



U.S. Food Flows: A Cold Chain Network Analysis of Freight Movements to Inform Local and Regional Food Issues (Summary)

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This is a summary of U.S. Food Flows: A Cold Chain Network Analysis of Freight Movements to Inform Local and Regional Food Issues by Michelle Miller and Megan Konar.¹ This research and analysis received funding from USDA’s Agricultural Marketing Service (AMS) through cooperative agreement number 20-TMTSD-WI-0012. The opinions and conclusions expressed are the authors’ and do not necessarily reflect the views of USDA or the Agricultural Marketing Service. The full report is available online at: https://minds.wisconsin.edu/bitstream/handle/1793/84167/submittedUSDA%20report_final.pdf?sequence=6&isAllowed=y.

WHAT IS THE ISSUE?

Perishable foods—such as meat and dairy products—tend to be nutritious and essential to a [healthy diet](#). They also have high economic value in the U.S. food system. However, perishability means they are costly to transport because they have limited shelf-life and special handling requirements (e.g., require refrigeration). Disruptions—both natural (e.g., flood, earthquake) and humanmade (e.g., change in consumer demand)—have changed cold chain networks, which supply perishable foods to consumers.²

Even though perishable foods move largely by refrigerated trucks, no study before this one has analyzed how perishable products flow through supply chains by refrigerated trucks. This study fills that gap by breaking down publicly available data to the county level, revealing how specific, high-value, cold-chain-dependent foods flow across the continental United States.

To capture a more detailed picture of the cold-chain networks, the research identified “core counties,” which move high volumes of perishable food. Core counties contain and/or have easy access to cold chain infrastructure and

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² Cold chain food flows refer to the temperature-controlled delivery of food products from producer to end consumer by refrigerated trucks. (Badia-Melis et al 2018).

disproportionately bear the weight of food distribution. These core counties are likely tied to large processing plants, private distribution warehouse centers, and vertically integrated wholesale and retail markets. All of these elements are linked by the interstate transportation system and vulnerable to disruptions. Likewise, the research identified peripheral counties which are in the bottom 10 percent of counties in terms of their access to cold chain infrastructure.

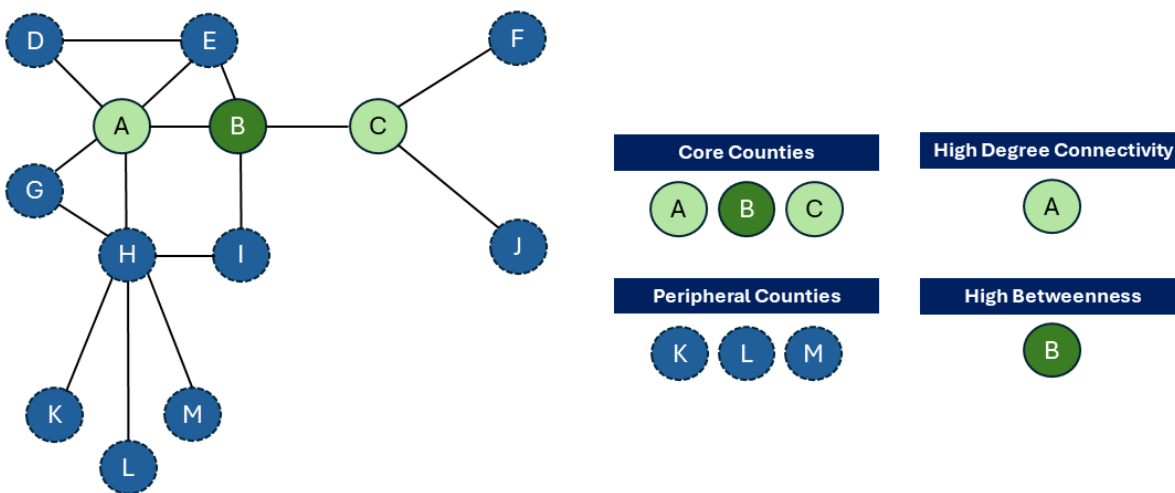
By analyzing networks critical to transporting perishable food, this research seeks to understand supply chain vulnerabilities and regional capacity to adapt. A growing understanding of cold-chain networks can help illuminate the unique transportation and infrastructure needs for perishable products, as well as locate bottlenecks in the cold-chain transportation infrastructure (e.g., refrigerated trucks, warehouses, electric charging stations). Ultimately, developing a more comprehensive understanding will help stabilize and strengthen these networks.

HOW WAS THE STUDY CONDUCTED?

The researchers graphed network relationships between all continental U.S. counties to reveal the national cold-chain networks and identify counties critical to cold-chain food movements. Using 2017 Commodity Flow Survey data, the researchers mapped refrigerated commodity flows for two high-level commodity groupings under the Standard Classification of Transported Good (SCTG) categories of perishable meat and perishable prepared foods such as ice cream, butter, and other dairy; frozen, canned, and fresh (processed) fruits and vegetables; etc. Because these two SCTG categories move largely by truck, the research provided an approximation of intra-continental U.S. refrigerated truck movements. (This approach departed from earlier studies, which did not segregate by commodity grouping or perishability.) The researchers then created a local and regional map of cold-chain networks to identify opportunities for regional market development—for example, in peripheral communities both rural and urban, where necessary infrastructure improvements could improve food flow to these areas.

To assess the quality of cold-chain networks, the researchers looked at “outlier counties”—the places that are most central (top 10 percent) and least central (bottom 10 percent) to the overall structure of cold-chain networks. To measure the extent to which particular counties are central, the researchers analyzed “centrality” at the county, State, and regional levels. One measure of centrality—the “degree of connectivity”—considers the number of counties each county is connected to. (Counties with many connections have high degree connectivity.) Another measure of centrality—“betweenness”—considers how many other counties depend on a particular county for their connection to a cold-chain network. Counties on which many other counties depend have high levels of betweenness. These counties are points of critical connection (e.g., because of a link to a critical road, bridge, or interstate highway) (fig. 1).

Figure 1: Key Centrality Concepts



Note: Figure 1 illustrates the key centrality concepts. In figure 1, each circle represents a county. A, B and C are core counties, that is they are core to the supply network. Among the core counties, County A has high degree connectivity as it has more connections than counties B and C. However, county B has higher betweenness connectivity as it lies between counties A and C. Counties K, L, and M are on the periphery.

WHAT DID THE STUDY FIND?

Meat and Perishable Prepared Foods Networks Show Similar Patterns, With a Key Difference. Patterns of geographic concentration are similar between meat and prepared foods networks. Notably, however, these two types of cold chain networks differ in their number of core counties. Meat cold chains have many more core counties than do cold chains for perishable processed foods. This finding suggests meat supply networks (which transport from processing to retail sales) are more geographically concentrated than are perishable prepared foods networks (which transport from farm to retail). For meat supply networks, there are 17 core counties—particularly, counties in Southern California and Chicago. Of these core counties, five southern California counties rank in the top seven. For perishable prepared foods networks, five Chicago area core counties and two California core counties (ranked one and two) dominate. Of most concern are five Southern California counties that together dominate distribution of both meat and perishable prepared foods. Disruption in these counties would quickly disrupt national food supply networks upstream and downstream.

Supply Networks for Meat Are Weaker Than for Processed Foods at the State Level. With regard to meat supply chains, at the State level, 18 States have some counties that are core. Also, with regard to meat supply chains, three States have especially large shares of core counties. Core counties comprise 73 percent of Arkansas’s counties (because of highly concentrated chicken processing); 60 percent of Nebraska’s counties (because of beef processing); and 35 percent of North Carolina’s counties (because of pork processing). Twenty-one States have at least some counties in the bottom 10 percent of network centrality scores—i.e., “peripheral” counties. Of those 21, 14 States have more than 20 percent of their counties that are peripheral. Some of these 14 States have significant metro regions. However, several—Arizona, New Mexico, Oregon, North Dakota and South Dakota—are predominantly rural and have significant agricultural receipts from animal production. Farmers in these States may rely on distant processing facilities in other States and pay to ship livestock from their farms.

Perishable prepared food networks are considerably less geographically concentrated. Thirty-two States have counties strongly connected to supply networks, and in nine States, more than 20 percent of counties are core. Perishable prepared food networks also have fewer peripheral counties than meat networks have. Overall, 16 States have at least some peripheral counties, and for 7 of those, more than 20 percent of counties are peripheral.

Some States Exhibit Both High and Low Centrality. Some States have counties with uneven connections to the supply network, having a mix of both core and peripheral counties. For meat, these are Michigan, Oklahoma, Pennsylvania, Texas, and Washington. Michigan has many more peripheral than core counties (43 percent peripheral, 12 percent core), while Texas has more core than peripheral (19 percent core, 5 percent peripheral). These findings suggest that—while meat moves well through some parts of the State—other parts are not well-linked to the flow.

For perishable prepared foods—despite Arizona’s status as a Fruitful Rim State—13 percent of Arizona counties rank as core, but 60 percent of Arizona counties are peripheral.³ Similarly, in the same category (processed foods), despite Texas’s Fruitful Rim status, 11 percent of Texas counties are core and 15 percent of its counties are peripheral. Other notable States with large disparities in these supply networks are Montana (2 percent core, 39 percent peripheral); Georgia (13 percent core, 35 percent peripheral); North Dakota (2 percent core, 25 percent peripheral); and Colorado (2 percent core, 20 percent peripheral).

Rural States Have Low Centrality. Low connection to the national distribution network, creates a challenge for farmers to access markets and for communities to access food. Arizona, Michigan, Montana, North Dakota, South Dakota, Texas, and West Virginia have high shares of counties that are peripheral for both the meat and perishable prepared foods categories. These regions contain “frontier and remote” (FAR) areas, with above-average Native American populations and rural poverty.⁴ For example, apart from West Virginia, all these States have more than 20 percent of acres that are rural and at least 10 percent remote (FAR designation 4)—with Montana, South Dakota, and North Dakota as the most rural and remote.⁵ Notably, some of these States are engaged in agricultural production (all of Montana, North Dakota, and South Dakota, and select counties in Arizona and Texas).

³ Largest share of large and very large family farms and nonfamily farms

⁴ USDA’s Economic Research Service (ERS) describes frontier and remote as a “territory characterized by some combination of low population size and high geographic remoteness. FAR areas are defined in relation to the time it takes to travel by car to the edges of nearby Urban Areas.” ERS has developed ZIP-code-level frontier and remote area (FAR) codes.

⁵ According to ERS, FAR designation 4 refers to “rural areas that are 15 minutes or more from an urban area of 2,500-9,999 people; 30 minutes or more from an urban area of 10,000-24,999 people; 45 minutes or more from an urban area of 25,000-49,999 people; and 60 minutes or more from an urban area of 50,000 or more people.”

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