

**SUPPLY CHAIN DESIGN FOR HIGH QUALITY PRODUCTS:
ECONOMIC CONCEPTS AND EXAMPLES
FROM THE UNITED STATES**

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ABSTRACT

The food system is undergoing significant structural change at local, national, and international levels. As the food system evolves, some segments along the chain between producers and consumers are disappearing. Others are being transformed. Supply chain concepts are useful for identifying and assessing alternative designs for the reconfiguration of food product production systems. Changes in the food system will require farm managers to adopt new ways of thinking and new perspectives on collaboration with trading partners. They also will require farm management economists to draw on a wider set of economic theories and concepts than we have in the past. This paper begins with brief descriptions of emerging supply chains for high quality food products in the U.S.: (i) a branded product chain, (ii) a genetics-based chain, and (iii) a production-practice based chain. These illustrate the variety of emerging supply chain structures and the challenges firms face in designing new supply chains. The next section presents an overview of key elements of four theoretical frameworks that are helpful in supply chain analysis and design: (i) transaction cost economics, (ii) agency theory, (iii) property rights theory, and (iv) the resource based view of the firm. Concepts from these theories are used to explain structural differences in the three illustrative cases. Looking to the future, key challenges include improving system-wide efficiency through information sharing and logistics management, promoting transparency and trust among trading partners, and designing incentive systems that ensure an equitable distribution of costs and returns.

The food system is undergoing significant structural change at local, national, and international levels. New products, new business practices, and new relationships among trading partners are noteworthy indicators of this change. Biotechnology, information technology, and globalization are among the most important forces driving it.

The U.S. food system experienced an equally dramatic transformation in the late nineteenth and early twentieth centuries. Business historian Alfred D. Chandler (1977) argues in *The Visible Hand* that the revolution in transportation and communications initiated by the development of railroad, telegraph, and telephone systems led to radically new production and distribution systems in many sectors of the U.S. economy, including the food

sector. Mass production and distribution systems emerged in tandem as new manufacturing and logistics systems were developed. Food processing and packaging technologies were the basis for the development of national and international brands and for the emergence of food retailing chains.

Concurrently, linkages between farmers and consumers weakened, since it was processing and distribution that gave food products their brand identity, and farmers' share of the consumer's food dollar began a decline that has continued to the present.

At the start of the twenty-first century, concerns about food safety and quality are motivating consumers to seek closer connections with farmers. At the same time, biotechnology and information technology make it easier for food manufacturers and retailers to substitute primary product attributes for processing of agricultural commodities. Locally, these changes are fostering an increase in direct marketing through on-farm shops, roadside stands, and farmers markets. Regionally and nationally, there is rapidly growing demand for natural and organic food products and for "functional foods" with special health attributes. Often, these new branded foods based on agricultural product attributes are offered by the same food processing firms that played a key role in the "old" food system. Internationally, concerns over genetically modified organisms and BSE are having profound impacts on trade of food and feed grains and livestock products. At the same time, global markets for products with a strong local identity – e.g., Protected Denomination of Origin products from the EU – are expanding rapidly, as is international trade of high quality fruits and vegetables to ensure a year-round supply.

As the food system evolves, some segments along the chain between producers and consumers are disappearing. Others are being transformed. Supply chain concepts are useful for identifying and assessing alternative designs for the reconfiguration of food product production systems. A supply chain is a linked set of value creating activities encompassing product design, input procurement, primary production and processing, marketing, distribution, and service. Supply chain thinking emphasizes the importance of viewing a chain as a unified system. Key concerns include questions about how to achieve: efficient investment and operating decisions across all

segments, equitable distribution of returns and costs among trading partners, product quality and safety, and innovation.

Changes in the food system will require farm managers to adopt new ways of thinking and new perspectives on collaboration with trading partners. They also will require farm management economists to draw on a wider set of economic theories and concepts than we have in the past. The ultimate goal in this paper is to provide an overview of economic tools for expanding the scope of analyses of farm management problems in a supply chain context. The paper begins, however, with brief descriptions of emerging supply chains for high quality food products in the U.S., since the usefulness of new concepts is best assessed in terms of their ability to explain real phenomena. The second section of the paper introduces key elements of four theoretical frameworks that are helpful in designing and evaluating such supply chains: (i) transaction cost economics, (ii) agency theory, (iii) property rights theory, and (iv) the resource based view of the firm. The concluding section looks ahead to some of the challenges and opportunities farmers will face in adapting to change in the food system.

EXAMPLES OF EMERGING FOOD PRODUCT SUPPLY CHAINS IN THE U.S.

There is great diversity in the structure of emerging supply chains for food products. In this section, we briefly describe supply chains for (1) a branded product, (2) a genetics-based product, and (3) a production practice-based product.¹ One of the key drivers of supply chain structure is the locus and strength of chain leadership, and leadership rests in a different segment for each of these chains. This affects overall chain structure, product and information flows, and the distribution of returns and costs.

A Branded Product Chain – Sourcing Wheat for Wheaties Breakfast Cereal²

Wheaties is a popular breakfast cereal made from whole wheat. It has been manufactured by General Mills since 1921. Until recently, General Mills procured wheat for Wheaties in traditional commodity markets. However, company researchers discovered that cereal flakes made from particular wheat varieties are more curly, crispy, and resistant to breakage than flakes made

with other varieties, and cereal made with the special varieties is consistently preferred in consumer taste tests. As a result, General Mills decided to use only these special varieties, and the company has developed a supply chain to ensure an adequate supply of identity preserved wheat to its manufacturing plants.

The Wheaties supply chain has five technologically separable segments prior to the cereal plant: seed production, seed distribution, farm production, assembly and storage, and transportation. General Mills, the chain leader, controls all of these except farm production through elevators it owns in Idaho. Through these elevators, General Mills contracts with farmers for production of identity preserved wheat, paying premiums ranging from \$0.05 to \$0.25 per bushel. It is difficult to quantify the added value created through identity preservation, because General Mills does not even convey information about the use of special wheat varieties to consumers, but nearly all the benefits and costs for the system accrue to General Mills. With the tight control afforded by vertical integration, General Mills manages information flows and the logistics of product flows to manufacturing plants. The system also helps minimize monitoring and testing costs, since there is little incentive for elevators to misrepresent product quality when they are wholly owned subsidiaries. Finally, the high degree of vertical integration both helps and hinders innovation. On the one hand, General Mills can quickly change to a new variety and can use the system to source identity preserved grains for other branded products. On the other hand, the investment in elevators in a single region make it more difficult to shift production elsewhere.

A Genetics-Based Chain – LoSatSoy™ Oil³

Over the past decade seed companies have placed increased emphasis on developing varieties with traits well suited for special purposes. The low palmitic-acid soybean, developed at Iowa State University using traditional breeding methods and commercialized by Pioneer Hi-Bred International under a license agreement is an example of such a variety. LoSatSoy™ cooking oil produced with low saturate soybeans has a low level of saturated fat, comparable to that in canola oil (Iowa State University Office of Biotechnology, 1997). LoSatSoy™ oil sells for a retail price premium relative

to standard soybean oil that translates into a premium of approximately \$2.21 per bushel of soybeans.

The DuPont Company, which owns Pioneer Hi-Bred, faces two difficult challenges in commercializing varieties like low saturate soybeans. First, varieties with special traits have added value only if varietal integrity is maintained during farm production and as the product moves from the farm to the manufacturer. Second, while seed companies operate at the upstream end of the supply chain, the added value for these products is not realized until they reach downstream users. Both identity preservation and value capture are difficult when ownership changes hands several times as they move through the supply chain. Working through Pioneer Hi-Bred and two other subsidiaries – Optimum Quality Grains, L.L.C. (OQG) and Protein Technologies International (PTI) – DuPont has developed an innovative supply chain that helps address these challenges.

OQG coordinates the upstream segments of the chain (seed production and distribution through farm production and assembly and transportation) through an Internet-based contracting system called OSCAR™ that allows farmers to identify nearby elevators that are offering contracts for identity preserved products. Low saturate soybean seeds are only sold to farmers who have contracted through this system. The contracts stipulate production practices that ensure varietal integrity and require farmers to deliver all their production to the contracting elevator. In return, farmers receive a premium of \$0.25 over the local price for commodity soybeans. Contracting elevators, not OQG, purchase the low saturate soybeans from the farmers. OQG reimburses the elevators for the identity preservation premium paid to farmers, pays the elevators a small fee for segregating the low saturate soybeans during storage, and directs elevators to ship the identity preserved soybeans to a crushing plant when they are needed.

PTI coordinates the downstream segments of the chain (crushing, refining, and distribution to retail channels) and works with retail customers to promote demand for LoSatSoy™ oil. PTI contracts with a crushing plant and a refining plant to maintain identity preservation of the product as it is processed, but PTI never actually owns the soybeans or the oil derived from

them. Rather, PTI pays small quantity-based premiums to the crusher and refiner and then charges a royalty fee to the refiner for each unit of LoSatSoy™ oil it sells.

The LoSatSoy™ oil supply chain brings many independent actors together in a well integrated identity preserved system. Working through its subsidiaries, DuPont gathers valuable information on end-user demand, projected seed requirements for the next growing season, and the spatial pattern of production and stocks. At the same time, DuPont captures a large share of the added value in the chain by effectively negotiating premiums received by farmers, elevator and crusher handling fees, and royalties received by the refiner, while never actually taking title to the low saturate soybeans or the products derived from them. The chain is highly adaptable, since the contracting elevators, crusher, and refiner can be changed from year to year. Also, this same basic structure has been used by DuPont to create identity preserved supply chains for other genetics-based products.

A Production-Practice Based Chain – Whole Farm Cooperative⁴

Small farmers who use sustainable practices use a variety of approaches to develop stronger direct linkages to consumers and capture a greater share of food expenditures. These include direct marketing through farmers markets or roadside stands and community supported agriculture arrangements in which consumers pay a significant advance fee in order to receive weekly deliveries of in-season produce through the growing season. One of the most interesting and unique approaches is that developed by Whole Farm Cooperative, a group of sustainable producers based in Long Prairie, a small town in western Minnesota.

This group formed in 1996, with the original objective of selling meat products to local colleges for dormitory food service operations. After months of trying to arrange this, however, they realized that institutions' contracts with large food service firms would not allow significant purchases of food products from outside vendors. With their market opportunity gone, one member of the group began sending a product price list by email to potential customers in the Minneapolis-St. Paul metropolitan area. The response was favorable, and cooperative members now make several trips to the city each

month to deliver product to “drop points” at churches or customer homes where customers pick up their orders. The cooperative also sells through several small independent grocery stores that have agreed to carry their products.

Whole Farm Cooperative offers a wide range of meat, dairy, produce, bakery, and craft items under a common label. Committees have developed minimum production standards for each product group, but the producer’s name is also stamped on most product labels. Customers can go to the cooperative’s web site (<http://www.alexweb.net/wholefarmcoop/index.html>) to read farmer profiles, and customers can request that their orders be filled with products from specified producers. Sales grew from approximately \$25,000 in 1998 to over \$200,000 in 1999, and there was continued growth in 2000. In addition to serving customers in the Minneapolis-St. Paul area, the cooperative is increasing its sales to consumers in the Long Prairie area.

The supply chain developed by the Whole Farm Cooperative uses information technology and personal contact to establish a strong, direct link between producers and consumers. By working together, producers realize economies of size in processing and storage, product promotion, order taking, and transportation. They have reached a significant customer base without going through chain intermediaries. Now they have grown to the point where they will be hiring a manager, and they are striving for continuous improvement in product quality and consistency.

CONCEPTUAL TOOLS FOR SUPPLY CHAIN ANALYSIS AND DESIGN

Production economics has been the foundation for farm management research and teaching since the late 1940s (Jensen, 1977). The focus is on technical and allocative efficiency for firms that operate in perfectly competitive markets. As we look toward the emerging food system, with greater emphasis placed on coordination across firm boundaries in the production and distribution of more differentiated products, we need to draw on a broader set of economic concepts and theories. The rapidly growing literature on the economics of business organization is especially relevant for

farm management in this new setting. In this section, we present brief overviews of four important theoretical frameworks from this literature: transaction cost economics, agency theory, property rights theory, and the resource based theory of the firm.⁵

Transaction Cost Economics

Transaction cost economics (TCE) draws on the fundamental insight from Coase (1937) that there are costs associated with using markets to coordinate linkages between technologically separable segments of a production process. More fully developed by Williamson (1975, 1990), TCE focuses on the structure of economic relationships governing these linkages, ranging along a continuum for competitive markets to vertical integration. Factors affecting the choice of governance structures include the frequency of transactions, the level of uncertainty inherent in them, and the presence of asset specificity. Asset specificity refers to the fact that investments in specialized physical or human capital or choice of a location for assets that are difficult to move may be necessary to establish an efficient linkage between segments but may also fundamentally alter bargaining power between segments if they are controlled by separate firms.

TCE helps explain some of the differences in the three supply chains described earlier. For example, in procuring wheat for Wheaties, General Mills reduces transaction costs by having vertically integrated upstream to own grain elevators. Information about projected annual needs and short term shipments to manufacturing plants can flow quickly and confidentially, and the need for laboratory checks to ensure varietal integrity is minimized. The design of the LoSatSoy™ chain is novel because it allows DuPont's subsidiaries to control product and information flows across several firm boundaries without ever actually owning the product or making major investments in location and product specific assets for grain assembly, storage, and processing. Furthermore, this chain allows participants to use the highly efficient price discovery and risk management tools of commodity markets as the low saturate soybeans move through the chain. To gain these benefits, though, DuPont incurs significant costs for testing product integrity each time ownership changes and has made significant investments in the transaction

technology embodied in the OSCAR™ system. Finally, Whole Farm Cooperative uses the Internet as a tool for linking directly to a large number of geographically dispersed customers, bypassing traditional wholesale and retail systems that usually intermediate between farmers and consumers. By integrating horizontally in a cooperative, individual farmers share the fixed costs of establishing this system. It is also important to note that the members of Whole Farm Cooperative incur significant costs by integrating downstream into retail distribution and marketing. They cannot achieve the efficiency of large scale wholesale and retail operations in moving products to consumers.

TCE provides several useful insights for those considering the design of or affiliation with a new supply chains. First, it encourages the development of business relationships and information systems that help minimize transaction costs. Second, it encourages explicit consideration of tradeoffs between maximizing technical efficiency and minimizing transaction costs across the entire supply chain. Finally, TCE encourages chain participants to think through the implications of fundamental changes in bargaining power that occur after asset specific investments are made.

Agency Theory

Agency theory focuses on situations where two or more individuals with conflicting objectives contribute to a production process. Normative principal-agent models (Ross, 1973); Stiglitz, 1974, 1975; Holmström, 1979) are concerned with the design of incentive systems that help align the interests of employees (agent) with employers (principals) when it is difficult to monitor and measure effort. Team production adds to the complexity of agency relationships (Alchian and Demsetz, 1972). Optimal incentive schemes usually involve some monitoring of output or effort and a link between measurable performance and the agent's compensation. When there is uncertainty in the production process, linking pay to performance can shift risk to the agent, leading to risk averse behavior that may not be in the best interest of the principal.

Insights from agency theory are clearly relevant to the problem of food product supply chain design and management, since the supply chain leader works with employees and/or independent trading partners to deliver a high

quality product as efficiently as possible. For example, the farmer contracts used in both the Wheaties and LoSatSoyTM supply chains call for sale of all production from a specified number of acres at the current commodity price plus a pre-set premium. This allows the supply chain leader to monitor production during the growing season and provides strong incentives for all production to be delivered rather than sold outside the chain. Both General Mills and DuPont also incur costs for laboratory testing to guarantee the varietal integrity of the product farmers deliver. Agency theory can also help explain the monitoring and compensation schemes used in downstream segments of both these chains.

Agency relationships are largely eliminated under the direct marketing approach used by Whole Farm Cooperative, but agency theory does help explain responses to team production problems arising from the fact that a large number of independently produced products are marketed under a single brand. Product committees enforce quality standards by not allowing substandard items to be sold through the cooperative, and the fact that customers can request a particular farmer as their supplier for a product provides added incentives for quality assurance. Finally, as the cooperative grows and uses a hired employee to manage operations and promote the Whole Farm Cooperative brand, new agency problems will emerge.

Agency models do not help explain who is or should be chain leader, since the identity of the principal is almost always established by prior assumption. Similarly, these models usually assume technology and institutions are fixed and so are not very useful for explaining adaptability to changing technology and market conditions. Regarding distribution of costs and returns across the chain, static agency models emphasize the adversarial relationship between principals and agents and predict that principals will drive compensation down as close to the reservation wage as possible, but reputation becomes a factor in dynamic models and so they can shed some insights on the importance of stable trading partner relationships and broader sharing of net benefits.

Property Rights Theory

Property rights theory is concerned with the question of who should own assets in settings where two or more technologically separable activities are

vertically linked and it is not possible to write and enforce contracts that specify the actions of all parties. This is similar to the stylized setting for agency theory, but property rights theory focuses on system-wide impacts of alternative asset ownership rather than on the design of incentive systems. In this respect, these two frameworks are complementary. Oliver Hart's (1995) recent book, *Firms, Contracts, and Financial Structure*, provides a good introduction to property rights theory. Earlier papers by Grossman and Hart (1986) and by Hart and Moore (1990) develop key ideas underlying this framework. Each focuses attention on tradeoffs associated with concentrating ownership (defined as residual rights of control) of relation-specific assets. The following are some general propositions derived by Hart and Moore (1990, pp. 1131-1139) and by Hart (1995, pp. 44-55):

- An agent should own an asset if this ownership does not affect investment incentives of other agents.
- An agent should own an asset if it has value only when she owns it.
- If a group of agents are needed to make investment in an asset productive, control should be governed by majority voting among the group.
- When assets are economically independent, independent ownership is better than integration.
- When assets are highly complementary, some form of integration is better than independent ownership.

These propositions help explain the case examples. In the LoSatSoy™ chain, DuPont owns the firms that are critical for varietal development and for the coordination of product and information flows needed to protect its intellectual property rights downstream through the chain. Given the design of this chain, farmland, grain elevators, and processing plants are economically independent and so are independently owned. In contrast, General Mills views its elevator system as complementary to its manufacturing plants (not only for Wheaties but also for other products) and so there is a high degree of vertical integration in its chain. Finally, the key asset of Whole Farm Cooperative is its brand, which is identified with small farmers using sustainable production practices and selling directly to

consumers. This brand identity can be achieved only by a group, and the cooperative form they have adopted calls for democratic control of this asset.

The primary contribution of property rights theory is in providing insights on who should be the chain leader. Most models in this framework have a simplistic treatment of distributional issues, quality assurance mechanisms, and responsiveness to technological and institutional change.

The Resource Based View of the Firm

The resource based view of the firm (RBV) focuses on acquisition and effective use of intangible assets – e.g., knowledge, unique skills, systems for learning, and brand image – as well as the tangible assets that emphasized in other theories. *The Theory of the Growth of the Firm* by Edith Penrose (1959) develops many key concepts in this framework. Prahalad and Hamel(1990), Mahoney (1992), and Langlois and Robertson (1995) provide more recent overviews. Still more recently, Gulati, Nohria, and Zaheer (2000) have extended the resource based perspective to networks, arguing that unique, inimitable knowledge and skills may reside in a network of firms, such as a supply chain, and may be a source of competitive advantage for the entire network or an impediment to systemic change that requires actions by several independent firms.

Work under the RBV is less formal analytically and less unified in key assumptions and methods than research associated with the other theories discussed here. However, the need to develop and exploit unique resources that are not easily imitated and the importance of organizational learning are common themes in the RBV literature – themes that shed light on the structure of at least two of the three supply chains described earlier. DuPont has structured the LoSatSoyTM oil supply chain to protect and enhance the value of its intellectual property. At the same time, this chain helps DuPont learn about market conditions in each segment of the supply chain, extending all the way to the retail level. The much less complex supply chain developed by Whole Farm Cooperative helps individual producers establish strong links with their consumers without incurring the high costs associated with other forms of direct marketing. This is accomplished through farmer profiles on the cooperative's web site and farmer names on each product sold. The use of

electronic communication also makes it easy for the cooperative to receive comments and suggestions from consumers. Finally, the product committees established within the cooperative strengthen positive network externalities and facilitate knowledge transfer among cooperative members.

A key contribution of the RBV is the insight that a supply chain can be viewed as a unique collection of resources that can give its participants sustainable competitive advantage. Often cooperation among trading partners within the chain or tight control by the chain leader is needed to fully exploit existing resources or respond to new opportunities. The RBV helps explain efficiency gains from effective supply chain design and helps analysts and participants identify forces that foster or inhibit innovation.

Concluding Remarks on Theoretical Frameworks

Each of the theoretical frameworks described in this section helps explain existing supply chain structures and provides insights for designing new chains. These theories start with different assumptions, emphasize different aspects of supply chain design and management, and sometimes yield conflicting predictions and prescriptions. However, they are also highly complementary, and it is valuable to approach supply chain problems from multiple perspectives. Finally, it is important to recognize that our knowledge of how to apply these theories in practical settings is still limited, though applied work is progressing rapidly.

OPPORTUNITIES AND CHALLENGES FOR FARM MANAGERS

Changes in the food system are making quality attributes based on farm production more important as food products move downstream toward consumers. In addition to focusing on the efficiency of their own operations, farm managers need to give increased attention to market-based and contractual relationships with trading partners and consumers. Theories presented here can be useful tools for analyzing and designing these relationships.

Looking to the future, all participants in the food system will need to continually emphasize improvements in system-wide efficiency and quality assurance. Improvements in product design, logistics, and information sharing will be key to these improvements, though efficiency gains in specific

segments will also be important. Designing supply chain structures that promote transparency and trust among trading partners will be another important challenge. Here farmers can learn much from efforts at the retail end of the supply chain (King, 1998). Finally, designing incentive systems that ensure equitable distribution of returns and costs among supply chain participants is likely to be one of the most difficult challenges. The renewed emphasis on quality attributes based on farm production creates an opportunity for farmers to regain a larger share of the consumer food dollar, but increasing concentration and market power in other segments may make it difficult to exploit this opportunity.

ENDNOTES

¹ See Venturini and King (in press) for descriptions of several other European food product supply chains.

² This supply chain description is based on presentations by and personal communication with Ronald D. Olson, Vice President Grain Operations, General Mills. It is a synopsis of a more complete description in Venturini and King (in press).

³ This supply chain description is based on personal communication with Robert E. Kennedy at Optimum Quality Grain and on information from Web sites for Optimum Quality Grains, L.L.C. (<http://oscar.dupontsg.com/>) and Protein Technologies International (<http://www.protein.com>). This is a synopsis of a more complete description in King (2000, pp. 2-6).

⁴ See King and DiGiacomo (2000, pp. 75-79) for a more complete description of the Whole Farm Cooperative's history and operations.

⁵ Much of this section summarizes a more extensive overview of these theories in Venturini and King (in press). I gratefully acknowledge Luciano Venturini's contributions to my knowledge of these theories.

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