

Markets, Contracts, or Integration? The Adoption, Diffusion, and Evolution of Organizational Form

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Abstract: The rise of contract farming and vertical integration is one of the most important changes in modern agriculture. Yet the adoption and diffusion of these new forms of organization has varied widely across regions, commodities, and farm types. Transaction cost and other modern theories of the firm help explain the advantages of contracting and integration over reliance on spot markets and commodity brokers. However, these theories do not address the *variation* in adoption rates of new organizational forms. This paper lays out a more dynamic framework for understanding the evolution of organizational practices in U.S. agriculture, drawing on theories of the diffusion of technology and organizational complementarities. Using recent trends as stylized facts we argue that the agrifood sector is characterized by strong complementarities and that identifying and describing these complementarities more fully sheds considerable light on the organizational structure of agricultural production. We illustrate our arguments with case studies from the oilseed, poultry, and hog industries.

Keywords: contracting, vertical integration, organizational innovation, diffusion

JEL: L14, L22, Q13, O33

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The Adoption, Diffusion, and Evolution of Organizational Form

Introduction

The US agricultural sector is characterized by a wide of array of organizational arrangements. The past two decades witnessed a tremendous increase in the shares of many products produced or marketed under contract. Contracts now govern 36 percent of the value of all agricultural production, up from 12 percent in 1969 (MacDonald et al.). The adoption of contracting has not proceeded evenly across commodities, however. Between 1991 and 2001 the value of rice production under contract increased from 20 percent to 39 percent. For cotton the increase was 31 percent to 52 percent; for hogs, 30 percent to 61 percent; and for tobacco, less than 1 percent to 48 percent. For livestock commodities such as milk, hogs, and broilers, and for crops such as sugar beets, fruit, and tomatoes, contracts are the primary means of handling production and sales. Moreover, data on contracts tell only part of the story. For instance, Grimes et al. report the percent of hogs sold on the negotiated cash market fell from 62 percent in 1994 to 12 percent in 2004, suggesting an increase in vertical integration to accompany the increase in contracting for hogs. Vertical integration is also common in the production of poultry, turkey, and particularly eggs.

Besides these differences across commodities, we also observe differences in the adoption and diffusion of contracting and other organizational arrangements across regions. The value share of product under contract varies from a low of 25 percent in the USDA's Northern Great Plains region to over 68 percent in the Southern Seaboard region. Furthermore, the use of contracts varies across regions and over time. For instance, McDonald and Korb show that the

value share of rice contracted in the Mississippi Portal region grew from roughly 10 to 18 percent between 1993 and 2003 while growing from 40 to over 90 percent in the Fruitful Rim region over the same period. The value share of hog production under contract rose from 20 to roughly 40 percent in the Heartland region while growing from just over 80 to over 95 percent in the Southern Seaboard region. Similarly, the degree of vertical integration differs across regions for particular commodities such as hogs and sugar beets.

MacDonald et al, Martinez (1999, 2002), and Martinez and Zering attempt to explain these trends using theories such as transaction cost economics (TCE) that focus on the discrete choice of one organizational form (e.g. spot-market exchange) versus another (e.g. vertical integration) in a static equilibrium context. However, this approach has serious limitations for understanding economic change, particularly the processes by which new organizational forms are established. If exogenous determinants of organizational form have cumulative or interactive effects on behavior, then changes in observed patterns of behavior may not closely track changes in any particular exogenous characteristic. This suggests the need for a more dynamic “systems” approach to understanding the choice of organizational form (Milgrom and Roberts).

In this paper we argue that recent theories of the diffusion of technology and organizational complementarities provide valuable insights into the evolution of organizational practices in US agriculture. We first summarize the pattern of organizational adoption rates across agricultural products and producing regions over time. We then outline the key insights of the organizational complementarities literature. We illustrate our argument with case studies from the oilseed, poultry and hog industries, showing how the timing of organizational change was determined by the emergence of clusters of technological and market characteristics. We conclude by

suggesting how an understanding of complementarities can generate new ways of thinking about the organizational structure of US agriculture.

The Vertical Coordination of Agricultural Production: A Bird's-Eye View

The rise of contract farming and vertically integrated forms of production is undoubtedly one of the most important changes in late twentieth-century US agriculture. As noted above, the value of production under contract has risen dramatically in recent years, roughly tripling over the last three decades, though exact numbers vary by source (MacDonald et al.).¹ Some details are less widely publicized, however. First, use of contracting is concentrated among large and commercial farms. In 2001, only about 11 percent of US farms used contracts of any type, while 42 percent of all commercial farms used them. The number of farms using contracts, and the value of production under contract, rises monotonically with firm size (a pattern that has remained roughly consistent throughout the 1990s, the period for which detailed data are available). Even if there were no within-farm changes in the organization of production, we would expect an increase in contracting to accompany the generally observed increase in average farm size.

Second, the use of contracting varies widely across regions. The value of production under contract is substantially higher in the USDA's Heartland, Southern Seaboard, and Mississippi Portal Regions than the national averages. Reimund, Martin, and Moore and MacDonald et al. suggest that contracting initially spreads among producers within a particular region before spreading to other regions.² Data on changes in contracting practices across regions are spotty, however. MacDonald et al. base their story on the USDA's Agricultural Resource Management Survey (ARMS), but the survey was first deployed only in 1991 and does not examine all commodities with equal depth in all years.

Third, the use of contracts and other forms of vertical coordination differs substantially among commodities. Contracts now govern about half of livestock production but only one-fourth of crop production. Livestock producers use both marketing and production contracts, while crop production rarely involves production contracts (MacDonald et al.). Within livestock, contracts govern about 20 percent of the value of cattle production, while contracts or vertical integration account for about 75 percent of the hog market, 90 percent of the turkey market, 90 percent of the egg market, and virtually all of the broiler market (Martinez 1999, 2002; Roy). Often we observe variety among types of contracts even for a single commodity within a given region.³

More importantly, the speed at which contracts and vertical integration were adopted varies widely across farm type, regions, and commodities. In some sectors, new organizational practices diffused very rapidly. The broiler industry was one of the earliest US agricultural sectors to move from spot-market production to more tightly vertically coordinated forms of organization. In 1950 only 5 percent of broiler production was under contract or processor ownership; by 1955, 88 percent was under production contract and 2 percent was vertically integrated (Roy). Since the 1950s, 85 to 90 percent of production has remained under production contracts, with most of the rest produced under vertical integration (Martinez 1999, 2002). The typical production contract has not changed much over the last half-century, with the processor providing baby chicks, feed, veterinary services, and managerial expertise to growers, who supply labor and chicken houses and are paid for each chicken produced (Martin).⁴ Spot-market procurement is similarly rare in turkey and egg production, though vertical integration plays a larger role in those sectors.

In the hog market, the adoption of contracts and vertical integration was more recent and not quite as rapid. In 1993, 87 percent of hogs were acquired on the spot market, 11 percent through marketing contracts, and 2 percent through vertical integration (Hayenga et al.). By 2000, the figures were about 25 percent for the spot market, about 50 percent for marketing contracts, and about 25 percent for vertical integration (Lawrence and Grimes). Spot market purchases fell further to 17 percent in 2002 (Grimes and Meyer).

By contrast, in crop production, the use of contracts and vertical integration has increased only gradually over the last few decades (MacDonald et al.), although there are a few notable exceptions. Tobacco saw a dramatic rise in contracting, increasing from 9 percent to 81 percent between 2000 and 2001. Conversely, contracting in peanuts declined from 48 percent to 21 percent between 1992 and 2001 and contracting for cotton declined from 48 percent to 7 percent between 1995 and 2004. Yet crop production is subject to many of the same technological and market changes (genetic modification, consumer demands for quality and traceability) that are thought to have driven organizational change in livestock production. Existing literature says little about these differences in the adoption and diffusion of more tightly coordinated vertical modes of production.⁵

Why Do Contracting Practices Differ?

As this brief overview demonstrates, the adoption of contracts and vertical integration has not proceeded evenly across commodities or regions, and diffusion rates also vary within commodity groups and within regions. How can we explain these different rates of adoption and diffusion?

The transaction cost approach

One approach is a static equilibrium explanation in which agents are modeled as always choosing optimal organizational practices, yet these optima vary cross-sectionally and over time

due to exogenous changes in resources or technology. For example, the transaction cost approach (Klein, Crawford and Alchian; Williamson 1979, 1985) explains the efficient form of organization in terms of underlying transactional characteristics such as asset specificity, uncertainty, and frequency. Investment in relationship-specific investments exposes parties to certain risks; when circumstances change, their trading partners may try to expropriate the rents accruing to the specific assets by renegotiating the terms of trade. Contracts and vertical integration are a means of protecting these rents. To explain variation in contracting practices across markets or over time, one would look for corresponding variation in the appropriate underlying characteristics.

Transaction cost economics has many obvious applications to agricultural production.⁶ Martinez (1999, 2002) and Martinez and Zering use TCE to explain contractual practices in poultry, eggs, and hogs. The poultry and egg sectors experienced rapid technological change in the decades immediately following World War II, as specialized production facilities replaced the general-purpose farm equipment used previously. The switch to these more mechanized modes of production led to increased use specificity (assets specialized to particular uses), and consolidation driven by scale economies along with perishability led to increased user specificity (asset specialized to particular trading partners). Similar changes occurred in hog production, though the timing came later and with greater variation across regions. Because hogs can be transported greater distances without losing value and can be slaughtered at different ages, site and temporal specificities are less important in the pork industry where (less tightly coordinated) marketing contracts, rather than vertical integration or production contracts, appear sufficient to mitigate opportunism.

This type of explanation suffers from several drawbacks, however. First, if specificity is the main driver of organizational change, then what explains the cross-sectional and time-series variation in the exogenous technological or demand shocks underlying the hypothesized changes in asset specificity? To explain the contracting patterns described in the previous section, a more dynamic theory of the diffusion of technology is required. In Martinez's (1999, 2002) analysis of hog production, for example, the adoption of marketing contracts and vertical integration tracks closely the adoption of newer, specialized production technologies (including genetic information), which constitute forms of asset specificity, and increases in processor concentration, which make producers more dependent on particular processors (what Williamson describes as small-numbers bargaining conditions). However, technology, industry structure, and organizational form are endogenous; specialized technologies may only emerge after the appropriate governance structures have been devised and deployed. The fact that the particular underlying characteristics change as organizational form changes does not, by itself, provide us with a causal explanation for organizational change.

Second, the variation in transactional attributes we observe does not always closely fit known patterns of vertical coordination. For instance, site and temporal specificities apply to other commodities, such as dairy products, that have not experienced rapid adoptions of contracting.

Other explanations for changes in the organization of agricultural production appeal to corresponding changes in market structure or consumer preferences.⁷ Practitioners often cite the rise of large, consolidated retailers and recent increases in processor concentration as the drivers behind increased reliance on contracting. Powerful downstream participants use their market power to force producers to accept contracts or buyouts. One problem with such explanations, besides their ad hoc nature, is that the underlying structural changes may themselves be

endogenous; or, rather, organizational form and market structure may be determined simultaneously by variables omitted from these kinds of stories. Martinez and Zering note the role of increased consumer demand for quality differentiation and standardization across markets. The increased demand for lean pork, for example, raises measurement costs (in Barzel's sense), for which marketing contracts can be an effective solution. The challenge here is to explain why preferences have changed for some commodities but not others.⁸

Complementarities and the diffusion of innovation

Economists have devoted less attention to theories of economic change than to static models of economic efficiency. One important exception is the literature on the adoption and diffusion of new technologies. It is widely recognized that diffusion rates vary considerably. Rosenberg observes that “in the history of diffusion of many innovations, one cannot help being struck by two characteristics of the diffusion process: its apparent overall slowness on the one hand, and the wide variations in the rates of acceptance of different inventions, on the other.” As modeled, for example, by Hall and Khan, an individual producer's decision to adopt a new technology depends on the ratio of short-term transition costs (particularly learning) and the long-term benefits of using the superior method of production. When these future benefits are uncertain, and agents have different expectations about them, there is an option value to deferring the decision to adopt. Increased uncertainty and heterogeneity of expectations thus explains the variation in adoption rates across technologies and markets.

Technological innovation can diffuse slowly and unevenly for other reasons. First, there is a need for complementary organizational structures. Chandler (1962, 1977) shows how the rise of large, vertically integrated industrial enterprises during the early twentieth century gave manufacturers the ability and incentives to develop and deploy new technologies. More recently,

new information-management technologies (supply-chain management and distribution systems) have given power to large retailers, whose procurement systems drive the entire vertical process of production. Second, complementary marketing and branding strategies must be developed. Of course, as pointed out above, technology and organization may be simultaneously determined, leaving us without a causal explanation for the observed variation in organizational form. Moreover, these complementary factors are themselves endogenous.

Complementarities exist when one organizational attribute or element of a system cannot exist or change without the existence or change of at least one other constituent element. When such complementarities are strong, a transaction cost model, in which organizational attributes are treated independently, may not be adequate. Exogenous changes in technology, competition, demand, or regulation may suggest particular changes in firm strategy or structure, but the firm's behavior will not be affected until all attributes of the cluster are ready for change. For example, technological innovation may imply a different production method, but if that production method is efficient only when associated with a particular contractual practice, and market conditions do not accommodate that practice, then the firm will stick with the old production method as a second-best solution, until market conditions have also changed. Thus even if technological innovation affects all commodities or regions, if market conditions vary across commodities or regions then firm behavior will not adjust uniformly. This would lead to observations of sudden and discontinuous change, as well as considerable variety in firm practices across markets or regions.

There is a growing body of theoretical work on complementarities within organizational systems. Holmstrom and Milgrom develop a multi-task agency model in which high performance incentives, worker ownership of assets, and worker freedom from direct managerial

control are complementary instruments for motivating workers. They show that weak performance incentives, firm ownership of assets, and significant restrictions of worker activity are typical characteristics of employment, while strong output-based incentives, worker ownership of productive assets, and worker freedom are characteristic of independent contracting. Milgrom and Roberts argue, similarly, that the “fit” between firm strategy, structure, and production and managerial processes helps to explain firm performance. For example, mass production is most effective when combined with long production runs, an emphasis on volume, mass marketing, infrequent product changes, the use of specialized rather than flexible machinery and jobs skills, sequential product development, hierarchal planning and control, and vertical integration. Organizations that mass produce but have short production runs, make-to-order inventories, and that emphasize cost and quality will be less effective than companies that adopt the complementary practices and structures. Case studies from sectors ranging from steel (Ichniowski et al) to information technology (Bresnahan et al) confirm the importance of complementarities to organizational performance.

Most important for our purposes, the existence of complementarities helps account for the extent and effectiveness of organizational change. Milgrom and Roberts (pp. 190-91) note that their analysis of complementarities within organizations provides

a reason why change in a system marked by strong and widespread complementarities may be difficult and why centrally directed change may be important for altering systems. Changing only a few of the system elements at a time to their optimal values may not come at all close to achieving all the benefits that are available through a fully coordinated move, and may even have negative payoffs. Of course, if those making the choices fail to recognize all the dimensions across which the complementarities operate, then they may fail to make the full range of necessary adaptations, with unfortunate results. At the same time, coordinating the general direction of a move may substantially ease the coordination problem while still retaining most of the potential benefits of change. Moreover, the systematic errors associated with centrally directed change are less costly than similarly large but uncoordinated errors of independently operating unit.

For a system characterized by strong complementarities, changes designed for some features must be coordinated with all complementary elements within the system. By contrast, when complementarities within a system are weak—for example, when production and organization are “modular” (Henderson and Clark; Langlois)—then features of the system could be changed individually. The key insight here is that organizational change will tend to diffuse quickly within a system when complementarities are strong and coexisting elements also change. In contrast, organizational change tends to be slow and uneven when complementarities are weak or when complementarities are strong and but coexisting attributes are slow to change.

We argue that the notion of complementarities is important for understanding the uneven pattern of adoption and diffusion rates of contracting and other organizational forms within the agrifood sector. As we explain below, agricultural production is generally characterized by strong complementarities, but some sectors are likely to have stronger links among system elements than other sectors. Sectors such as poultry and hogs that underwent relatively rapid rates of organizational change, for example, did so in part because complementary variables within those sectors also changed to correspond with the production contracting system. Sectors and regions that have been slow to adapt, by contrast, have not experienced complementary changes of key variables. In some cases, complementarities within the sector might be relatively weak. Because research on complementarities is relatively young and, to our knowledge, has not been applied systematically to the agrifood sector, we believe that efforts to identify “syndromes of attributes” that exist within particular sectors of the agrifood chain will greatly enhance our understanding of organizational changes we observe.

The following section identifies possible complementary factors in food and agricultural production. Our objective is to show that if there are complementarities and if they are strong,

then the choice of organizational arrangement in agriculture, such as spot market transaction, marketing contract, production contract, and vertical integration, will be closely tied to complementary variables within the entire agrifood value-added system. Thus, unlike the literature that explores complementarities within distinct organizational units, such as firms, we postulate that there are strong complementarities existing within the entire value-added food chain and that these complementarities explain the pattern of organizational structures described above.

Complementarities in the Agrifood Sector

The agriculture system is a complex and highly structured system. Agricultural producers take raw inputs, such as farm supplies, seeds, feed and machinery, and produce raw agricultural products, such as grains, oilseed crops, vegetables, poultry, livestock and dairy products. These raw products are marketed either through brokers or directly to food processors, who transform raw agricultural products to finished foodstuffs or feedstock. Processors then market their food products to wholesalers and retailers, such as grocery stores and restaurants, where they are finally consumed by consumers.

Given the complex nature of the agriculture sector and increasing demand for differentiated and specialized end products, which require greater coordination across levels of the value chain, it is reasonable to expect that complementarity would play a significant role in affecting organizational structures between and across levels of production. Although we are primarily interested in the organizational structure of the producer-processor stage, concepts of complementarity require us to consider how this stage fits into the overall value chain in addition to the nature of the characteristics of the producer and processors themselves.

For instance, demand for GM-free food products offers potential premiums to industry participants that can effectively develop segregated identity-preserving supply systems, but both the premiums and the organizational structure of the segregation systems will depend on the agricultural product and its end use. If demand for GM segregation is a driver for adoption of production contracts in grains and oilseeds, we would expect more contracting in soybeans and corn than in wheat, for instance. Because a vast majority of corn in the US is ultimately consumed by animals rather than people, we might also expect different rates of GM-based contracting among soybeans and corn. Finally, because demand for GM segregation is primarily for export markets, we would expect contract programs to be geographically concentrated in proximity to export transportation systems.

Segregation systems also require a physical infrastructure to maintain product identity. Maltzbarger and Kalaitzandonakes and Barnes demonstrate that the costs of identity preserved segregation at the elevator and seed plant levels, respectively, are highly sensitive to the configuration of storage bin assets. This suggests contract opportunities and the volumes and premiums offered in those contracts would vary across regions based on existing infrastructure. Since volume and premiums are the primary source of value to producers, we would therefore also expect the rate of adoption (or the success of contract programs) to be correlated with market infrastructure as well as the availability of on-farm storage. Thus, the nature of a range of complementary assets and product characteristics combine to explain different rates of contract adoption across regions and commodities.

Figure 1 illustrates how the nature of infrastructure affects the type of contracts offered across regions. The figure shows the locations of elevators participating in Continental Grain & Barge's (CG&B) contract program for GM-free soybeans in the 2000 crop year. The panel on the

left denotes locations for harvest delivery (HD) contracts, which permitted producers to deliver anytime during the harvest season (October through November, 2000). The panel on the right denotes locations for buyer's call (BC) contracts, which required producers to deliver at the elevator's discretion within a contractually specified call window ranging as far as August 2001 depending on the contract.⁹

Figure 1 shows all seven Ohio River terminal elevators offering BC contracts but not offering HD contracts. This is consistent with predictions based on Maltzbarger and Kalaitzandonakes' results, since river terminals tend to have storage bin configurations that create high costs of segregation. BC contracts would allow these elevators to avoid tying up storage with segregated soybeans by allowing them to call for delivery when product could be direct-loaded onto barges. However, by offering only BC contracts these elevators shifted storage costs and quality risks onto producers in these areas that were not borne by producers selling under HD contracts to other CG&B elevators (Sykuta and Parcell). Because the premium CG&B offered on the BC contracts was the same as that offered on HD contracts elsewhere, producers in the Ohio River region received lower benefits from participating in the contract program.

While the case of non-GM contracting in soybeans presents a consumer-driven change that works its way back through the supply chain, financing in hog and poultry production may provide an input-driven set of complementary changes in organization. Production contracts in poultry and hogs typically require producers to provide specifically-designed production facilities (buildings) that often require financing for the producer. While these production facilities are long-lived, Knoeber (p. 276) notes that none of the contracts in his study "appear to be designed to last for the likely economic life of the housing facilities provided by a grower, and even longer term contracts provide for early termination by the company (or the grower)." Banks

lending to producers have pushed integrators for longer-term contracts as a condition for providing capital for building production facilities. Integrators have, in some cases, also provided financing to producers. Thus, the need for and access to external financial capital, which varies across agricultural production activities, may have significant influence on the structure of contractual relations between producers and integrators. Since producers have traditionally relied more on rural commercial banks for financing (Keeton) and given consolidation in the banking industry and entry of larger banks into rural markets (Gilbert and Belongia), access to credit may also vary regionally as well as across agricultural products.

These cases represent very different issues facing varying sectors of the agrifood system, but they suggest that complementary resources affect the introduction, adoption and diffusion of different forms of organization. In short, there are several variables originating at many levels of the agrifood chain that may affect the propensity to introduce and the rate of adoption of different forms of contracting or other organizational forms. To illustrate more fully the role of complementarities in the agrifood sector, particularly as they pertain to organizational change, we present short case studies of the poultry and hog industries. In both cases technology, genetics, production practices, consumer demand, and rapid organizational change are linked in ways consistent with a role for strong complementarities.

Organizational change in poultry and hogs

In both poultry (broilers) and hogs production takes place primarily in concentrated and confined feeding operations and is governed largely by production contracts. These trends are correlated: production contracts are needed to justify the increased risks producers take on by adopting confinement production practices.¹⁰ However, while the transition occurred rapidly in the case of broilers, it occurred much later in the case of hogs. If the production of hogs today

using production and governance systems similar to those used in poultry are efficient (see Martinez, 1999), then why did the hog industry not switch suddenly from spot-market procurement to contracts and vertical integration at the same time as the poultry industry? If hog producers in the 1990s recognized the efficiencies of confinement production and contracting, why didn't they do so in the 1960s or 1970s? As we show, the theory of complementarities provides a compelling argument why change occurred more slowly in the hog sector than in the poultry industry. Specifically, a key element of complementary change did not occur in the case of hogs until the 1980s. Once this change occurred, transition in both production and contracting practices proceeded relatively rapidly.

The poultry sector saw a very rapid transition to contracting during the 1950s, increasing from roughly five percent in 1950 to nearly 90 percent in 1955. This change coincided with the transition from small-farm production, in which most farms raised chickens, to large-scale confinement operations. Importantly, the chickens raised in open farms feeding on seeds or whatever chickens could find were not amenable to confinement production. Boyd documents the scientific and technological developments in poultry beginning in the 1910s and 1920s that were necessary for confinement production. Most critical was the need to develop a chicken genetically that could be raised in confinement. Chickens raised indoors do not have access to natural ultraviolet light. This absence creates a nutritional deficiency known as "leg weakness." As Boyd states, "Until this problem could be solved, industrial broiler production remained a distant prospect." A nutritional supplement involving the introduction of vitamin D to chicken diets, identified in the 1920s, solved this problem. But confinement production faced other problems. One of them was the need to control for the spread of disease. Vaccines were developed for poultry viruses during the 1920s, but research into antibiotics as a means to control

disease and promote growth did not occur until the 1940s. Not coincidentally, the FDA approved the use of penicillin and chlortetracycline as additives in feed only in 1951 (Boyd).

However, these changes alone do not account for the evolution in poultry production practices. As Boyd (p. 652) says: “If confinement provided the foundation for subordinating broiler biology to the dictates of industrial production, and if advances in nutrition and growth promotion marked the first step in the process of biological intensification, breeding and genetic improvement proved to be the primary drivers in the effort to accelerate biological productivity.” Simply put, confinement and contracting in poultry would not have been feasible without complementary changes introduced into chicken genetics. Chickens raised in traditional methods had meat that was “tough, dry, and strongly flavored,” a characteristic of chickens that, at the time, were raised more for egg production than for meat consumption (Martinez, 1999, p. 2).

In contrast, confinement production required the delivery of large numbers of uniform-quality chicks that could grow rapidly on corn and soybean meal supplemented with antibiotic additives and that were light, broad-breasted, “meat-type” chickens (Boyd). According to Boyd, the “watershed” in the development of appropriate genetic characteristics occurred as a result of “Chicken of Tomorrow” contests sponsored by the Great Atlantic and Pacific Tea Company in 1948 and 1951. Within a few years, more than two-thirds of all commercial broiler production in the U.S. were from the “blood lines” of the winners of these contests.

Perry et al summarize the changes needed to support the evolution of contracting and confinement production in poultry as follows: “In the 1940s, agricultural research brought new technologies to the poultry industry. Included were the introduction of new breeds for meat, better nutrition and disease control, better management of confined poultry, processes that correctly sexed chicks, and the candling of eggs. These practices introduced U.S. farmers to the

possibilities of raising broilers and fryers for commercial consumption.” The point is that each of the elements listed—genetics, nutrition, disease control, confinement management, etc.—is an indication of the complementarities that exist in poultry production. Importantly, change in organizational structure could not occur without them and, perhaps more controversially, efforts to change the genetic characteristics of chickens, to develop better nutritional formulas, and the like would not have occurred but for the desire to move toward a large-scale, confinement-oriented production system in poultry.

Could hog producers have taken advantage of the knowledge gained in poultry production to organize hog production along similar lines? The complementarities approach suggests that if hog production is also characterized by strong complementarities, then hog producers could adopt new organizational arrangements only if all necessary elements of the complementary bundle were in place.

Like poultry production, “animal biology is ... crucial to the intensified capitalization of swine husbandry, to the more thorough extension of packer influence into animal production directly, and to the structuring of authority that coordinates the industrial-like manufacturing networks through which pork commodities reach retail markets” (Rich, p. 4). Hogs produced in confinement operations differ from hogs produced in more traditional, free-range, systems. “Indoor pigs” are smaller, more prone to disease, and have a lower fat content than “outdoor pigs.” Outdoor pigs perform poorly in confinement, whereas indoor pigs perform poorly outdoors. Moreover, pigs that do well outside of confined operations—that is, those with a relatively high fat content—are not optimal for the mechanical processing favored by large-scale processors and meat packers which require lean carcasses (Whittemore and Kyriazakis). As Rich (p. 6) states: “Leanness, then, is key to the biology of hog production today, is integral to the increasing coor-

dination of pork production and to the presence of large automated animal processors.” Leanness is linked to confinement because lean hogs are biologically fragile, being susceptible to several forms of stress. Stress arises from proximity to other animals, variations in feed formulations, and the genetic characteristics of lean hogs which ironically are exacerbated within confined production systems.¹¹ However, confinement allows producers to control production to minimize animal stress. Confinement also allows the control of feed, which must be precisely formulated and administered to promote efficient growth, an issue not relevant in hogs that are bred for outdoor production.

In short, leanness of hogs is likely related to a host of complementary elements. Processors and packers desire lean hogs for mechanical processing. Leanness requires (a) confined production, (b) production contracting to provide incentives for growers to make investments in confinement capital, and (c) the development of appropriate nutritional formulation. However, pigs must be bred not only for leanness, but also to control the emergence of the recessive allele linked porcine stress. In other words, without leanness there would be no large-scale confined-animal feeding operations in hogs and, without confinement production, there would be no significant pressures for production contracting.

Why didn’t pork production experience the same rapid transition to confined production and production contracting experienced by poultry production during the 1950s? The answer is that while the knowledge to produce a lean hog was available during the 1950s, the technology and incentives needed to produce a lean hog that performed well through the growth and processing stages did not develop until the 1980s and 1990s. According to Martinez and Zering, pork producers desired to producer a leaner hog as early as the 1950s, in part to meet consumer demands for leaner meats. In the 1950s, the amount of backfat in hogs was one and one-half inches, com-

pared with one-third of an inch backfat in contemporary hogs (Coppin). However, early attempts resulted in “pale, soft, exudative” pork, which had undesirable production and consumption qualities. As stated above, genetic disposition to leanness also increased the likelihood that hogs would become susceptible to stress during production. Because the production cycle of hogs is longer than that for poultry—roughly nine months for hogs in contrast to roughly six or seven weeks for poultry—it took considerably longer for breeders to develop the genetic strains in hogs that resulted in the appropriate share of fat in hogs consistent with mechanical processing requirements and also produced hogs less susceptible to stress. Those advances had to wait until science advanced to the point that genetic modifications could be done in the laboratory rather than through traditional reproduction techniques.

Even today, there remains uncertainty about the appropriate leanness of hogs (Notter), especially given the existence of tradeoffs in the genetic manipulation for pork—involving selection for leanness, stress and palatability—that are more difficult to identify compared with poultry. This goes a long way toward explaining why the hog industry is less vertically integrated than the poultry industry.

Summary

Complementary factors need not be limited to technological or tangible factors in the production process, such as genetics, production practices or production technology. Producers’ attitudes toward alternate organizational forms as well as differences in producers’ characteristics and human capital may also affect their willingness to try new organizational arrangements. The density of production practices, both among producers and among processors, may affect information flows and learning among industry participants, thereby affecting the rate of adoption geographically or across members in a particular industry. The diversity of farming

practices across regions may also affect the spill-over of contract experiences in one agricultural product to contracting practices in another.

Obviously, the list of potential complementary factors is large. Our challenge is to begin distilling the factors into manageable sets and identifying how those particular factors are likely to apply across agricultural products, producers, and regions. The GM-free soybean example suggests that physical infrastructure characteristics and contracting structures are likely complementary variables. The examples of poultry and pork suggest that genetics, confined production, vertical integration and contracting and scale are possible complementary variables. The list of significant variables may be long and specific to particular sectors of the agrifood system. For these reasons we believe there is potential for innovative and informative research examining the regional rates of adoption of alternate organizational forms in livestock, poultry, grains, and vegetables, and the correlation of adoption rates with key factors identified above. One approach would be to examine changes in response both to fiscal stimuli such as market prices or financial crises and to changes in technologies and consumer demands such as demand for GM-free food products. Such empirical investigation is the next step of this on-going stream of research.

Implications and Discussion

We argue that the adoption, diffusion, and evolution of organizational forms are affected by the nature and strength of complementarities in the incumbent structure of the industry. Systems characterized by strong complementarities will likely see slow or uneven adoption and diffusion rates of organizational form when other characteristic features of the system are also slow to change or when they change unevenly over time or in different geographic regions within the same industry. By contrast, adoption, diffusion and evolution of organizational form are likely to

be rapid in strongly complementary systems when the complementary characteristics of the system change in consort.

Furthermore, because strong complementarities reduce the effectiveness or value of incremental changes at local or individual levels, more dramatic sector-level changes will be expected as market forces push the supply chain past the tipping point where large-scale changes are economically justified (in terms of switching costs, scale economies, etc.). Hence, in the context of the adoption and diffusion literature, we expect sectors characterized by strong complementarities to have a relatively steep adoption curve once a new form is embraced, but a long tail preceding adoption. Conversely, we expect sectors characterized by weak complementarities to have flatter, and perhaps less comprehensive adoption curves (i.e., ones that plateau at lower overall adoption rates).

Given differences in key factors across products and geographic regions, we expect the degree of complementarity—and its resulting implications for organizational change—should similarly vary across these dimensions, especially if exogenous shocks to the system are localized. Given an exogenous shock, regions with more flexible asset structures (human and physical) and complementing factors may adopt more dramatic changes in organizational form (i.e., moving to vertical integration versus moving to contracting) than regions with more rigid asset structures and over a shorter time period.

These general insights imply questions and lines of research about organizational change in US agriculture. As argued throughout the paper, we believe that important complementarities exist within agricultural production and that these complementarities explain adoption and diffusion of organizational form. What variables are complementary and how strong the complementarities are among different bundles are, however, questions for further research. For

example, we note that the adoption of contracting varies geographically and that some regions adopted contracting more readily than others. While we do not investigate this hypothesis empirically in the discussion above, the evidence and cases discussed here suggest several specific lines of inquiry. For example, why did the Midwest fail to adopt contracting as rapidly as the Far West, South, and Southeast? If lean hog genetics was available to all producers at roughly the same time, why did some regions stick to the old technology and marketing strategy?

Consider another illustration involving the relationship between demand for IP segregation, commodity characteristics, and contracting. What, precisely, are the complementary elements in IP segregation systems? How strong are they? If they are strong, we expect greater demand for IP segregation to increase the likelihood of long-term contracting. This also suggests that long-term contracting is more likely in soybeans and corn than in wheat, and more likely in soybeans than corn (because most corn in the US is used for animal feed). However, these are empirical questions that require detailed analyses of contract rates and trends in multiple commodity production systems.

Furthermore, we previously suggested that financing of hog and poultry production represent an input-driven process of complementary changes. The degree to which financing is complementary to production is a question left largely unanswered. If complementarities are weak, then our financing story appears to be just a variation of the standard TCE argument. What differentiates the complementarities argument from the transaction cost explanation is that if complementarities are strong, changes at one level of the value chain may affect transaction costs at another level of the value chain, whereas typical transaction cost arguments focus on a single transaction independent of its place in the value chain. Of course, demonstrating that this is true

in a particular case such as financing in hog and poultry production requires an in-depth study of the timing of change and the terms existing in financing contracts.

Finally, the rate at which technological or organizational innovations spread throughout an economy depends on information (market participants must be familiar with the new methods or processes), switching costs, strategic considerations, and the strength of market feedback mechanisms. The literature on network effects suggests that positive feedback between producers and consumers can lead to “tipping points” during which a new technology or practice suddenly and rapidly displaces an older one (Shapiro and Varian). MacDonald et al. (p. 14) suggest that the rapid adoption of contracting and vertical integration in tobacco and hogs may result from such tipping points in marketing systems. It is unclear, however, what would be driving the network effects in these cases. Does the value of contract farming for a particular producer or processor depend on the number of other farmers or producers using contracts? Again, this is an empirical question that is ripe for study. If producers rely on informal exchanges of knowledge with other producers and input suppliers, then the existence of contracting in a particular geographic area could make producers in that area less reluctant to try it. To this end, one might study whether diversified agricultural regions, where markets for multiple commodities coexist, are more likely to adopt contracting than a region specializing in a particular commodity without a history of contracting.

References

- Akerberg, D.A., and M. Botticini. 2002. "Endogenous Matching and the Empirical Determinants of Contract Form," *Journal of Political Economy* 110, no. 3: 564–91.
- Allen, D.W., and D. Lueck. 2003. *The Nature of the Farm: Contracts, Risk, and Organization in Agriculture*, Cambridge, Mass.: MIT Press.
- Alston, L., and R. Higgs. 1982. "Contractual Mix in Southern Agriculture since the Civil War: Facts, Hypotheses, and Tests," *Journal of Economics History* 42, no. 2: 327-353.
- Barnes, J.N. 2004. *Regulation of Agricultural Biotechnology and Vertical Control in the Global Agri-Food Chain: An Application of the Coasian Lens*. PhD Dissertation, Department of Agricultural Economics, University of Missouri.
- Boyd, W., 2001. "Making Meat: Science, Technology, and American Poultry Production," *Technology and Culture*, 42, 631-664.
- Bresnahan, T.F., E. Brynjolfsson, and L.M. Hitt, 2002. "Information Technology, Workplace Organization, And The Demand For Skilled Labor: Firm-Level Evidence," *Quarterly Journal of Economics* 117, no. 1: 339–76
- Chandler, A.D., Jr., 1962, *Strategy and Structure: Chapters in the History of Industrial Enterprise*, Cambridge, Mass.: M.I.T. Press.
- Chandler, A.D., Jr. 1977. *The Visible Hand: The Managerial Revolution in American Business*. Cambridge, Mass.: Harvard University Press.
- Coppin, D. 2003. "Foucauldian Hog Futures: The Birth of Mega-Hog Farms," *The Sociological Quarterly*, 44(4), 597-616.

- Gilbert, R. A., and M. T. Belongia. 1988. "The Effects of Affiliation with Large Bank Holding Companies on Commercial Bank Lending to Agriculture." *American Journal Agricultural Economics* 70: 69-78.
- Grimes, G., and S. Meyer. 2002. "Hog Market Contract Study." University of Missouri Department of Agricultural Economics and National Pork Board.
- Grimes, G., R. Plain, and S. Meyer. 2004. "U.S Hog Marketing Contract Study," University of Missouri, Department of Agricultural Economics Working Paper AEWB 2004-07.
- Hall, B.H., and B. Khan. 2003. "Adoption of New Technology," *New Economy Handbook*, North-Holland: Elsevier.
- Hayenga, M.V., J. Rhodes, G. Grimes, and J. Lawrence. 1996. "Vertical Coordination in Hog Production." U.S. Department of Agriculture, GIPSA-RR-96-5.
- Henderson, R.M., and K.B. Clark. 1990. "Architectural Innovation: the Reconfiguration of Existing Product Technologies and the Failure of Established Firms," *Administrative Science Quarterly* 35.
- Holmstrom, B., and P. Milgrom. 1994. "The Firm as an Incentive System," *American Economic Review* 84, no. 4: 972-91.
- Ichniowski, C., K. Shaw, and G. Prennushi. 1997. "The Effects of Human Resource Management Practices on Productivity," *American Economic Review* 87, no. 3: 291-313.
- Keeton, W. R. 1996. "Do Bank Mergers Reduce Lending to Business and Farmers? New Evidence from the Tenth District States," *Economic Review*. Federal Reserve Bank of Kansas City, Third Quarter.
- Klein, B., R.A. Crawford, and A.A. Alchian. 1978. "Vertical Integration, Appropriable Rents, and the Competitive Contracting Process," *Journal of Law and Economics* 21: 297-326.

- Knoeber, C.R. 1989. "A Real Game of Chicken: Contracts, Tournaments, and the Production of Broilers," *Journal of Law, Economics, and Organization* 5: 271-92.
- Langlois, R.N. 2002. "Modularity in Technology and Organization," *Journal of Economic Behavior and Organization* 49: 19-37.
- Lawrence, J.D., and G. Grimes. 2001. "Production and Marketing Characteristics of U.S. Pork Producers, 2000," Iowa State University Staff Paper 343 (August).
- MacDonald, J., J. Perry, M. Ahearn, D. Banker, W. Chambers, C. Dimitri, N. Key, K. Nelson, and L. Southard. 2004. "Contracts, Markets, and Prices: Organizing the Production and Use of Agricultural Commodities," Agricultural Economic Report No. 837, U.S. Department of Agriculture, Economic Research Service.
- Maltsbarger, R., and N. Kalaitzandonakes. 2000. "Direct and Hidden Costs in Identity Preserved Supply Chains," *AgBioForum* 3: 236-42.
- Martin, L. 1994. *Pork... The Other White Meat? An Analysis of Vertical Coordination and Contracting in the North Carolina Pork Industry*, PhD Dissertation, Department of Economics, North Carolina State University.
- Martinez, S.W. 1999. "Vertical Coordination in the Pork and Broiler Industries: Implications for Pork and Chicken Products," Agricultural Economic Report No. 777, U.S. Department of Agriculture, Economic Research Service.
- Martinez, S.W. 2002. "A Comparison of Vertical Coordination in the U.S. Poultry, Egg, and Pork Industries," Current Issues in Economics of Food Markets, Agriculture Information Bulletin No. 747-05, U.S. Department of Agriculture, Economic Research Service.

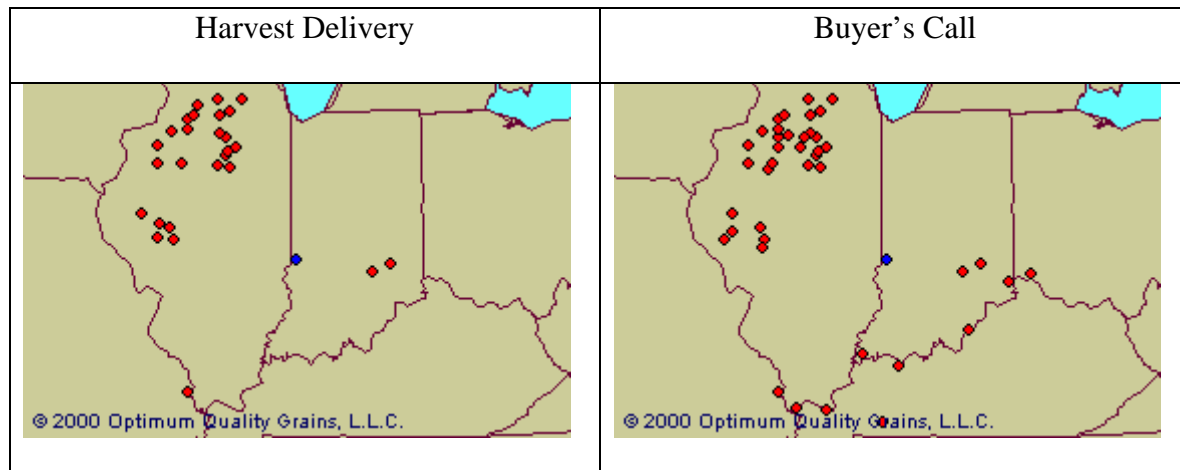
- Martinez, S.W., and K. Zering. 2004. "Pork Quality and the Role of Market Organization," Agricultural Economic Report 835, U.S. Department of Agriculture, Economic Research Service.
- Mazé, A. 2002. "Retailer's Branding Strategy: Contract Design, Organizational Change, and Learning," *Journal of Chain and Network Science* 2: 33-45.
- McDonald, J.M., and P. Korb. 2006. "Agricultural Contracting Update: Contracts in 2003." Economic Information Bulletin No., 9, U.S. Department of Agriculture, Economic Research Service.
- Ménard, C. 1996. "On Clusters, Hybrids and other Strange Forms: The Case of the French Poultry Industry," *Journal of Institutional and Theoretical Economics* 152: 154-83.
- Ménard, C., and P.G. Klein. 2004. "Organizational Issues in the Agri-food Sector: Toward a Comparative Approach," *American Journal of Agricultural Economics* 86, no. 3 (August): 750-55.
- Milgrom, P., and J. Roberts. 1995. "Complementarities and Fit: Strategy, Structure, and Organizational Change in Manufacturing," *Journal of Accounting and Economics*, 19: 179-208.
- Notter, D.R. 1999. "The Importance of Genetic Diversity in Livestock Populations of the Future," *Journal of Animal Science*, 77, 61-69.
- Perry, J., D. Banker, and R. Green 1999. "Broiler Farms' Organization, Management, and Performance," Resource Economic Division, Economic Research Service, U.S. Department of Agriculture, Agriculture Information Bulletin No. 748.

- Raynaud E., L. Sauvée, and E. Valceschini. 2002. "Quality Strategies and Producers' Organization in the European Agro-Food Sector: Competition Policy and Consumer Information," INRA Working Paper.
- Rich, D. Forthcoming, "Fecal Free: Biology and Authority in Industrialized Midwestern Pork Production," *Agriculture and Human Values*.
- Reimund, D. A., J. R. Martin, and C. V. Moore. 1981. *Structural Change in Agriculture: the Experience for Broilers, Fed Cattle and Processing Vegetables*. Technical Bulletin No. 1648. Washington, DC.
- Rosenberg, N. 1972. "Factors Affecting the Diffusion of Technology," *Explorations in Economic History* 10, no. 1: 3-33.
- Roumasset, J., and M. Uy. 1987. "Agency Cost and the Agricultural Firm," *Land Economics* 63, no. 3: 290-302.
- Roy, E.P. 1963. *Contract Farming, USA*, Danville, Ill.: Interstate Printers & Publishers.
- Shapiro, C., and H. Varian. 1999. *Information Rules: A Strategic Guide to the Network Economy*. Boston: Harvard Business School Press.
- Sykuta, M. and J. Parcell. 2003. "Contract Structure and Design in Identity-Preserved Soybean Production," *Review of Agricultural Economics* 25, no. 2: 332-350.
- Stiglitz, J.E., 1974. "Incentives and Risk Sharing in Sharecropping," *The Review of Economic Studies*, 41, no. 2: 219-255.
- Whittemore, C. and I. Kyriazakis, 2006. *Whittemore's Science and Practice of Pig Production*, 3/e. Oxford: Blackwell.
- Williamson, O.E. 1979. "Transaction-Cost Economics: The Governance of Contractual Relations," *Journal of Law and Economics*.

Williamson, O.E. 1985. *The Economic Institutions of Capitalism*, New York: Free Press.

Figure 1. Location of Elevators Offering GM-Free Soybean Contracts in 2000

This figure illustrates locations of Continental Grain & Barge Company elevators offering Harvest Delivery and Buyer’s Call contracts, respectively, for GM-Free Soybeans in the 2000 crop year. The image on the right shows major river terminals on the Ohio River offering only Buyer’s Call contracts while most locations offered both.



Source: Optimum Quality Grains, L.L.C, <http://oscar.itsoptimum.com/>, 2000

Endnotes

¹ Data on agricultural contracting are available from the Census of Agriculture, the Agricultural Resource Management Survey (ARMS), and other government and trade association reports. The appendix, “Data on Agricultural Contracts,” in MacDonald et al. explains these sources in detail.

² Similar variety is found in European agriculture. Vertical integration or tight vertical control led by large retailers is largely developed among northern members of E.U. (U.K., Germany, and

the Scandinavian countries). Complex contractual arrangements among hundreds or even thousands of participants are common in France, Italy, the Netherlands, and to a lesser degree Spain, particularly for developing and marketing products of “Protected Designations of Origin” and “Protected Geographical Indications” as well as organic products. Small independent producers that are less coordinated and tend to focus on local or regional markets are common in Southern Europe (Greece, Portugal, and parts of Spain, Italy and France) (Raynaud, Sauvée, and Valceschini; Ménard and Klein).

³ An extensive study of over 20,000 contracts in the poultry industry in France showed a differentiation among three types of contracts—“fixed-price,” “buy-and-sell,” and “putting-out” contracts—that clearly related to the degree of specific investments (Ménard).

⁴ Knoeber argues that grower ownership of production facilities serves as a performance bond; high-quality growers can signal their ability through their willingness to invest in costly, specialized equipment.

⁵ As noted by a referee, an important difference between livestock and crop production is that the former is today vastly less affected by weather and disease uncertainty than the latter. However, given that contract production and vertical integration are effective ways of managing such risks, one would expect more tightly coordinated forms of production to be relatively more attractive in crop, rather than livestock, production, the opposite of what we observe.

⁶ Some of the earliest modern studies on economic organization focused on agricultural contracting such as cropsharing (Stiglitz) and land tenancy arrangements (Roumasset and Uy, Alston and Higgs).

⁷ We do not say much about changes in risk preferences because, following Allen and Lueck, we question the role of risk in explaining the specific features of agricultural contracting. Allen and Lueck show, for example, that riskier crops are more likely to be associated with fixed-rent contracts, rather than share contracts, contrary to the predictions of standard agency models. Moreover, individuals often act simultaneously as principal in one transaction and agent in another, making it unlikely that contracting arises in response to differences in individuals' tolerances for risk. Allen and Lueck suggest instead that contracts serve primarily to reduce measurement costs and mitigate moral hazard problems arising from the unique characteristics of land. For a contrary perspective, arguing that studies of risk and transaction costs in agriculture do not adequately control for endogenous matching between principals and agents with unobserved idiosyncratic characteristics, see Akerberg and Botticini.

⁸ See Mazé and Raynaud et al. for discussions of contracting trends in Europe, where quality control plays a particularly strong role. They show, for example, that contracts involve an increasing number of detailed clauses regarding quality and the control and monitoring processes that render inputs traceable, all of which require increasingly tight control of the supply chain. On the other hand, the need for flexibility—for instance, matching producers' livestock to the ever changing quality needs of packers—sometimes leads to an increase in informal, relational contracting, rather than explicit agreements.

⁹ For a more complete discussion of the contract terms, see Sykuta and Parcell.

¹⁰ For example, in describing the developing of contracting in broilers, Martinez (1999, p. 3) states: "Financial resource requirements increased as production expanded and growers began operating broiler houses on a scale amenable to the new technology. Large capital requirements,

coupled with declining, highly variable live broiler prices, made broiler production a risky business. Many broiler growers ... were either financially unable to operate or unwilling to assume the price risk.” Large feed companies recognized the broiler industry’s potential for growth and the larger market that represented for their feed. Consequently, they established production contracts with growers.

¹¹ “Porcine Stress Syndrome (PSS) ... is directly related to the genetic predisposition for leanness that characterizes today’s hogs” (Rich, p. 7).