustrates the means and standard deviations of the number of consumers participating under each policy option. The number of consumers was significant \( (F(4,4995) = 9.52, p < 0.001) \) across the five different policies. In the figure, means that do not share a letter are significantly different, as calculated by post-hoc analysis. There was a small \( (d = 0.23) \) difference between Policy 1 (No Management) and Policy 2 (Supply & Demand). There was also a small \( (d = −0.22) \) difference between Policy 2 and Policy 5 (Size & Price).

Number of Participating Producers

Figure 3 illustrates the means and standard deviations of the number of producers participating under each policy option. The number of producers was significant \( (F(4,4995) =9.52, p < 0.001) \) across the five different policies. In the figure, means that do not share a letter are significantly different, as calculated by post-hoc analysis. There was a medium \( (d = 0.52) \) difference between Policy 1 (No Management) and Policy 2 (Supply & Demand), and a small \( (d = 0.37) \) difference between Policy 1 and Policy 4 (Price). There was a small \( (d = −0.36) \) difference between Policy 2 and Policy 3 (Size), and a small \( (d = −0.45) \) difference between the Policy 2 and Policy 5 (Size & Price). Likewise, there was a small \( (d = −0.21) \) difference between Policies 3 and 4. Finally, there was a small \( (d = −0.30) \) difference between Policies 4 and 5.
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Figure 3. Number of producers participating under each policy option. The bars represent standard deviation. Means that do not share a letter are significantly different.

Average Age of Consumers

Figure 4 illustrates the means and standard deviations of the age of consumers participating (blue bars) under each policy option. The average consumer age was significant ($F(4,4995)=6.07, p<0.001$) across the five different policies. In the figure, means that do not share a (upper case) letter are significantly different, as calculated by post-hoc analysis. None of the pairwise differences reached the small effect size threshold.

Figure 4. Average age of consumers and producers under each policy option. The bars represent standard deviation. Means that do not share a letter are significantly different.
Average Age of Producers

Figure 4 illustrates the means and standard deviations of the age of producers (green bars) participating under each policy option. The average producer age was significant \( (F(4,4995) = 179, p < 0.001) \) across the five different policies. In the figure, means that do not share a (lower case) letter are significantly different, as calculated by post-hoc analysis. There was a large \( (d = 1.07) \) difference between Policy 1 (No Management) and Policy 2 (Supply & Demand), and a medium \( (d = 0.73) \) difference between Policy 1 and Policy 4 (Price). There was a medium \( (d = 0.70) \) difference between Policy 2 and Policy 3 (Size), and a medium \( (d = -0.79) \) difference between Policy 2 and Policy 5 (Size & Price). All other pairwise combinations showed a small effect size \( (0.20 < d < 0.50) \), except for the negligible effect size between Policies 3 and 5.

Average Producer Size

Figure 5 illustrates the means for the number of participating producers by size: small producers (blue), medium producers (green), and large producers (red), under each policy option.

![Participating Producers by Size](image)

**Figure 5.** Average size category of producers under each policy option. Means from each producer size category that do not share a letter are significantly different.

*Small producers.* The number of small producers (blue bars in Figure 5) was significant \( (F(4,4995) = 86.3, p < 0.001) \) across the five different policies. In the figure, means that do not share a (upper case) letter are significantly different, as calculated by post-hoc analysis. There were small difference between the following pairs of means: between Policy 1 (No Management) and Policy 2 (Supply & Demand) \( (d = 0.44) \), and between Policy 1 and Policy 4 (Price) \( (d = 0.33) \). There
was a medium difference between the following pairs of means: between Policy 2 and Policy 3 (Size) \( (d = -0.64) \), between Policy 2 and Policy 5 (Size & Price) \( (d = -0.63) \), between Policy 3 and Policy 4 \( (d = 0.53) \), and between Policy 4 and Policy 5 \( (d = -0.52) \).

**Medium producers.** The number of medium-sized producers (green bars in Figure 5) was significant \( (F(4,4995) =35.3, p < 0.001) \) across the five different policies. In the figure, means that do not share a (lower case) letter are significantly different, as calculated by post-hoc analysis. Policy 1 (No Management) showed a small difference between every other policy: Policy 2 \( (d = 0.41) \), Policy 3 \( (d = 0.48) \), Policy 4 \( (d = 0.30) \), and Policy 5 \( (d = 0.31) \).

**Large producers.** The number of large producers (red bars in Figure 5) was significant \( (F(4,4995) =39.1, p < 0.001) \) across the five different policies. In the figure, means that do not share a (Greek) letter are significantly different, as calculated by post-hoc analysis. Policy 1 (No Management) showed a difference between every other policy: Policy 2 \( (d = 0.39, \text{small}) \), Policy 3 \( (d = 0.52, \text{medium}) \), Policy 4 \( (d = 0.21, \text{small}) \), and Policy 5 \( (d = 0.35, \text{small}) \). Additionally, there was a small \( (d = -0.29) \) difference between Policies 3 (Size) and 4 (Price).

**Average Producer Price**

Figure 6 illustrates the means for the number of participating producers by price: low price (blue), medium price (green), and high price (red), under each policy option.

![Figure 6](image)

**Figure 6.** Average price category of producers under each policy option. Means from each producer size category that do not share a letter are significantly different.

**Low price.** The number of low-price producers (blue bars in Figure 6) was significant \( (F(4,4995) =104.5, p < 0.001) \) across the five different policies. In the figure, means that do not share a (uppercase) letter are significantly different, as calculated by post-hoc analysis. There were small differences between the following
pairs of means: between Policy 1 (No Management) and Policy 3 (Size) \(d = 0.24\), between Policy 2 (Supply & Demand) and Policy 3 \(d = -0.30\), between Policy 3 and Policy 4 (Price) \(d = -0.31\), and between Policy 3 and Policy 5 (Size & Price) \(d = -0.34\). There was a medium difference between the following pairs of means: between Policies 1 and 2 \(d = 0.69\), between Policies 2 and 4 \(d = -0.76\), and between Policies 2 and 5 \(d = -0.79\).

**Medium price.** The number of medium-price producers (green bars in Figure 6) was significant \(F(4,4995) = 57.8, p < 0.001\) across the five different policies. In the figure, means that do not share a (lowercase) letter are significantly different, as calculated by post-hoc analysis. There were small differences between the following pairs of means: between Policy 1 (No Management) and Policy 2 (Supply & Demand) \(d = 0.46\), between Policy 2 and Policy 3 (Size) \(d = -0.30\), between Policy 2 and Policy 5 (Size & Price) \(d = -0.29\), between Policy 3 and Policy 4 (Price) \(d = 0.43\), and between Policies 4 and 5 \(d = -0.42\). There was a medium \(d = 0.59\) difference between Policies 1 and 4.

**High price.** The number of high-price producers (red bars in Figure 6) was significant \(F(4,4995) = 9.41, p < 0.001\) across the five different policies. In the figure, means that do not share a (Greek) letter are significantly different, as calculated by post-hoc analysis. There was a small \(d = 0.21\) difference between Policy 1 (No Management) and Policy 4 (Price). There was also a small \(d = 0.22\) difference between Policy 3 (Size) and Policy 4.

**Discussion**

Of all five sourcing policies, Policy 2 (the unmodified supply–demand selection policy) is the strictest. However, Policy 4 (Price) is effectively nearly as strict as Policy 2, since relatively few low-price producers attempt to participate in the food hub (a reflection of real-life producer behavior), and therefore an exception for these producers does not relax the supply–demand ratio constraint very much. By contrast, Policies 1, 3, and 5 represent less interference by the food hub manager. Based on the results of the ANOVA tests, all of the system performance metrics of interest were significantly influenced by the food hub manager’s choice of supplier selection policy. However, the effect sizes varied considerably for different pairwise comparisons of policies on each metric, which tended to reflect the difference between less restrictive approaches (as with Policies 1, 3, and 5) and strategies that were more selective (i.e., Policies 2 and 4).

Under Policy 2 (Supply & Demand), both the mean number of food units traded through the food hub and the number of participating consumers are shown to be significantly less than the mean values under Policies 1 and 5 (No Management and Size & Price, respectively). These results suggest that, in terms of sales, the best option for the food hub may be to continue allowing any producer
who wishes to join to become a member (i.e., maintain the status quo). If the food hub manager wants to implement a sourcing policy, he/she should consider relaxing restrictions for small-sized and low-price producers. Either of these strategies (Policy 1 or Policy 5) appears likely to support consumer satisfaction and continued participation.

On average, Policy 2 (Supply & Demand) yielded significantly fewer participating producers and a significantly greater average producer age than Policies 1, 3, and 5 (No Management, Size, and Size & Price). These three policies also resulted in a higher concentration of small-sized and low-price producers (a result that is preferred by consumers) than Policy 2. Interestingly, there is no significant difference between Policy 1 and Policy 4 (the supply−demand selection policy in which exceptions are made for low-price producers) with respect to the mean number of low-price producers. This suggests that consumers’ preferences for low prices can help to maintain a pool of competitive low-price producers without the need for food hub manager intervention.

These results indicate that in deciding which of these five supplier selection policies to implement, the food hub manager must make a tradeoff between protecting producers and meeting the needs of the consumers. By following “protectionist” Policy 2, the food hub manager’s loyalty to currently participating producers protects them from healthy competition and reduces the ability for consumer preferences (i.e., for lower prices and smaller producers) to be fully expressed. The food hub manager must determine whether it is in the food hub's best interest to fully support a smaller group of producers, or partially support many producers and allow for some competition among them. Additionally, though the modifications to Policy 2 to encourage small-sized/low-price producers yield statistically significant reductions in average producer size (with Policies 3, 4, and 5) and price (with Policy 3) when compared to the status quo, the food hub manager should carefully assess whether the effort involved in implementing these policies would be truly worthwhile in the long run, and whether the chosen policy would be perceived by the producers and consumers in the community as being socially responsible and equitable.

Conclusion

For VBOs like regional food hubs, developing a suitable sourcing strategy can be a challenging task. Food hubs are in a unique position of having to balance the social and economic concerns of both food producers and consumers. For a food hub manager, an appropriate policy for determining which producers should be allowed to participate in the system may not always be clear. Because regional food systems tend to be collaborative and community-based networks, maintaining traditional “arm’s length” or adversarial relationships with
producers can be difficult (and likely undesirable) for a manager. However, the
manager should be cautious about allowing relationships with producers to dictate
the food hub’s sourcing policy at the expense of consumer satisfaction.

This paper described an empirically based ABM of a regional food system
in central Iowa, in which the success of the entire system (including the producers,
consumers, and the food hub) relies on the achievement of potentially conflicting
social and economic objectives and the careful balance of meeting both producer
and consumer requirements. The experiments described in this paper show how
ABM can be used to capture the effects of different sourcing policies on regional
food hub consumer and producer participation. The results of these experiments
suggest that centralized control via management policies can lead to desired out-
comes, but such policies can also have unintended (and sometimes undesirable)
consequences for system behavior.

In future work, it will be interesting to observe the effects of different sourc-
ing policies on the evolution of the system’s consumer persona distribution. For
example, if the food hub manager implements a policy that strongly supports the
inclusion of low-cost producers, will the price-conscious Frugalist persona be-
come dominant? Would this strategy drive other personas away from the food
hub? How would this impact the food hub financially? Is this beneficial for indi-
vidual producers and consumers, and for the regional food system as a whole? The
ABM can be used to answer these questions.

The ABM will also be further developed to allow for social interactions
and information sharing among the consumer agents, and to assess the impact of
these interactions on food system metrics. These interactions may be personal; for
example, the consumer agents could discuss their experiences with one another
when they pick up their orders from the food hub. Alternatively, the interactions
could occur via the food hub’s website, through a system of producer ratings. The
implications of allowing and/or encouraging communication between consumers
would be useful for the food hub manager to understand. ABM is a particularly
useful tool for studying the effects of these types of complex interactions on system
behavior over time.

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