Exploring local food networks in Gloucestershire and North Cotswolds - considering rural resilience

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Abstract

Encouraging local food supply has emerged as a favoured research and policy approach to tackle various contemporary challenges, from reducing transport emissions to improving economic resilience and quality of life. Although increasingly discussed, little empirical analysis has explored the complex relational networks that define how small and medium-sized enterprises (SMEs) contribute and operate in local food and drink markets. This paper presents early results from a novel approach to investigate the complex networks of firms in the local food and drink supply chains of Gloucestershire and the North Cotswolds. Following a detailed pilot, we used social network analysis to map the supply networks of food and drink businesses and calculated key network centrality metrics. Our results reveal the interconnected nature of businesses (farm shops, producers, retailers and wholesalers), working together to facilitate local supply. In particular, farm shops emerge as central figures within these networks, maintaining collaborative relationships that can foster product and process innovation among and between their suppliers. While policies for economic development tend to focus support on large or 'high growth' firms, our initial findings suggest potential for alternative strategies better tailored to the specific needs of SMEs in food local networks, fostering business 'ecosystems' characterised by diversity, interdependence and resilience.

Keywords: Small and medium-sized enterprises (SMEs), local food networks, social network analysis, rural resilience, policy, suppliers and buyers

Introduction

Food business in rural areas is characterised by a relatively higher proportion of small and medium-sized enterprises (SMEs), when compared to the national average. The claimed benefits of local food include fairer prices for farmers, access to fresh and seasonal produce for shoppers, a smaller carbon footprint, improved traceability and economic benefits for the local community (Hendry et al., 2019, Bavorova et al., 2018). Moreover, Enthoven and Van den Broeck (2021) list eight claims made by governments and civil society organisations about local food systems: these include improving consumers' access to healthy food; consumers being willing to pay more for local food than for non-local food; providing farmers with a high level of social recognition; providing local economic benefits; fostering social ties between communities; benefiting the environment through the use of environmentally-friendly production practices; and reducing the impact of food production and consumption on climate change. Rural SMEs are a vital part of local food systems, not only providing employment, but also supporting rural development through the extension of industrialisation to rural areas (Jose and Shanmugam, 2020). SMEs in food supply chains also played an important role during the COVID-19 pandemic (Béné, 2020, Ali et al., 2021, Stein and Santini, 2022).

In recent years, the resilience of local food supply chains has increasingly attracted the attention of researchers and policy-makers seeking to support SMEs in overcoming their challenges (Kumar and Kumar Singh, 2017, Enthoven and Van den Broeck, 2021, Brusset and Teller, 2017, Asamoah et al., 2020, Ponomarov and Holcomb, 2009). Resilience refers to the ability of the supply chain to withstand disruption or to adapt and innovate in response to change (Jones et al., 2022, Ponomarov and Holcomb, 2009). The majority of supply chain resilience research has been conceptual in nature, with many studies concerned with defining or conceptualising concepts and theories (Asamoah et al., 2020, Mensah and Merkuryev, 2014, Bellamy and Basole, 2013, Blanchard, 2021, Craighead et al., 2020). Nevertheless, a body of literature focuses on the role of social network relationships, cooperation and responsiveness, and external recourse networks and partnerships in the development of supply chain management (Galaskiewicz, 2011, Asamoah et al., 2020). For example, it has been noted that a well-connected supply chain with redundant paths and alternative key players will have greater resilience capacity, with the potential to help maintain the level of relational capital between network actors (Osman et al., 2020).

Research highlights the importance of strategic collaboration between companies to build higher-order capabilities for supply chain resilience (Asamoah et al., 2020, Brusset and Teller, 2017). As described by Carter et al. (2015), no company operates in isolation from other companies, and the supply chain is a network of companies that work together; a number of interrelated companies (suppliers, manufacturers, distributors, retailers and customers) in an extended network that enhances the overall quality of the process (Mensah and Merkuryev, 2014). A network perspective allows for an understanding of the wider network in which firms operate, going beyond the dyadic relationship between the firms (Carter et al., 2015) or the investigation of individual companies on an individual basis (Trivette, 2019). The pattern of positioning in a supply chain network (Osman, 2018) and network relationships influence organisational behaviour and outcomes (Ahuja, 2000). In a supply network, the different degree of centrality or buyer-supplier connection reflects the degree of interconnectedness that a firm has with other firms in the network (Osman, 2018). According to Osman (2018), different patterns of connectivity and centrality in buyer-supplier relationships and embeddedness configurations within a supply network, can influence relational capital and provide competitive advantage to certain central actors.

Despite the research interest in networks and their potential benefits to businesses and local economies, government policies seeking to foster enterprise and innovation in both rural and urban settings have tended to focus on individual firms with ‘high growth potential’ (Innovate UK, 2023). Combined with selection criteria which frequently emphasize the creation of new employment (Gov.UK, 2024), this approach can easily lead to the exclusion of smaller businesses operating as interdependent elements within growing networks. This is particularly so in rural areas which are characterised by a higher proportion of SMEs and micro-businesses in primary and craft/small-scale manufacturing sectors, compared to urban centres.

As partners in NICRE[1] (the National Innovation Centre for Rural Enterprise), researchers at the CCRI engage with rural business groups across England. Particularly within Gloucestershire and the Cotswolds, we have worked in the agri-food domain to understand business needs and aspirations for development. In this context, we have noted many situations where rural businesses act as interlinked elements in an ‘ecosystem’, in which the interdependence of many small players, rather than their competitive ability, appears critical to success. We are keen to understand the functional characteristics of networks of rural businesses so as to explore how they affect firms’ survival, development and capacity for innovation. Understanding the links between local food SMEs and the position and roles of participating firms within a network could enable policy makers to better understand why and what kinds of distributed networks may

[1] National Innovation Centre for Rural Enterprise
https://nicre.co.uk

be critical to the growth, resilience and economic success of rural enterprise. This, in turn, could lead to more effective policy support.

We are examining in particular the local food and drink supply chains of Gloucestershire and the North Cotswolds, how these networks operate and how important they can be for rural economies and communities. Gloucestershire is a county with a significant rural component, as well as a diverse range of farm shops and local food and drink producers (Morris and Buller, 2003). Through close monitoring of a variety of local media, we know that these networks generally adapted well to the challenges of Covid and supported other key sectors such as tourism and hospitality during those difficult times (Phillipson et al., 2022, Wishart and Mole, 2022). While other researchers identified the UK Covid experience as highlighting a need to explore the strategies needed to sustain and strengthen the development of supply chain resilience for local food systems (Hendry et al., 2019), we have been exploring the potential of Social Network Analysis (SNA) (Wichmann and Kaufmann, 2016, Trivette, 2019), in this context.

We use SNA as an analytical tool to identify and analyse the pattern of relationships between businesses. Through this approach, we examine what sort of connections contribute to the network configuration of the local food supply system and how participating businesses are positioned, within this network. The connections reflect the roles of each business and the nature of their business interactions. These enable us to build a picture of all the main businesses engaged in the supply and exchange of local food products in the North Cotswolds / Gloucestershire area – covering a 50-mile radius from the county boundaries. SNA adopts a network perspective, wherein the local food and drink supply system is a network of nodes and links. A node is a company with the ability to supply and/or buy, and a link is the supply connection (food and drink) between two nodes.

We apply this framework to address the following research questions:

1. What companies work together in the operation and supply of locally-produced food and drink in the North Cotswolds / Gloucestershire area?

2. What is the pattern of connectivity in buyer-supplier relationships, and which companies have greater connectivity and centrality within the local food and drink supply network?

The paper is structured as follows: Section 2 reviews the literature and presents the supply chain challenges faced by SMEs, also social network analysis and the concepts of network centrality and connectivity. Section 3 outlines our research methodology. Section 4 is a presentation of the results and section 5 is a discussion of the findings, their implications and future directions.

2. Literature reviews

2.1 Small businesses and Food Supply Chain Networks

SMEs and micro-businesses face many of the same supply chain management complexities as larger companies, but they are more challenged to overcome these barriers due to limited resources, expertise and ability to invest (Liu et al., 2022, Blanchard, 2021). These businesses often face difficulties addressing issues such as technological upgrading, personnel development and new product development (Kumar and Kumar Singh, 2017, Buonanno et al., 2005). When it comes to dealing with suppliers, they are at a severe disadvantage because they do not have the scale or leverage to negotiate the most favourable terms (Wong et al., 2020). This can be exacerbated if many are highly dependent on a small number of key suppliers or local cooperatives for inputs and resources (Morris and Buller, 2003), such that the collapse of a nexus

supplier or a strategic supplier could have far-reaching negative consequences (Wichmann and Kaufmann, 2016, Yan et al., 2015).

Regulatory requirements such as food quality, availability, safety and freshness within a limited timeframe make food supply chain management more challenging and complex than other supply chains (Zhong et al., 2017, Jose and Shanmugam, 2020). A typical food supply chain includes a network of "(i) primary producer - farmers that grow or breed the raw material; (ii) marketer that store and sell products to producers; (iii) industrial producers - manufacturers that perform some value-adding activities to the raw material such as processing and packaging; (iv) wholesaler e distributers that store and move products between industrial producers and re- tailers; and (v) retailers - subjects that sale the products to the consumers" (Mattevi and Jones, 2016). In the food supply system, there are multiple layers of links between suppliers, via manufacturing and assembly companies, to distributors, retailers, other intermediaries and the customer (Trivette, 2019). The supply path may vary depending on the type of food, its characteristics, its scale and the market power of the supply chain members involved (Jose and Shanmugam, 2020).

According to Vaaland and Heide (2007), in a food supply chain system, competition applies not just to individual companies but to the entire integrated supply chain. It is the network of participants in the supply chain and the relationships between them that determine the *structure* of the supply chain (Lambert et al., 1998). Different entities in the supply chain work together to deliver value to customers. Woods et al. (2019) found that SMEs are better able to identify and innovate in response to new market opportunities as they become more connected to a larger network. There is evidence that small businesses can benefit from the identification of opportunities from external social networks, to enhance their supply chain management and resilience capacity (Asamoah et al., 2020). As firms interact and share resources with other firms in the network, it may become easier to monitor and identify opportunities in supply chain markets. Actors can build connections with multiple discounted networks and this increases the level of trust, reputation and mutual respect within the relationship (Osman et al., 2020, Ahuja, 2000). Specific actors within the network can later become reliable partners in sharing and providing support where needed (Osman, 2018).

2.2 Social Network Analysis and Connectivity

Social Network Analysis (SNA) is a well-established research approach in social and behavioural science, emphasizing the pattern of interactions (e.g., social relationships, patterns of communication or the flow of information) (Borgatti and Li, 2009). The importance and benefits of social network analysis in identifying and managing risks in the context of supply chain network have been emphasized (Carter et al., 2015, Woods et al., 2019, Bellamy and Basole, 2013, Trivette, 2019, Ribau et al., 2018, Wichmann and Kaufmann, 2016, Galaskiewicz, 2011). In a SNA approach, the focus is shifted from the examination of individual firms' characteristics in isolation, to the relationships and links between individuals or entities within a network (Trivette, 2019). In an SNA approach, there are nodes (e.g. organisations, individuals) and ties (links between two entities within a network). Ties or links represent relationships and interactions, which can be directed (e.g. giving advice) or undirected (e.g. physical proximity), and can be dichotomised (e.g. a tie exists or does not exist) or assessed by the strength of the interaction (Wichmann and Kaufmann, 2016, Borgatti and Li, 2009, Borgatti and Foster, 2003).

Network studies are concerned with identifying entities that are well-connected or centrally positioned in the network. By analysing a supply chain network, it is possible to identify key players or nodes within the supply chain (Han et al., 2020), having a significant impact on the way goods, information or resources flow through the network. Understanding the relationships and dependencies within a supply chain network can help to improve SMEs' supply chain efficiency, resilience and innovation (Woods et al., 2019).

In network analysis, there are different approaches to describing an organisation's network structure and its relative position within a network (Ahuja, 2000). One of the most commonly used measures is that of network centrality, which identifies the position of an organisation in terms of how central it is to the network as a whole (Osman, 2018, Woods et al., 2019). Measures of centrality and connection show the suppliers' and buyers' degree of connectivity in a network (Osman, 2018). Firms with a high degree of network centrality are at its centre and connected to a larger number of other firms, each with its own set of resources and capabilities. Centrality thus implies a more active role in supply chains than firms at the periphery of the network (Woods et al., 2019).

3. Method: Network Data Collection

Data collection and preparation for local food and drink supply chains in Gloucestershire and the North Cotswolds took place in four phases (2019 to 2023), progressing incrementally.

Phase one – Initially, we assembled and updated a list of businesses operating in the local food and drink sector (including contact information and main product/s), through online searches and team members' personal knowledge (a list of websites that were found to be useful is given in Appendix A). For example, *Made in Gloucestershire* provides contact details and social media links for local food and drink businesses in the county (although this branding was only launched in 2023, so the list is still being assembled). Particular care was taken to establish that the primary products being bought and sold were produced within the county or in neighbouring areas.

Phase two – A snowball sampling technique was chosen to begin collecting network information. Pilot sampling involved approaching three farm shops for face-to-face data collection, with all showing initial interest but only one fully engaging, due to time constraints. This pilot provided a valuable case study in successful farm shop operation. This enabled an online survey to be designed and circulated to relevant firms via a range of local partners (public, private and non-profit actors in the agri-food arena).

Phase three – Invitation letters and links to the survey were sent to all these businesses. The survey was launched in January 2023 and closed in August. However, with very low response rates (4 responses) in turbulent and demanding market conditions post-Covid 19, we identified a need for an alternative strategy.

Phase 4 – A new approach relied on the information available on food and drink company websites to build a model of the network. Many companies disclose basic details of their supply relationships with other food and drink companies on their websites, which proved a sufficient starting point to build a picture of the network without requiring further direct engagement (Lokier et al., 2021). We continued to search using all identified companies and products connected to Gloucestershire businesses, only stopping where we found duplicate or irrelevant entities, to avoid mis-specified network boundaries that could lead to misleading results (Wichmann and Kaufmann, 2016). The data requirements of SNA were met by defining selection criteria according to which enterprises are included or excluded (Borgatti and Foster, 2003).

3.1 Explaining SNA terms and roles

UCINET software was used to map the network of SMEs in local food and drink supply chains. We use network key features to identify and illustrate patterns of relationships in the exchange of food products; and explore how a particular business is connected to its local supply businesses and contributes to the larger local food network. The measurements used in this study are described below:

Reciprocal relationship: A reciprocal relationship exists when companies buy from each other, which of course means that they are suppliers to each other's business (McCallum, 2016).

Out-degree and in-degree centrality: A directed graph has two types of links and measures of centrality: out-degree and in-degree (Wichmann and Kaufmann, 2016). The out-degree indicates the total number of links with other enterprises in the network through the sale of food and drink products. A business with an out-degree is therefore a supplier or sender of products in the network. Businesses that are buyers or recipients of products in the network are represented by in-degree centrality. Measures of in-degree and out-degree centrality provide a good understanding of the relational networks of the suppliers and the buyers of the products.

Bonacich power centrality: This analysis provides two valuable insights into the network. The first one with the positive beta value (beta = 0.7063997) shows which nodes have centrality in the network and the second one with negative beta value (beta = -0.7063997) shows which nodes in the network are powerful ones (Hanneman and Riddle, 2005). If a node has connections to which those connections also have many connections, this node will be considered as weak. In the case of a supply network, this can be interpreted as this: if a business sells to another business and the buyer has many other choices (alternatives) to buy from, this makes the seller a weak business. The powerful business is one which is connected to weaker business(s).

Betweenness: The nodes with a high betweenness value are the ones that are the main bridges that connect the sub-networks and are important for the robustness of the network. A high degree of betweenness centrality means that other actors in the network are dependent on this actor if they want to reach other actors in the network (Wichmann and Kaufmann, 2016).

Closeness: A node with a high value for closeness has a very fast reachability to a large number of other nodes with the capacity to affect the network faster than others. The score that nodes receive in closeness centrality is based on the sum of the shortest paths between nodes in the network. Similar to degree centrality in directed networks, there are in-closeness and out-closeness centralities in this measurement (Wichmann and Kaufmann, 2016).

K-core: A k-core is a combination of at least *k* nodes connected in a network forming a subgraph, each of which has at least *k* connections to these members of the subgraph (Hanneman and Riddle, 2005).

4. Results and Findings

The network data was searched for small and isolated nodes. It showed a large component, and some nodes with one or few connections (in total 816 nodes and 1278 ties). A total of 803 nodes are part of the large component and 13 nodes are not connected to the large component. In the large component, every business has at least one connection in the network. We kept only the large component and looked for information about the businesses (actors) and connections (ties, links) between them, while the isolated nodes were removed from the network dataset. As a result, 803 businesses and 1269 supply links were identified within the network.

Table 1 shows the distribution of the sample according to the type of business and according to their geographical location of operation (within GL or not GL). In this network, there are 39 farm shops (4.9%), 305 primary producers (38.0%), 369 retailers (46.0%) and 90 wholesalers (11.2%). There are 8 farm shops (20.51% of this sample) that have supply relationships with each other. There are also 52 producers (17.1%) and 41 retailers (11.1%) that have supply relationships with similar types of enterprises. In this network there are 4 wholesalers having supply relationships with each other (4.4%).

Geographically, 461 businesses had a GL postcode (with 516 supply network connections within their network) and the total number of businesses that were not located in a GL postcode was 342 (with 191 supply network connections within their network). The majority of the companies operate and supply within GL, just as expected. Within the network, retailers had the highest number of enterprises with a GL geographical location (60.7%) and producers had the highest number of enterprises without a GL geographical location (49.1%). Within each business type, the number of farm shops is higher in the geographical location GL and the presence of wholesalers is higher in non-GL.

Table 1 network distribution and size by different type of businesses

					GL			Not GL		
	Number of nodes	% In the network	Number of ties within each	% ties within each	Number of nodes	% Within each	% In the network	Number of nodes	% Within each	% In the network
Farm shop	39	4.9	8	20.5	23	59.0	5.0	16	41.0	4.7
Producers	305	38.0	52	17.1	137	44.9	29.7	168	55.1	49.1
Retailers	369	46.0	41	11.1	280	75.9	60.7	89	24.1	26.0
Wholesalers	90	11.2	4	4.4	21	23.3	4.6	69	76.7	20.2
GL	461		516							
Not GL	342		191							

Table 2 shows that of the 803 enterprises in the network, 426 enterprises do not supply enterprises in the network by selling their food and drink products. In addition, there are 330 enterprises that do not have any supply links to buy from the enterprises presented in this network. A total of 377 businesses sell food and drink products to between one and 55 businesses in the network. Most of them are connected to between one and four businesses in the network (N=320). A total of 473 businesses buy food and drink products from one to 88 businesses in the network. Most of them connected to between one and four businesses in the network (N=430).

Table 2 Out-degree and in-degree centrality

	Out-degree (from 803 businesses)	In-degree *(from 803 businesses)*
0	426	330
1-4	320	430
5-9	28	19
10-14	7	7
15-19	9	8
20-24	5	4
25-29	2	1
30-34	3	0
35-39	1	0
40 and more*	2	4
*Maximum out-degree is 55 *Maximum in-degree is 88		

There are some companies in the network that have both out-degree centrality and in-degree centrality (N=47 companies). It means that these businesses are both suppliers of products to other companies in the network and also buyers of products from other businesses in the network. Among these that both sell and buy products from businesses in the network, one farm shop (ID 399) and one wholesaler (ID 657) that have the highest in-degree centrality (57 and 44 suppliers, respectively) and a producer (ID 329) that has the highest out-degree centrality (51 buyers).

The sociograms of the connected network within each type of business and business location are shown in Figure 1 and Figure 2. These sociograms are anonymous, and firms have not been identified by their company name on the network maps. We used a random numerical ID for each business, and they are identified by a number on the maps and datasets. Numerical IDs are switched off for visibility on the maps but in Appendix B the results are presented by numerical ID. On the network map, we have used colour differentiation (where necessary) to describe businesses based on their type of business and location. The arrow in the social maps is from suppliers to buyers.

In reciprocity supply relationship, the line (link) has headed arrows at both sides. The number of reciprocal links in this network is very low (8 links involving 7 companies). Two farm shops (ID 399 and ID100) are each other's suppliers, one of which (ID 399) also has a reciprocal relationship with a wholesaler in the network (ID 384). The other reciprocal relationships exist between two producers (ID 320 and ID 598), one has a reciprocal supply relationship with a farm shop (ID 732) and another one has a reciprocal relationship with a wholesaler (ID 657). None of the retailers have a reciprocal supply relationship with each other, nor do they have a reciprocal relationship with any other company in the network.

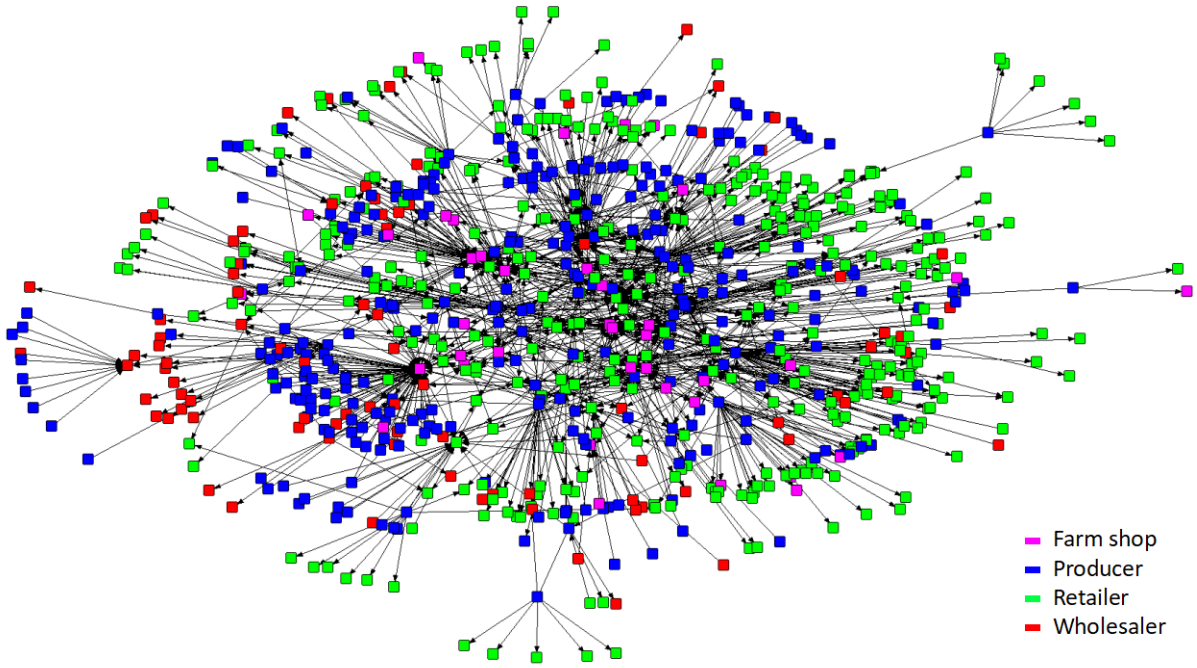

Figure 1 Sociogram of connected network

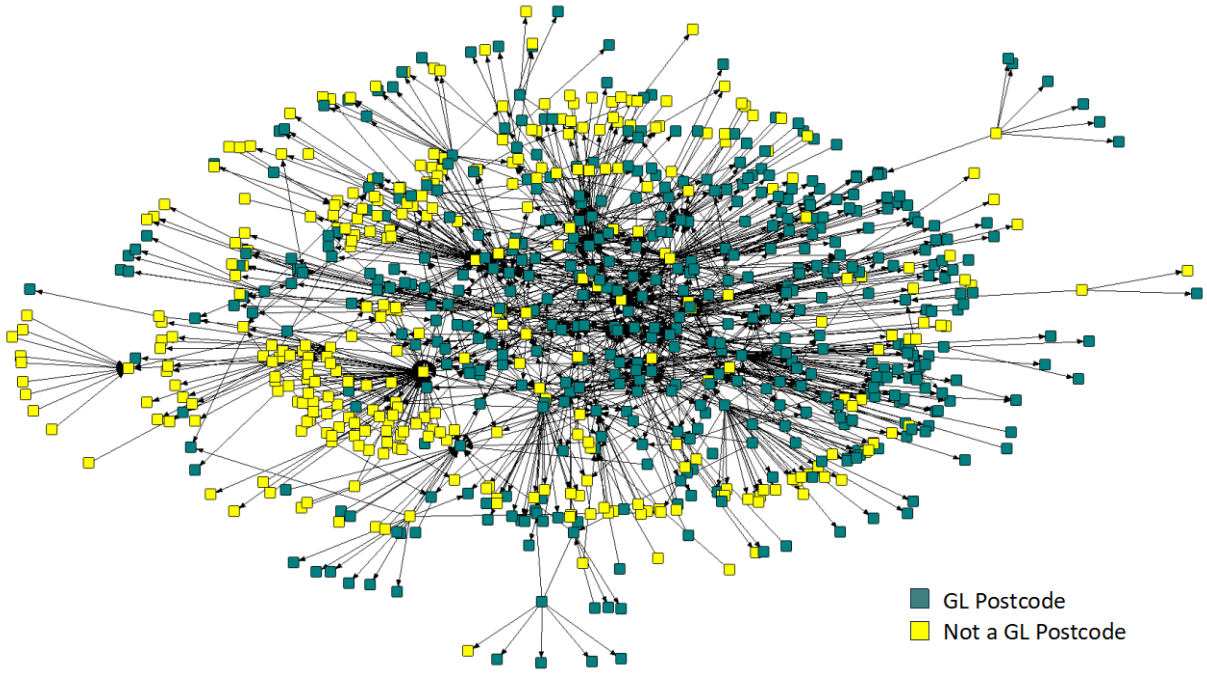

Figure 2 Sociogram of connected network based on location

For the sake of comparability, the out-degree and in-degree values have been divided into five categories from 'zero' to '50 and more' (Table 3). Unsurprisingly, producers stand out as main senders or suppliers: they have a much higher out-degree rate within the network (94.4%), followed by wholesalers (46.7%) and farm shops (33.3%). Most of them supply between 1 and 4 other businesses in the network. On the other hand, retailers have the lowest out-degree centrality (9.2%), indicating that they have fewer out-degree ties and a lower volume of products sold on to other businesses in the network.

In the in-degree centrality, retailers have the higher links, followed by wholesalers and farm shops, which indicates them as main recipients of products from other businesses in the network. Analysis of the farm shop supply network shows that 35.9% of the farm shops in this network have more than 4 suppliers, 17.9% have between 10 and 49 suppliers and 5.1% have more than 50 suppliers. However, only about 6.0 % of the retailers and 4.4% of wholesalers and 1% of the producers buy their products from 5 or more suppliers in this network.

Table 3 Out-degree and in-degree centrality measures by type of business (frequencies and percentages)

Outdegree-centrality										
	Farm shops		**Producers**		**Retailers**		**Wholesalers**		**Total**	
	N	%	N	%	N	%	N	%	N	%
Zero	26	66.7	17	5.6	335	90.8	48	53.3	426	53.1
1 to 4	12	30.8	238	78.0	30	8.1	40	44.4	320	39.9
5 to 9	0	0.0	23	7.5	3	0.8	2	2.2	28	3.5
10 to 49	1	2.6	25	8.2	1	0.3	0	0.0	27	3.4
50 and more	0	0.0	2	0.7	0	0.0	0	0.0	2	0.2

Indegree-centrality										
	Farm shops		Producers		Retailers		Wholesalers		Total	
	N	%	N	%	N	%	N	%	N	%
Zero	4	10.3	269	88.2	24	6.5	33	36.7	330	41.1
1 to 4	21	53.8	33	10.8	323	87.5	53	58.9	430	53.5
5 to 9	5	12.8	2	0.7	10	2.7	2	2.2	19	2.4
10 to 49	7	17.9	1	0.3	12	3.3	2	2.2	22	2.7
50 and more	2	5.1	0	0.0	0	0.0	0	0.0	2	0.2

Visual representations of out-degree and in-degree network centrality are shown in Figure 3 and Figure 4. Centrality is represented by the size of the nodes in the sociograms. Large nodes show higher centrality, which may indicate their importance and influence in the network. It is interesting to note that the out-degree map shows the high presence of producers (shown in blue) and the in-degree map shows the high presence of retailers (shown in green). In the out-degree, the producers are more active nodes in the network with the presence of larger nodes. The presence of retailers is higher in terms of in-degree centrality. However, there are two farm shops (ID 310 and ID 399) and a wholesaler (ID 657) with a higher in-degree centrality.

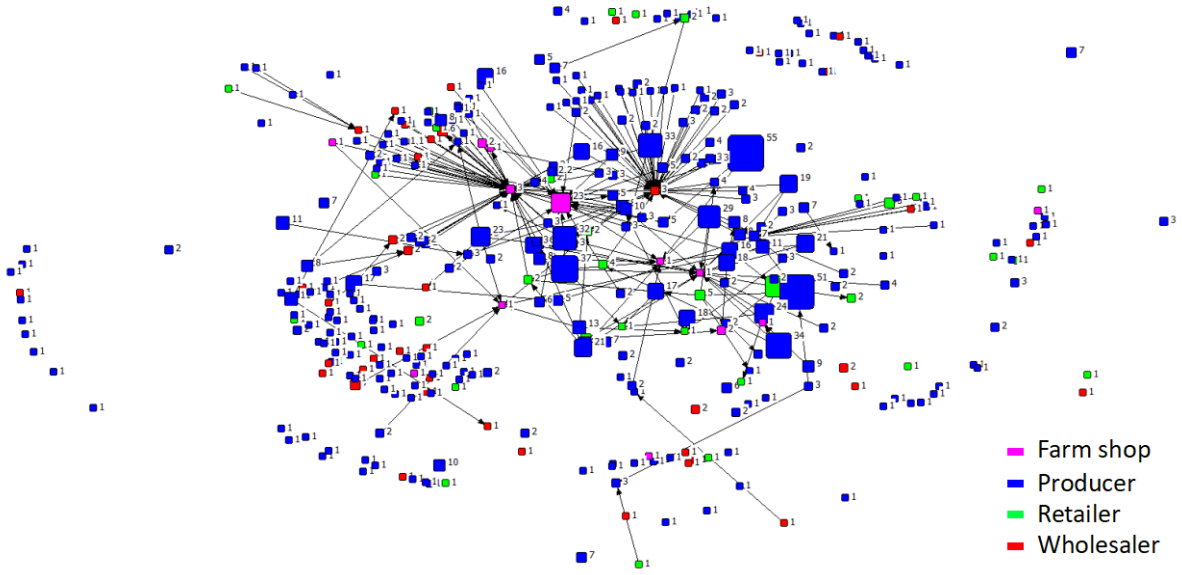

Figure 3 Out-degree centrality (out-degree 1 to 55)

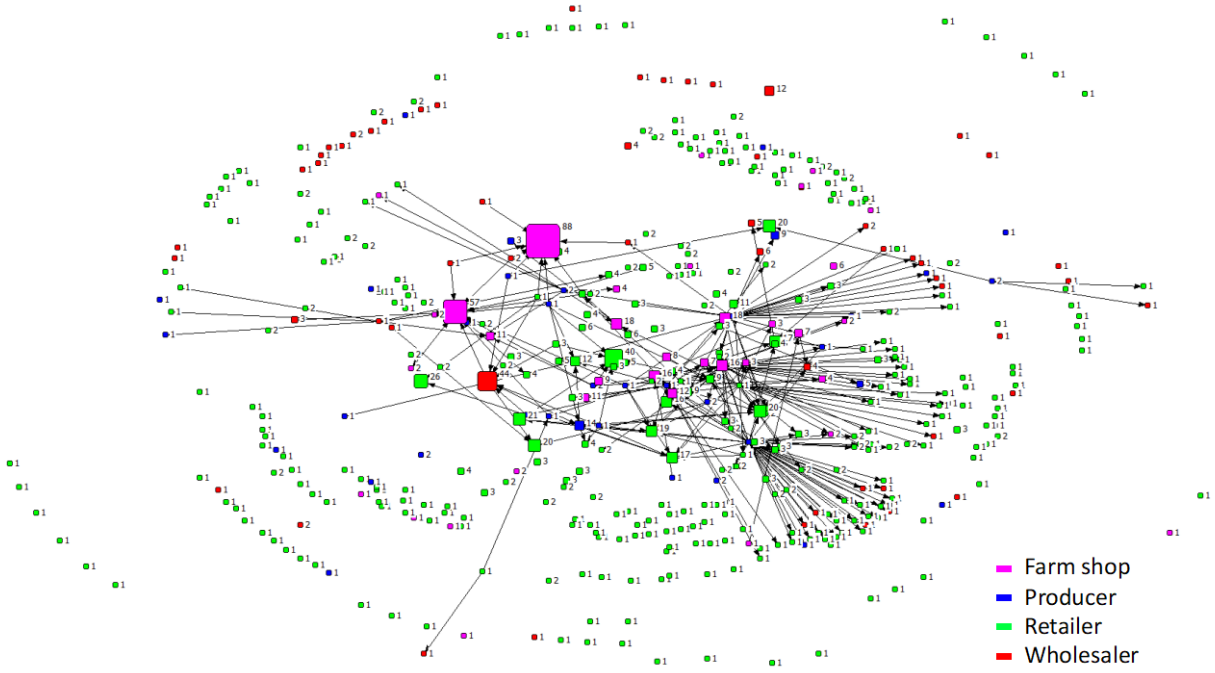

Figure 4 In-degree centrality (in-degree 1 to 88)

The results of the out-degree and in-degree measures were used to identify businesses in their network according to the type of supply relationship they have with other businesses: supplier (has only out-degree centrality), buyer (has only in-degree centrality) or supplier and buyer (has both out-degree centrality and in-degree centrality). As can be seen from Table 4, the majority of producers are suppliers (88.2%) and the majority of retailers are buyers (90.8%). 66.7% of the farm shops have suppliers who are part of this network. 23.1% were presented with the role of both the supplier and the buyer in this network. 36.7% of wholesalers have links with suppliers and 53.3% have links with buyers. Only 10.0% of wholesalers in this network have both buying and selling relationships with businesses presented within the network. This figure is lower for producers and retailers.

In the network, businesses with the geographical location GL are mainly buyers of food and beverages (71.1%) and in the non-GL they are mainly suppliers (61.2%). The percentage of both suppliers and buyers is higher in the geographical location of the GL (63.8%).

Table 4 Relational supply role between different types of businesses (frequencies and percentages)

	Suppliers		Buyers		Suppliers & Buyers		All	
	N	%	N	%	N	%	N	%
Farm shop	4	10.3	26	66.7	9	23.1	39	100
Producer	269	88.2	17	5.6	19	6.2	305	100
Retailer	24	6.5	335	90.8	10	2.7	369	100
Wholesaler	33	36.7	48	53.3	9	10.0	90	100
GL	128	38.8	303	71.1	30	63.8	461	100
Not GL	202	61.2	123	28.9	17	36.2	342	100

Centrality analysis using positive beta identified 9 central nodes with values greater than 44000. The nearest central node with a value less than 44000 is 122. Due to this massive difference, only the 9 nodes with high values were considered as central nodes (Table 5). Farm shops have the lowest number of nodes in the network but have 3 central nodes and the retailer has 4 central nodes in the network. Producers and wholesalers each have 1 central node in the network. In the second part of the analysis with negative beta, 6 of these 9 nodes were the most powerful nodes and 3 were the least powerful. Farmers, retailers and wholesalers each have one node as weakest. Among the strong nodes there are three retailers (ID 617, ID 272 and ID 307), two farm shops (ID 399 and ID 491) and one producer (ID 473). There is no strong central node for wholesalers in this network.

Table 5 Centrality and power in the network among businesses

Centrality and power	All	Farm shop	Producer	Retailer	Wholesaler
Centrality of 1000 and more	9	3	1	4	1
Power of -1000 and less	3	1	0	1	1
Power of 1000 and more	6	2	1	3	0

Table 6 shows the results of the centrality measure of betweenness, in-closeness, out-closeness, and k-core by the business type. In total 40 businesses have betweenness centrality greater than 1. The highest betweenness value belongs to a farm shop (ID 399) with a value of 1086. In order to give some meaning to this value, there is no other node in the whole network with a betweenness value higher than 1000. Interestingly, almost 17.9% of farm shops appeared as important nodes, acting as bridges in the high betweenness network. Wholesalers, producers and retailers come next with the total of 8.9%, 5.6% and 2.2%, respectively.

The range of in-closeness centrality is between 0 to 153 and out-closeness is between 0 to 239. Businesses with high closeness centrality can quickly interact with other businesses in the network (Wichmann and Kaufmann, 2016). As expected, producers have the lowest percentages of nodes compared to other businesses for in-closeness centrality. The in-closeness values are higher for retailers, farm shops and wholesalers. Only farm shops, with 7.7% of their nodes, have a higher in-closeness (≥ 10), leading this type of businesses over all other types of businesses in the network. For out-closeness, retailers have the lowest percentage of nodes in the network and producers have the highest values among all the business types.

The results of the K-core analysis shows that 64.1% of farm shops are in K-core 2 or higher, with over 25.6% in K-core 5. Nodes belonging to the high k-core value in the network can function more robustly. Figure 5 shows the k-core for the entire sample. The nodes in the centre of the map belong to k-cores 4 and 5. K-core of nodes gets lower and smaller towards the edges. As we can see, 38.5% of farm shops are in K-core 4 and 5, whereas these figures are 12.5% for producers, 8.1% for retailers and 4.4% for wholesalers. This is an indication of the vital role of farm shops in sustaining the local food system.

Table 6 Betweenness, In-closeness centrality, out-closeness centrality, and k-core by business type (frequencies and percentages)

		Farm shop		Producer		Retailer		Wholesaler		All	
		N	%	N	%	N	%	N	%	N	%
Betweenness centrality (1 to 1086)	1 to 9	4	10.3	5	1.6	2	0.5	4	4.4	15	37.5
	10 to 99	1	2.6	10	3.3	6	1.6	2	2.2	19	47.5
	100 to 999	1	2.6	2	0.7	0	0.0	2	2.2	5	12.5
	1000 and more	1	2.6	0	0.0	0	0.0	0	0.0	1	2.5

In-closeness (0 to 153)	zero	4	10.3	269	88.2	24	6.5	33	36.7	330	41.1
	1 to 9	32	82.1	26	8.5	342	92.7	54	60.0	454	56.5
	10 to 99	3	7.7	9	3.0	2	0.5	3	3.3	17	2.1
	100 and more	0	0.0	1	0.3	1	0.3	0	0.0	2	0.2
Out-closeness (0 to 239)	zero	26	66.7	17	5.6	335	90.8	48	53.3	426	53.1
	1 to 9	9	23.1	164	53.8	21	5.7	31	34.4	225	28.0
	10 to 99	4	10.3	116	38.0	12	3.3	11	12.2	143	17.8
	100 and more	0	0.0	8	2.6	1	0.3	0	0.0	9	1.1
k-core	K-Core 1	14	35.9	187	61.3	256	69.4	72	80.0	529	65.9
	K-Core 2	8	20.5	54	17.7	57	15.4	9	10.0	128	15.9
	K-Core 3	2	5.1	26	8.5	26	7.0	5	5.6	59	7.3
	K-Core 4	5	12.8	17	5.6	17	4.6	3	3.3	42	5.2
	K-Core 5	10	25.6	21	6.9	13	3.5	1	1.1	45	5.6

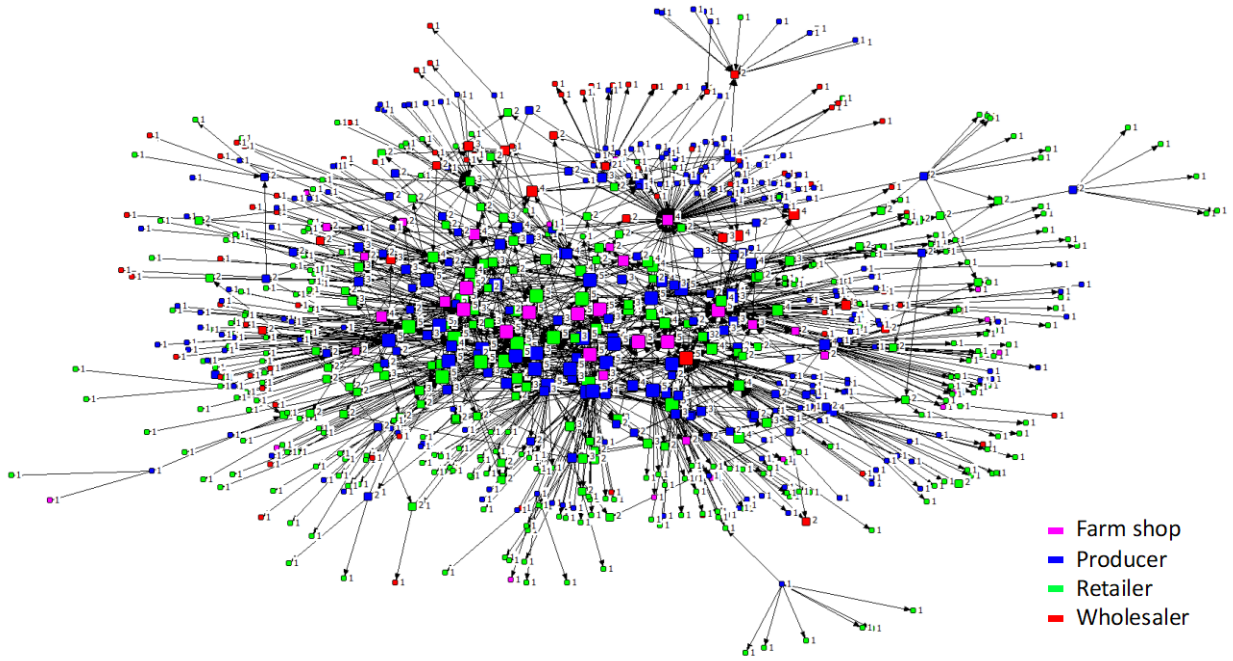

Figure 5 K-core for entire sample

5. Key Findings and Conclusions

Network research is a valuable way to monitor key players and better assess risks and opportunities within a supply chain (Yan et al., 2015, Wichmann and Kaufmann, 2016). It provides knowledge that enables policymakers to better understand the structural characteristics of extended networks in supply chain

management and suggests ways in which SMEs can adapt to many unforeseen changes (Wichmann and Kaufmann, 2016).

In this study, we identified a company's supply network, the role of its supply exchange business within that network, the basic characteristics of its type of business and its geographical location. Examining relational criteria across the network, and using our pilot case study and initial scoping, we could identify the different roles of business types and examine their contributions to network characteristics. This helped us consider the value of a network-focused approach to rural enterprise and innovation, and potential policy implications. The development of network maps has enabled us to visualise and characterise the interconnectedness of local food and drink businesses, whether farm shops, producers, retailers, or wholesalers. Through the use of SNA, we have identified patterns in relationships, examining how individual businesses are linked to others and contribute to the wider network.

The results showed that different types of enterprise play different roles in these maps, each with a particular role to play in a local food system in ensuring that the supply chain functions properly, and products are delivered effectively to end users. Findings from the network maps show that certain SMEs play pivotal roles at the local level. Their centrality within the interconnected network highlights the crucial position of farm shops for maintaining the efficiency and sustainability of the system. Although farm shops face multiple challenges and barriers to their enterprises (e.g., seasonality of produce, consumer awareness and shop identity) (Lokier et al., 2021), they are a vital link in holding the wider system together and greatly increasing consumer access to local food. A farm shop sells many kinds of food and drink and provides services to other types of businesses (McKague et al., 2021, Bavorova et al., 2018). In previous research, farm shops were suggested as most profitable for value added in Gloucestershire (Morris and Buller, 2003).

From our pilot cases and associated in-person interviews, we identify potential for farm shops and other small retailers to encourage local producers to innovate and enhance their product range and quality, as well as to foster greater collaborative activity across the network, promoting local products, and improving customer understanding. Several examples have been identified where farm shops operate to stimulate their suppliers to innovate with new products, enhancing the offer to a loyal customer base. In addition, where producers move on from local to national markets, or where they cease trading, farm shops will seek to replace them by identifying other new and smaller suppliers of similar products, thus fostering new enterprise and newcomers to the network.

Acknowledging the challenges of collecting data on relational networks directly from SMEs, the use of online secondary data offered an advantageous approach to studying linkages between firms. Despite limitations in terms of scope and depth, it has enabled us to gain meaningful insights, to identify and illustrate patterns of relationships in food exchange; and begin to consider how policy might be more specifically developed to support and strengthen rural business networks of this type.

One potential policy option would be to target collective needs of groups of businesses within a network, rather than assessing the case for support at the level of a single business. For example, funding could be devoted to providing support across a network, rather than only by individual businesses, in order to address labour and skills needs. Apprenticeships can be difficult for small producers or manufacturers to support on their own, but might be feasible if the trainee can work across a number of firms to gain experience whilst pursuing their qualifications. Another possibility could be to offer support to help those firms that act as key nodes within the network, to develop strategic plans for network growth and development which could ultimately benefit a wide range of network actors in addition to themselves. Also, facilitation and communication are often important to the effective functioning of networks. Another option for policy consideration might therefore be to investigate what kinds of facilitation and communication skills or capacities could be needed to enhance particular attributes within the local networks that they seek to

strengthen. Clearly, all these kinds of support should be co-developed with actors in the relevant networks, as far as possible.

Limitations and future research directions

The scope of this study was limited to a very few direct meetings and interviews, plus the online information available on businesses' websites, so the network analysis cannot present the strengths and weights of its links, including the frequency and the length of the supply, the importance of the supply to the shared value of the businesses' turnover, the type and number of products in the supply chain between businesses. We calculated some of the network metrics to answer the research questions: who supplies whom; and which types of business have the most central roles in the network. Our focus on the supply chain was primarily on local nodes, to the exclusion of companies that are less connected. Other network measures could be assessed where data allow assessment of network structure (Wichmann and Kaufmann, 2016, Trivette, 2019).

We are keen to consider how best to extend this type of study so as to enable increased insights into network functioning, whilst recognising the barriers to engagement which typify such small and complex enterprises where the owners and staff often work long hours and have limited capacity to engage with researchers. We also hope to identify opportunities to use the network information already assembled, to inform policy and support strategies among local authorities and relevant NGOs, most notably those active in Gloucestershire's Food and Farming partnership which has ambitions to build and champion a sustainable food and farming future for the county.

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Appendix A Websites searched for food and drink businesses in the Gloucestershire and the North Cotswolds

Name of website	**Links**
Find Local Produce	https://findlocalproduce.co.uk/Gloucestershire/Farm-Shops.asp?categoryID=9&qAID15=yes
Discover Local Food	https://www.bigbarn.co.uk/places/Gloucestershire/Coombe-Hill/Farm-Shop/
Open food network	https://openfoodnetwork.org.uk/producers#/
Farm shop.uk.com	http://www.farmshop.uk.com/local-area/south-west/gloucestershire/
Made in Gloucestershire	https://www.madeingloucestershire.com/member-directory/
The wholesaler.co.uk	https://www.thewholesaler.co.uk/suppliers/vegan/
Shambles market stroud	http://shamblesmarketstroud.co.uk/stalls.php
Happerley	https://happerley.co.uk/browse_members?producer_keyword_filter=farm+shop&submit=
Visit Gloucester	https://www.visitgloucester.co.uk/shopping/markets
Fresh-n-local	https://fresh-n-local.co.uk/?s=&post_types=trader&markets=gloucester-farmers-market
Farm Retail	https://farmretail.co.uk/find-a-farm-retailer/
Fabulous farm shops	https://www.fabulousfarmshops.co.uk/gloucestershire.html

Appendix B 20 highlighted businesses in the network (with ID identification)

Out-degree	In-degree	Centrality and power	Central suppliers and buyers	K-core	Betweenness	In-centrality	Out-centrality
181**	310*	399*	399(60)*	399(5)*	399(1086)*	329(153)**	571(239)**
329**	399*	491*	329(52)**	657(5)****	657(880)****	43(103)***	329(152)**
738**	657****	272***	657(47)****	732(5)*	384(676)****	371(74)**	34(148)**
40**	766***	307***	732 (39)*	598(5)**	732(504.5)*	320(69)**	181(146)**
520**	472***	473**	296(26)***	320(5)**	598(468)**	732(57)*	40(116)**
751**	169***	617***	371(24)**	329(5)**	320(152)**	1(57)**	738(109)**
796**	54***	*569****	598(21)**	358(5)**	329(82)**	42(57)**	11(104)**
296***	278***	*100**	487(19)*	296(5)***	43(44)***	229(56)***	43(101)***
414**	57***	*384*****	358(18)**	487(5)*	560(36)***	358(55)**	409(101)**
371**	161***		274(10)**	794(5)**	274(33.5)**	598(41)**	87(95)**
732*	487*		794(9)**	792(5)**	371(33.5)**	657(38)****	456(93)**
581**	526*		193(9)*	193(5)*	358(33.5)**	274(29)**	271(92)**
568**	753***		206(8)*	766(5)***	658(27)****	192(25)**	584(92)**
638**	318***		320(7)**	169(5)***	229(26)***	560(24)***	703(92)**
270**	732*		384(7)****	54(5)***	296(24)***	96(24)****	747(92)**

364**	293***		43(6)***	278(5)***	192(22)**	100(24)*	253(91)**
18**	361*		792(6)**	161(5)***	487(21)*	225(23)**	486(91)**
358**	598**		238(6)**	526(5)*	728(21)***	399(16)*	512(91)****
34**	693***		560(6)***	753(5)***	96(20)****	384(14)****	674(91)**
80*+	737*		728(5)***	293(5)***	42(20)**	9(5)**	559(87)**

* Farm shop
** Producer
***Retailer
****Wholesaler
Italic = least powerful