Thinking in Terms of Supply Chains Rather Than Individual Markets

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Analysis of agri-food systems should recognize that modern systems benefit from high innovation rates. Multi-tiered supply chains commercialize innovations. The supply chains for innovation and the product supply chains are interdependent and co-evolving. We analyze the behavior of these supply chains using an example. Increasing investment in agricultural research and developing credit lines to implement agricultural innovation can increase the social benefit of the agri-food system.

The invention of baby carrots in 1987 helped increase per capita carrot consumption.

Photo Credit: Grimmway Farms.

Traditional societies had low rates of technological change and small, competitive farm operations that frequently traded directly with the consumer in fresh markets. However, especially over the last century, the agri-food supply system has transformed; it has high rates of technological innovation, a tiered structure with multiple stages leading from the farm to the consumer, large organizations, and substantial market power.

This paper presents the results of a growing body of research analyzing the changing structure and performance of agri-food systems. It emphasizes the importance of the innovation supply chain, which translates innovative ideas into practical plans for new products or services, and the product supply chain, which implements these innovations. Product and innovation supply chains are symbiotic since they co-evolve and are interdependent. The synergy between innovation and improved products gives California agriculture its dynamism and edge. We will first analyze the basic components of the innovation supply chain, then the product supply chain, their interaction, and some of the policy implications recognizing their importance.

Innovation Supply Chains

Innovation is a new way of doing things that may be embodied in a product or a service. In the innovation supply chain, an idea or research discovery is the upstream part of the chain, development is midstream, and scaling the idea or discovery up to a commercial product or service is downstream on the chain. Innovation starts with an idea and new knowledge, and there are different paths through which an idea can travel into an implementable innovation.

The first type of innovation supply chain is found in the educational-industrial complex, where university researchers or a private company (possibly a startup) develop or upscale discoveries from the university or a research institute into viable products or services. Many pest-control methods, nutritional strategies, or genetic materials are developed this way. The classic example is the evolution of ammonia for fertilizer. University professor Fritz Haber discovered the process of producing ammonia from nitrogen in the air. Carl Bosch, who worked for BASF (still the largest chemical company in the world), developed it into a commercial process.

The second type of innovation supply chain stems from recombinant innovation. Recombinant innovation arises when techniques and knowledge from multiple fields are modified and expanded to create a new product. Henry Ford utilized existing technologies, including the assembly line, to revolutionize the automobile industry. Agribusiness has often taken advantage of innovations developed for other industries, such as the automobile industry (e.g., internal combustion engines in tractors) and the mineral industry (e.g., drilling or piping for irrigation systems).

A third type of innovation supply chain is associated with relentless innovations. Companies have research programs to improve existing technologies. Product development is a constant process of continuous performance improvement. For example, automobile fuel efficiency, crop fertilizer efficiency, and irrigation efficiency have all increased over time due to relentless innovations. Product improvement is crucial for an organization's long-term survival; therefore, they develop research and development (R&D) units.

Product Supply Chains

Product supply chains may have multiple tiers. Suppliers of inputs into agricultural production (e.g., fertilizers, chemicals, or irrigation equipment) are upstream in agri-food

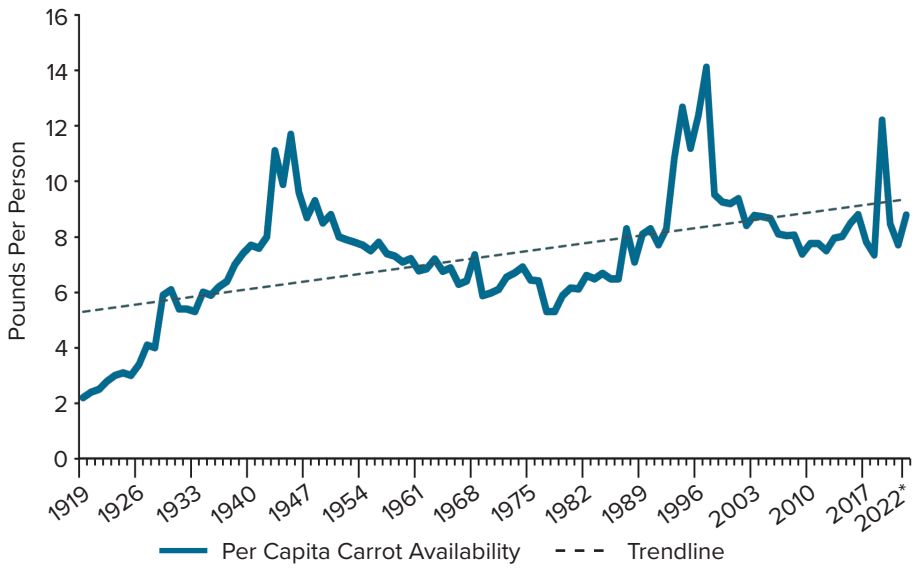
production. The farming sector is midstream, and it provides the intermediary input for food products, which are then transmitted downstream to processors, followed by distributors and retailers.

There are several avenues through which a new product may be introduced, and agricultural product innovations may be introduced in multiple ways. For example, during the European colonization of the United States, immigrating farmers brought seeds or genetic material from their own countries and started growing their crops on new land. In other cases, Cooperative Extension identified new crops and informed farmers about how to grow them, and together the farmers established cooperatives to produce, process, and market the new products.

This process has changed recently. Now, intermediaries may identify a new product, establish processing facilities to produce the final product and work up and downstream to obtain intermediary inputs (crops), distributors, and retailers. For example, Mike Yurosek, a California farmer, invented baby carrots (larger carrots cut into smaller snackable chunks) as a snack product in 1987. He developed this initial technology after experiencing frustration wasting large percentages of his carrot crop that were deemed too unattractive for the market (thereby discovering the potential of "ugly" produce). After he developed the initial technology to produce baby carrots, demand quickly increased, and another farming family, the Grimm brothers—who established Grimmway—improved the technology to scale up production. In 1995, they bought Yurosek's farm, and the product took off.

The headquarters of Grimmway, and its large production facility, are located in Kern County, where Grimmway farms 45,000 acres of carrots. The company improved the process of converting standard carrots into baby carrots.

Figure 1. U.S. Fresh Carrot Availability Per Capita Between 1919 and 2022, USDA



Source: USDA, Economic Research Service calculations using USDA, National Agricultural Statistics Service and U.S. Department of Commerce, Bureau of the Census data.

Note: *Indicates forecasted per capita carrot availability.

Over time, it expanded processing and production facilities to five other regions in the United States, and now Grimmway exports carrots globally. It also developed the capacity to produce other products, eventually becoming one of the largest organic farms in the United States.

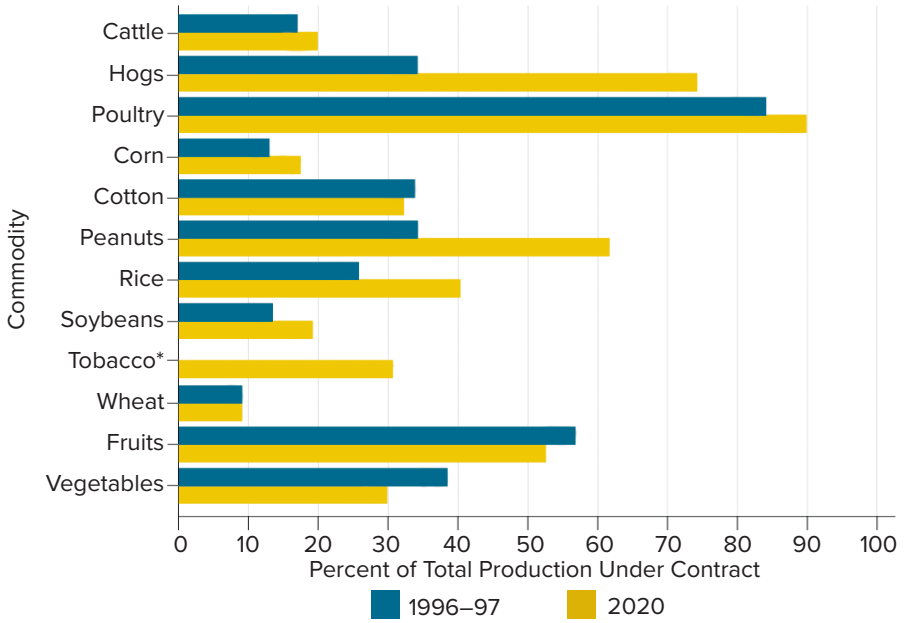
As Figure 1 shows, the consumption of carrots has increased slightly over time. In 1997, carrot consumption per capita peaked and somewhat declined afterward. Seventy percent of the carrots sold now are baby carrots. One reason for the adjustment after 1997 is the increased input use efficiency in transforming standard carrots into baby carrots. The story of baby carrots is a story of the transition from an innovation to the product supply chain. It is also the story of the symbiotic relationship between the two supply chains since the producer of the carrots developed an R&D system to innovate and improve the product and its production.

In designing a product supply chain, the entrepreneur must project the demand for the product over time and develop a strategy to maximize the expected discounted profit (the sum of future forecasted profits valued in current dollars). The businessperson must determine how much to produce in each period, how to divide the output among different categories, how much to make (in-house), and how much to buy from markets or through contracts. Figure 2 (on page 6) shows that most poultry and hogs are produced under contract, about 35% of vegetables are produced under contract, and more than 50% of fruits are produced under contract. As agricultural products become more differentiated and input specifications become more detailed, the contracting share tends to rise.

Dynamics and Constraints of Supply Chain Development

Entrepreneurs need to account for several factors in designing strategies to develop supply chains. They include increased productivity dynamics, location and consumer heterogeneity, competition, credit constraints, and random events. There is a significant body of evidence of increased productivity over time, both in crop production and in processing, reflect-

Figure 2. The Value of U.S. Farm Production Under Contract Changed for Many Commodities From 1996–1997 to 2020



Source: USDA, Economic Research Service and National Agricultural Statistics Service, Agricultural Resrouce Management Survey, 1996, 1997, and 2020.

Note: Includes the value of production under marketing and production contracts combined. An average of 1996 and 1997 values was used to provide a more statistically reliable estimate. *No tobacco production was covered by contracts in 1996–1997.

ing improved varieties and techniques and "learning by doing." The productivity of the farm sector in the United States has increased annually by about 1.5% over the last 30 years.

Learning by doing refers to the tendency for productivity to increase over time as industries mature, driving down per unit costs. For example, the cost of processing ethanol was reduced by 50% over 20 years in the United States after the sector expanded. Firms expect this cost reduction and recognize that these lower costs allow them to increase production, reduce prices, and grow.

In the early life of a new product, companies tend to produce in the most favorable location, considering both production costs and targeting customers with the highest willingness to pay. These tendencies lead to a gradual diffusion of products over consumer segments and areas. The learning during the early period first allows for cost reduction and the development of improved outcomes, and then the expansion of product sales and even production in new regions. The decision to expand considers profitability potential and considers transportation and product adaptation costs. As production capacity increases, firms may develop products differentiated by quality, size, and ingredients. The baby carrot was initially produced for the California market in Kern County, then production expanded to Washington, Colorado, and Florida, and finally, the product was exported overseas.

Market Power

Firms that create a supply chain to introduce a new product or service tend to have market power in input and output markets, which may lead to extra profits. However, the extra profitability leads to new entrants, extending product availability to consumers and reducing the original firm's market power. Over time, an innovation may result in an industry with several competing companies with unique characteristics and brand- or product-specific market power. Still, competition between them will push prices down and expand the supply. For example, Fresh Express was an early leader in the production of salad kits, and today at least 10 companies operate in this market. Policies or practices that restrict the entry of new firms and maintain the market power of the incumbent company tend to reduce the overall economic well-being of consumers and producers, measured in monetary terms.

The key element of supply chain expansion is apparent from the cases of restaurant chains, as they are an important component of the agri-food sector. Most restaurant chains are controlled by an intermediary that buys raw materials from suppliers in the farm sector, processes the product, provides directions for cooking, and distributes it to the final retailers. In the case of fast food, chains may buy in the market or contract out for inputs like potatoes or meat, but may produce some inputs themselves.

McDonald's started with a few restaurants in California and the Midwest, where it refined the product. That led to an expansion within the United States, followed by an extension globally. The company must continue to develop its products to improve production, processing costs, and the product line, and to consider changes in consumer taste and production technologies.

Furthermore, McDonald's has to consider competition from other fast food chains and increase its efficiency while improving its product over time. Entering a new market, especially outside the United States, requires finding local markets and modifying products to specific locations, assuring high-quality and affordable supply. Thus, large agri-food firms that control large agricultural supply chains

tend to maintain internal R&D strategies, work with universities and other research institutes to develop new technologies, and may take over start-ups or other companies that enable technological innovation, improve access to markets, and enhance profitability.

Credit Availability

Credit availability is a significant constraint on the supply chain. Plans to develop new agricultural products or supply chains are uncertain and seem risky to lenders. Thus, one reason innovators must start small is the lack of credit. Frequently, they rely on their own resources to finance new enterprises. So, when a farm owner wants to develop a processed-product supply chain—as in the case of Mike Yurosek—they can borrow by mortgaging their land.

Once success is apparent, new funding sources often become available, including commercial banks and different forms of financial instruments. However, credit constraints may affect the structure of a supply chain. Large livestock processors like Tyson rely on contract growers to raise the chicks the company provides because investments in real estate and facilities to feed and raise chickens are very expensive. Tyson had the choice to invest in chicken houses or processing facilities and decided to specialize in processing.

Indeed, the broiler sector exemplifies the symbiosis between innovation and product supply chains. Growing chickens for meat started in 1930 in Delaware and Georgia. Public research improved breeding and diet practices, increasing broiler chickens' feed-conversion efficiency and reducing the growing period.

Tyson began as the shipper of chicks from Arkansas to the Midwest, added shipping grains to Arkansas, and provided high-quality genetic materials and grain to contract growers. The company expanded its output from whole chickens to chicken parts and premade meals. Its market grew globally and expanded to processing other meats. While Tyson has significant market power, especially regarding contract growers, other entrants to the industry reduced the power of this leading firm. Furthermore, other large processors that follow a similar approach to Tyson emerged worldwide, including JBS in Brazil, CP Group in Thailand, and Dooyoo Group and Sunner Development Co. in China.

Resilience to Shocks

The operations of an agri-food supply chain are subject to weather shocks that affect yields and transportation, economic fluctuations that affect consumer demand and the cost of supplies, disasters like tsunamis and earthquakes, and pandemics. The design and operation of supply chains must have resilience that will allow adjustment to shocks.

Several mechanisms are used to enhance resilience. One includes various insurance mechanisms. Crop insurance protects firms against low-yield risk. Future markets stabilize prices and protect against low prices. A second mechanism is maintaining inventory to address supply chain fluctuations, mainly in terms of yield. Inventory accumulates during periods of abundance and is used during shortages. However, maintaining inventory is costly, and optimizing inventory is a major challenge to supply chain management.

Diversification is a third avenue to address shocks. Having several lines of activity and engaging with multiple suppliers in markets not subject to similar risks increases the capacity to overcome shocks. Sound infrastructure, including roads, communication systems, and well-designed facilities, can also improve resilience.

The critical element for resilience is adaptability: the ability to modify supply chain design and pivot to alternative solutions. The response to the COVID-19 pandemic demonstrated the importance of pivoting. Social distancing led to consumers' reluctance to go to stores and eat in restaurants. In response, food delivery services like Doordash and Uber Eats expanded their operations, and grocery retailers expanded their use of computers and automation. That led to new online shopping opportunities with curb pick-up and home delivery services. Some food processors developed software to sell directly to consumers. Restaurants shifted to takeout. Before the pandemic, the share of online restaurant delivery was 9%; it has risen to 13% in 2020 and is predicted to rise to 25% by 2025.

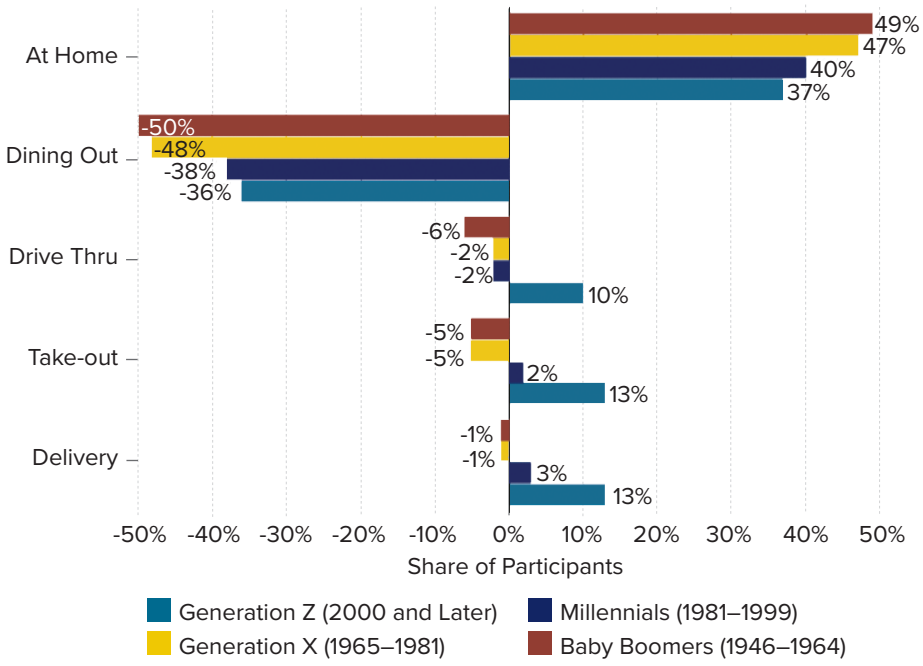
As shown in Figure 3 on page 8, eating habits have changed in response to the pandemic. The older generation, Baby Boomers, have replaced eating at restaurants with eating at home. Generation Z, the more computer-literate, younger population, has replaced restaurant dining with takeout, drive-thrus, and increased reliance on home delivery.

The agricultural and food supply chain has become more heavily digitized and better linked, and the changes during the pandemic will continue since the investment has been made. These new adaptations can pay for themselves.

Conclusion

We live in an era of fast change and specialization in agriculture. New technologies are introduced, and new supply chains are implemented. The supply chains are synergistic and evolving, adapting to economic and biophysical changes, and taking advantage of new technologies and regulations. The traditional competitive farm model needs to be expanded

Figure 3. Net Change in Food Purchases Due to COVID-19 in the United States in 2020, by Generation



Source: YouGov © Statista 2022.

to include activities beyond the farmgate in order to be more representative of the realities of modern agri-food systems. We need to better understand and analyze the processes that drive agricultural innovation and new organizational design in order to develop better policies and be better prepared for the future.

The implementation of innovations leads to the emergence of new supply chains and firms with market power that may harm consumers and suppliers. Some of the profits are associated with market power and the rewards for risk-taking and creativity. However, stagnation of industries that would prevent market entry and slow technological change may lead to excessive market power.

Therefore, it is important to develop policies that allow the agri-food sector to reinvent itself and address challenges emerging over time. Such policies should enhance rather than deter innovation, support new entrants in the market, and promote continuous investment in research and education.

Research discoveries, new skills, human capital developed in universities, and innovations can modify industry production activities and structure. Credit availability, especially for the initial stages of innovation and product development, is another crucial component for the emergence of new innovative supply chains. In some cases, government support for innovative efforts to enhance social objectives, like those addressing climate change and food security, may also be valuable. Welfare maximizing regulatory policies should seek to enhance safety, but not deter innovations, since regulatory delays frequently harm innovative activities.

Finally, there is a role for antitrust policies that identify and prevent activities that aim to reduce innovation and maintain excessive market power. As economists, we are challenged to develop the analytical tools to provide the foundation for such policies.

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The findings and conclusions in this paper are those of the authors and should not be construed to represent any official USDA or U.S. Government determination or policy.

For additional information, the authors recommend:

Zilberman, David, Thomas Reardon, Jed Silver, Liang Lu, and Amir Heiman. 2022. "From the Laboratory to the Consumer: Innovation, Supply Chain, and Adoption With Applications to Natural Resources." *Proceedings of the National Academy of Sciences* 119(23): e2115880119. Available at: https://bit.ly/3AdFsLY.

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