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Zoonotic Disease Risks and Socioeconomic Structure of Industrial Poultry Production: Review of the US Experience with Contract Growing

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ABSTRACT

The US model of food animal production, characterized by its industrial scale and organization, is currently expanding globally and supplanting traditional methods and organization of animal husbandry. These changes have multiple impacts, which include implications for control of zoonotic disease risks for both animal and human populations. The industrialization of poultry production into confined operations is viewed by some policy-makers as a way to reduce human health risks at this critical animal:human interface. Yet recent outbreaks of HPAI (highly pathogenic avian influenza) in poultry in the UK, the Netherlands, Canada and China, as well as little-publicized outbreaks of LPAI (low pathogenic avian influenza) the United States (US) in 2007 and 2008, provide evidence that these risks are not prevented by standard biosecurity and biocontainment practices. Large poultry operations, while confined, are not inherently bio-secure or bio-contained. Furthermore, the lack of adequate management of animal wastes and the transport of these and other byproduct materials over long distances may provide a major route of pathogen release and transfer.

Economic forces specific to large scale poultry production encourage the high level of vertical coordination observed in the industry. The US poultry industry, which may be regarded as the 'global role model', is characterized by the practice of contract poultry growing, in which firms

contract out the raising of live chickens to farmers who become highly dependent upon the continuation of contractual arrangements with firms. This system allows the firm (or integrator) to outsource negative externalities of production onto the grower and exclude byproducts that are hazardous and expensive to manage from the firm's costs of production. Contract growers assume the burdens of many of the financial costs, and also the negative health and social externalities of poultry production, including those associated with waste management, farm-level biosecurity and social decline.

In light of concerns regarding emerging zoonoses, particularly pandemic influenza, there are significant risks associated with a system, in which agribusinesses can selectively bypass responsibility for the management of potentially infectious wastes and the health of poultry workers. A full understanding of the US experience with poultry contract growing, with particular focus on the implications of this practice for zoonotic disease emergence and economic impacts for farm communities, can inform public health policies in nations where the private sector is increasingly adopting a similar contracting model.

1. Introduction

Methods of food animal production impact agricultural and national economies, consumer food safety, and the environment. Despite a growing awareness of the global food safety implications of current methods of food animal production, the effects of these practices on the health, economic and social wellbeing of rural communities are not well understood. With increased awareness of existing and emerging zoonotic disease, consideration of these practices is relevant to the development and implementation of programs for prevention and rapid response. Human contact with live poultry, both in small household farms and in industrial operations, is a clear risk factor for exposure to avian commensals that can infect humans, including bacteria such as *Campylobacter* spp., *Salmonella* spp., and *Listeria monocytogenes*, as well as viruses such as avian influenza. Epidemiological analyses of human infections with the H5N1 avian influenza strain demonstrate that close interaction with domesticated live poultry is a risk factor for human infection with the virus [van Boven *et al*., 2007; Babakir-Mina *et al*., 2007].

Over the past 70 years, the production of animals for human consumption has undergone dramatic transformations in intensity, scale and geographic concentration. The poultry industry in the US was the first sector in which rapid consolidation and vertical coordination occurred, starting in the 1930s, altering broiler poultry production from household-level enterprises to a high throughput agribusiness following an industrial model [Martinez 1999]. Today, this highly integrated and intensive nature of poultry production characterizes the industry in most developed countries; in the US, over 97% of broiler poultry products come from this system. This model is also being adopted globally. In particular, Thailand, Brazil and China, have witnessed a rapid industrialization in the production of food animals for domestic consumption and export in recent years, and these trends are expected to continue as demand for poultry increases around the world [OECD-FAO 2006].

The industrialization of food animal production facilitates the reliable production and delivery of low-cost animal protein to both domestic and global markets, providing improved quality control and the structure for the rapid uptake of new technology. Along with these benefits, however, high throughput animal husbandry has led to increased concerns about food quality, animal welfare, environmental contamination, sustainability due to high energy costs, cohesion of farming communities and the development of antibiotic resistance, among others [Cole *et al.,* 2000, Silbergeld *et al.*, 2008]. Additionally, the low costs seen by the consumer mask significant externalities associated with industrial food animal production, which may have dramatic impacts on public health and community welfare. Among these are the increasing risks of zoonotic diseases spreading from animals to humans.

Industrial poultry production in the US is characterized by contractual relationships between firms and poultry farmers. Firms within the industrial poultry model often contract the raising of chickens to independent farmers, who in turn are responsible for the delivery of chickens of market weight back to the firm for slaughter, processing and sale. The farmer is paid according to the acceptability and total weight of the finished product. He bears the costs of feed, energy, labor, and any loss of chickens over the growing period. Contract growing is a central component of the industrial poultry model in the US. This practice is being expanded both by US firms in other countries (e.g. Tyson in Mexico) as well as adopted by local businesses in some middle-income countries (e.g. Sadia in Brazil).

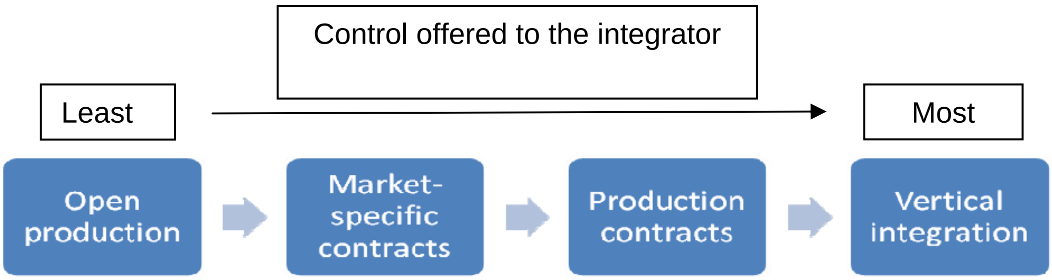
The implications of contract growing for zoonotic disease emergence and spread are not well understood. In this paper, we examine potential consequences of this production model for zoonotic disease exposure and the economic sustainability of rural communities. These two risks are related in that negative impacts on the socioeconomic vitality of communities can compromise access to health care. Because of the almost complete transformation of poultry production in the US to the industrial model, we highlight evidence from the US experience with contract growing, focusing on the economic forces driving vertical coordination in the industry and the documented impacts of contracting on workers and local communities. These experiences can help inform public health policies in other countries focused on protecting farming communities and maximizing benefits from poultry production.

2. Structure of the Poultry Industry in the United States

Industrial food animal production is defined by its high throughput production methods, in which thousands of animals of a single breed are grown at one site under highly controlled conditions. The animals are typically raised in confined housing, provided with defined feeds rather than access to forage, and managed to facilitate the uniform and reliable production of meat, milk or eggs.

The transformation of poultry production in the US over the past half century is characterized by vertical integration, vertical coordination and specialization. Vertical integration occurs when a single firm, known as an integrator, controls all or most aspects of production from "farm to fork." Vertical coordination is an organizational structure in which the firm ensures that each production process is managed and coordinated without the firm necessarily controlling all aspects of production.[1] Contracts between farmer and integrator in agriculture are typically market- or production-specific; poultry growing contracts are production contracts, granting the integrator greater control over the process. Figure 1 provides a visual depiction of a spectrum of organizational structure associated with contracts and vertical coordination.

Figure 1: Methods of vertical coordination and integrator control



Source: Mighell and Jones (1963)

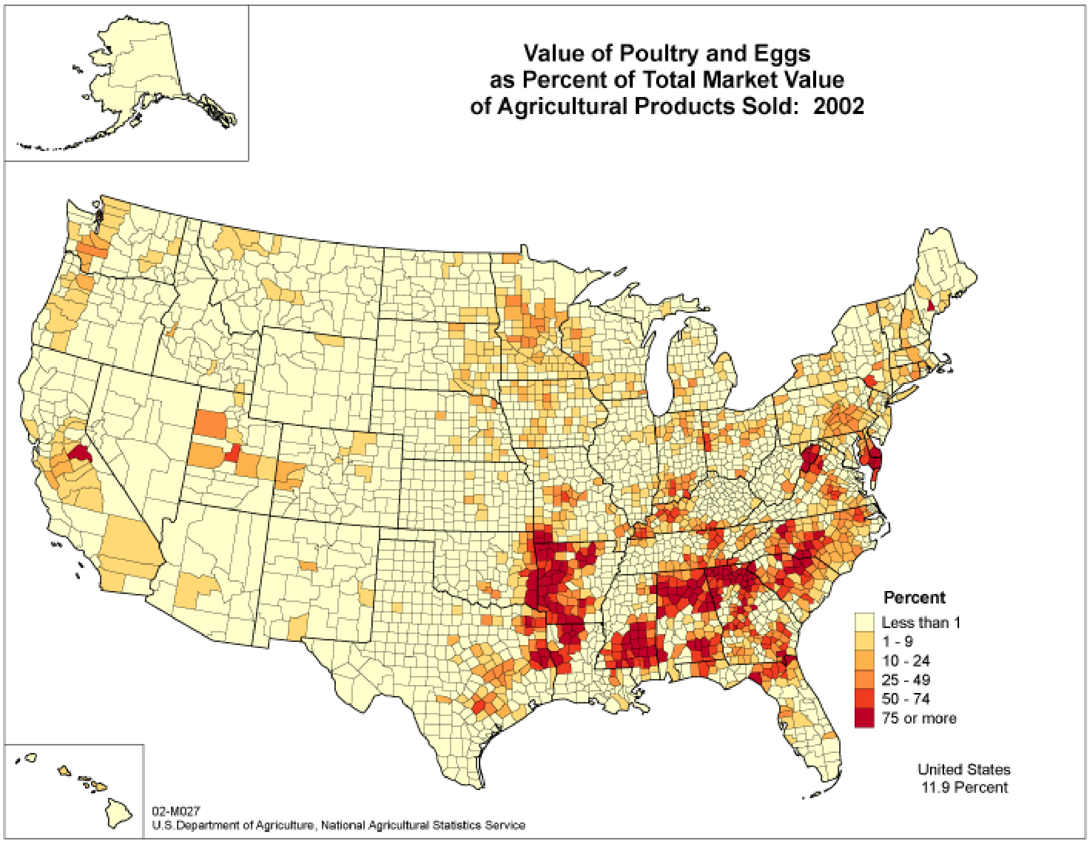
In the US, a relatively small number of corporations function as poultry integrators. Tyson Foods, Pilgrim's Pride, Gold Kist and Perdue together control production of 75% of the broilers sold annually by weight [US Poultry and Egg Association 2005]. The poultry industry is highly specialized, with different firms dominating egg, broiler and turkey production. Specialization

[1] From a precise definitional perspective, the poultry industry in the US is vertically coordinated, rather than integrated, since key functions (notably raising the animals) are contracted out; however, the central firm in this structure is commonly referred to as an integrator, and we will use this term in this paper.

allows firms to enhance economies of scale by narrowing the range of products produced and streamlining operations. Moreover, a key characteristic in the organization of the integrated industry is that the integrator controls the slaughter and processing of animals, thus maintaining economic control at the switch point between agriculture and animal-source inputs for the food industry. Because of this control, it is difficult for independent farmers, to enter the market.

The poultry industry in the US currently produces nearly nine billion broiler chickens per year [USDA 2005]. The industry observed staggering increases in production and concentration over the last half century. In 1954, there were no broiler poultry farms in the US with more than 100,000 birds. By 1974, 30% of farms had 100,000 birds or more, and by the middle of the 1990s, nearly 100% of broiler facilities housed more than 100,000 birds at a time [Hinrichs and Welch, 2002]. Broilers are the single largest commodity among poultry products, accounting for US$20.9 billion of the US$28.8 billion revenue from poultry in 2005 [USDA 2005]. Poultry production is highly concentrated along the eastern seaboard and southeastern states of the US, with nearly 70% of total value from poultry generated in the Northeast, Appalachia, Mississippi Delta and the Southeast (Figure 2).

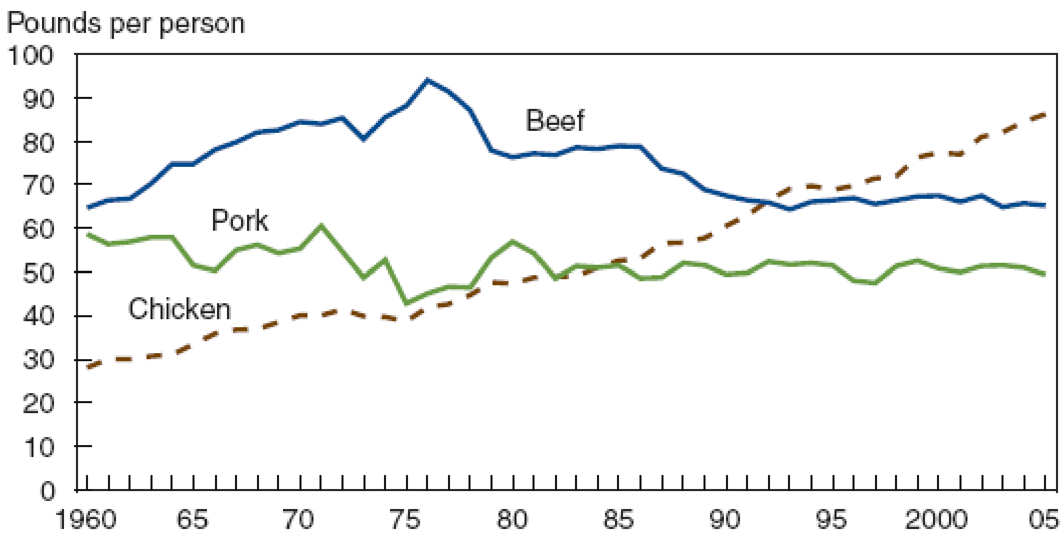
Figure 2: Value of poultry and eggs as percent of total market value of agricultural products sold in the US, 2002



Source: United States Department of Agriculture (USDA), Census of Agriculture, 2002.

This highly restricted localization of poultry production is independent of major markets or population centers in the US. The ability to absorb costs, including energy associated with transporting poultry products from these concentrated production areas to major market centers, speaks to the vast economies of scale derived from integration. Consumption of broilers has increased steadily in the US coinciding with the coordination of the industry, even as demand for other meat products has remained relatively stable (Figure 3).

Figure 3: Trends in *per capita* meat consumption in the US, 1960-2005



Source: MacDonald 2008.

This transformation in organization and density of production has profoundly affected the workforce involved in food animal production and the nature of this work in the US. On the farm, the growers manage and tend to flocks, usually with the help of a small number of hired workers and family members. Other workers are hired by the integrator, including chicken catchers, who harvest live chickens from the growers' facilities at the end of the six week growing cycle. At present, Gray *et al.* (2007) estimate that there are 54,000 poultry and swine workers in the US, of which 10,500 work in broiler confinement facilities.

3. Limits of an Open Market in Poultry: The Economic Motivation for Vertical Co-ordination

Costs and capital investments specific to broiler production contribute to the high level of vertical coordination observed in this industry. Commercial poultry producers in the early 20th century were subject to open market forces which created significant uncertainty for small firms (often family operations), and as a result, some of these firms sought to control multiple aspects of the production process to reduce financial risk. The Perdue Company is often considered a pioneer in this respect beginning with its operations in the 1930s (see http://www.perdue.com/company/history/index.html).

Here, we discuss five central drivers of vertical coordination and integration in the industry: (i) the desire to align supply with consumer demand; (ii) reduce opportunistic behavior stemming from specific assets; (iii) reduce transaction costs; (iv) improve quality control and product uniformity; and (v) achieve economies of scale through improvements in management and feed technology. These drivers play a role in shaping the structure of the industry worldwide, by affecting incentives faced by commercial poultry producers.

Supply and demand alignment

Poultry production is a multi-staged process with distinct components, including the growing of feed crops and feed production, breeding and maintaining breeder stocks, hatching, growing, slaughter, processing/packing and distribution. In the first half of the 20th century, the commercial poultry industry in the US was characterized by different firms independently controlling these various phases of production. The involvement of multiple firms and physical distances among stages of production in the pre-integrated poultry industry resulted in a lack of coordination among the different participants in the supply chain. This disconnection inherently limited producers' ability to adapt production in a timely way to changing consumer demand, and led to overproduction [Martinez 1999]. As the industry grew in the late 1950s, prices became increasingly unstable as a result of dramatic increases in supply; between 1958 and 1959, live broiler prices dropped 13% [Martinez 1999]. Vertical coordination was a mechanism to better control supply and, by extension, poultry prices.

Control over processing in particular became the key to controlling the industry since processing occupies the middle ground between production and consumption. Control over processing allowed the firm to match the flow of raw inputs with the supply of products to the market. Integrators could strategically match the flow of live animals to the capacity of the processing facility and price the product to maximize efficient use of these facilities [Martinez 1999].

Specific assets

Commercial poultry production is characterized by significant capital investment in facilities with limited alternative uses, termed 'specific assets.' Specific assets can encourage opportunistic behavior, in which one party takes advantage of another's production constraints. Reducing opportunistic behavior along the production line was a key motivator for vertical integration.

Additionally, contracting allows integrators to pass on the economic burden of specific assets within the industry to growers, reducing their own expenditure for such assets.

Specific assets can be of three types – temporal, site, and functional – all of which are relevant for broiler production and encouraged integration. Temporal specific assets are those whose value decreases rapidly with time lags in production. The quality of fresh broiler meat quickly deteriorates after collection from the farm, and in the absence of a vertically coordinated system, processing firms could extort extra payments from growers by stalling slaughter after the animals are collected. Site specific assets refer to property whose geographic location or type is of central importance to profit. Since poultry quality decreases rapidly with transport and time, integrators sought to co-localize facilities involved in the business – feed mills, hatcheries, growing houses, and processing and distribution facilities – in areas with access to markets.

Specific assets that are limited by function are especially relevant in broiler production. As the technological and density requirements for chicken houses increased, these facilities become increasingly expensive to build and maintain, effectively preventing reuse for another purpose without major reinvestment. Contract growing allows integrators to avoid investment in these functionally limited specific assets, passing these capital costs on to growers.

Reducing transaction costs

Reducing the high transaction costs within a multi-firm production model also provides a strong incentive for integration. Costs associated with negotiations and inter-firm coordination along the production chain from hatching to distribution depressed overall profits, and firms saw a distinct financial benefit in eliminating these costs [Martinez 2004; Frank and Henderson, 1992].

Quality control

Integration allows firms to reduce costs associated with quality control by creating streamlined, consistent methods of production that result in uniform products. Food safety regulations, particularly the Poultry Products Inspection Act of 1959, provided an impetus to standardize production techniques and output. This legislation required the USDA to inspect all poultry for sale in the US. As the costs associated with ensuring food safety increased alongside regulatory demands, firms could capture significant savings by developing higher throughput facilities and standard processes that made body sizes equivalent and facilitated inspection at the most expeditious points, as well as improve the efficiency of slaughter and processing [Martinez 1999; Hennessy 1996]. Uniformity also allowed firms to differentiate their product based on price and establish brand-name recognition.

The 1959 legislation also effectively forced smaller and independent farms into contracting relationships or out of production by forbidding slaughter on the farm. The separation between poultry growing and slaughter encouraged the development of large slaughterhouse facilities which could spread the costs of regulatory compliance over many animals (Pollan 2006). Contractual relationships with integrators became a means of securing market access for growers.

Economies of scale through advances in technology

Integration lets firms achieve economies of scale and maximize efficiency and output. The marginal cost of producing additional broilers was greatly offset by the increased revenue generated from reductions in growing time and increases in processing speed, as well as reduced poultry morbidity and mortality. The ability to achieve heightened output and significant economies of scale was facilitated by three innovations: 1) breeding to maximize weight gain, specifically that of the most desired portions (in the US, broiler breast meat); 2) standardizing growing conditions to maximize and standardize size and growth (for example, maintaining a 24 hour light cycle in growing houses to increase feed intake); and 3) formulation of specific feeds with additives. Innovations intended to maximize growth and weight gain increased the amount of saleable meat per unit input and reduced the labor necessary to grow poultry. In addition, breeding to standardize the size of chickens allows for mechanization in slaughter and processing, reducing costs associated with these processes [Bugos 1992].

Technological advances in poultry growing, including mixing feed with specific nutrients, climate-controlled facilities and high-throughput ventilation systems within animal houses facilitated the containment of thousands of animals at one time and reduced the marginal cost of increasing the size of the flock. Confinement itself encouraged further automation in animal husbandry technology, including feeding and watering equipment and chick sorters, which reduced labor inputs and further standardized output. The introduction of antibiotics as additives to animal feed, based on observation of decreased feed consumption and increased growth rates began in the US in 1947 and continues in widespread practice to facilitate dense poultry production with fewer costly inputs [Silbergeld *et al.*, 2008]. Recent evidence indicates, however, that the costs of antibiotic use in food animals, notably for growth promotion, may exceed their benefits [Graham *et al*., 2007].

4. Contract Growing: A modern 'Share-cropping' Model

Contract growing became commonplace in the US soon after mid-20th century. By 1960, 90% of broiler production occurred through contract growing [Welsh 1997], and currently more than 98%

of broilers produced in the US are raised by contract growers [MacDonald 2008]. Integrators breed the parent stock, produce and hatch eggs, and provide chicks, feed and veterinary care (including antibiotics and other additives). Growers provide chicken houses, labor, utilities and operating and maintenance costs. Growers are responsible for the disposal of animal wastes and dead birds as well as cleaning and sanitizing their facilities. Notably, growers are also responsible for many of the costs associated with the implementation of biosecurity measures at the farm level. Growers often, but not always, own the land on which animals are raised, but they do not own the animals.

Contract growers are required to sign exclusive contracts with integrators and therefore cannot produce chickens for multiple integrators at a time. Often, a single integrator dominates a given region, so it is impossible for a grower to switch integrators [MacDonald 2008]. Integrators retain ownership of the animals throughout the growing process and have full access to the contract growers' facilities.

In essence, the grower's product is his labor and capital investment, not the animals he raises. The system is reminiscent of sharecropping, an agricultural system common in the American South in the second half of the 19th century, in which the farmer sells his labor and works land owned by others in exchange for a share in the profits determined by the firm to which he is contracted. Sharecroppers, like poultry growers, also did not sell directly to the consumer market and therefore could not adjust directly to market demands.

Integrators set the criteria for raising chickens in the contract, which requires chicken houses to be built to precise specifications, including stipulations for design, construction, ventilation, heating, cooling and lighting systems. One of the incentives to grow poultry rather than other animals or crops is that return per acre of land is relatively high and labor inputs relatively low for an agricultural investment, and as a result, many growers operate multiple poultry houses at a single time. Most growers in a recent USDA survey reported having six or fewer poultry houses on their properties (Table 1). Approximately 43% of growers have 3-4 houses, and farms of this size contribute 37% of total broilers by weight. While fewer than 4.5% of growers have nine or more houses, these large farms contribute nearly 15% of total broiler production [MacDonald 2008].

Start-up costs for poultry growing are considerable and growers may borrow as much as 110% of the cost of construction over 10-15 year loans. A contract with an integrator makes it easier for growers to secure loans [Stull and Broadway, 2003]. Start-up costs per growing house average US$170,000, and new growers entering the industry often face costs up to US$600,000 for multiple houses [Cunningham 2005].

Table 1: Farm organization, by size of broiler operation, 2008

Number of houses	Percent of farms in survey*	Pounds of broilers removed (% of total)
1-2	27.3	10.7
3-4	43.1	37.4
5-6	18.7	26.0
7-8	6.1	11.3
9-10	1.7	4.2
11-12	1.2	3.6
13-18	1.6	6.7
Total	**100.0**	**100.0**

* Farms with more than 1,000 broilers at a time and located in the 17 US states that contains 94% of poultry production were approached for participation in the survey. Responses from 1,568 farms were included in the results presented here.

Source: MacDonald 2008.

Production contracts specify payment in terms of pounds of acceptable live broiler produced at the end of the growing period. However, this payment is reduced by the cost of feeds required to bring the flock to market weight, and the grower bears the costs of energy and labor (hiring workers) over the time required to reach market weight. Specifics of grower contracts differ by integrator, but most are structured using a “tournament scheme” in which a component of payment is based on relative performance of a given grower. For the tournament component of payment, growers are rewarded or penalized based on their feed conversion rate (the amount of feed required to produce a set weight of acceptable broiler at the end of the growing period) in comparison to that of a comparable group of growers contracted with the same integrator that same harvest period. Contracts also generally include a minimum guaranteed payment per pound of saleable meat (currently about US$.05/pound).

While contract duration varies in length by integrator, most are very short term and cover a single flock at a time (about six weeks) [Vukina and Leegomonchai, 2006]. Contracts generally do not guarantee the number of flocks the grower will receive per year. A recent study by the USDA found that 45% of growers reported that their contracts only cover a single flock at a time, with another 23% having contracts lasting from 1-3 years [MacDonald 2008]. The short term nature of contracts between the grower and the integrator, coupled with the high capital costs and debt associated with contract growing, create significant job insecurity for contractors. The system effectively binds growers financially to their integrator’s conditions of contract renewal and worsens the power imbalance between grower and integrator.

Growing contracts provide clear benefits to integrators. They allow integrators to retain control of the stages of production most critical in maintaining the link between demand and supply and safeguard them from a central form of uncertainty in the poultry production process: the actual rearing and survival of marketable chickens. Tournament payments reduce the cost of contracting to the integrator and allow the integrator to pass on some of the risk involved in raising healthy chickens to the grower. This contract structure rewards technical efficiency among growers, to the extent possible given integrator specifications, promoting efficient use of feed, antibiotics, energy and labor inputs [Knoeber 1989]. Contracting also allows integrators to accommodate new technology into production practices without incurring significant costs to the firm, by making such upgrades a requirement of contract renewal [Vukina 2001].

Importantly, contracting allows integrators to avoid two large costs, both of which are shifted to the grower: costs associated with waste management, allowing the integrator freedom to increase production density with reduced concern for regulatory or environmental constraints posed by disposal of a high volume of animal wastes; and the cost of capital investment in building and maintaining chicken houses. Growers, not integrators, absorb the risk associated with these specific assets, effectively binding them to poultry production. The location of the growing facilities in close proximity to a particular processing plant and/or a feed mill may also bind a grower to a specific integrator, as can construction and maintenance specifications that vary among firms, making it difficult for a grower to switch integrators [Vukina and Leegomonchai, 2006]. Due to their substantial personal investment in highly specialized chicken houses and limited employment alternatives in many agricultural regions, contract growing creates an uneven economic dynamic that disadvantages growers [Knoeber 1989].

Contracting does pose certain benefits for growers. Contracting ensures the grower a market for his product during contracted periods. A steady relationship with an integrator can alleviate the cash flow problems that often plague independent farmers [Vukina 2006]. As noted earlier, the intensive methods of broiler production reduce the labor costs for farmers. Furthermore, contract growing provides an opportunity for farmers to maintain a rural, agricultural lifestyle despite national declines in numbers of small farms, especially in the traditionally agricultural regions of the southern US.

Despite these benefits, however, many contract growers express significant discontent about relationships with integrators. A 1999 survey of 1424 contract growers in 10 states found the tournament scheme in particular to be the source of considerable grievances [Farmers' Legal Action Group, 2001]. Nearly half of growers surveyed believed that the tournament scheme provided poor incentives for hard work. Seventy-eight percent of growers responded that their pay depended more on the quality of the inputs provided by the integrator (chicks, feed) than on the quality of their own labor. Grower distrust of the integrator's measurements was also a significant issue in the survey. One-third of respondents expressed confusion regarding their post-harvest settlement sheets, and growers also articulated mistrust about the accuracy of feed weighing, the prompt weighing of birds at the processing facility and higher than expected condemnation rates at processing. One-third of respondents reported that they are sometimes or often left without a contract long enough to cause financial hardship.

5. Contracting: Shifting the Burdens of Poultry Production

From a financial perspective, as discussed, contracting allows integrators to maintain equity in the product and control over its production while shifting some of the risks involved in producing live animals to the contractor. From a public health vantage point, contracting results in a transfer of the health risk associated with intense exposure to live animals and their wastes from integrator to grower, and, in the absence of regulatory controls, ultimately to the public.

High density animal production is associated with a host of risks to occupational health and community well-being, from infections and respiratory disease to odor pollution [Cole *et al*., 2000; Donham *et al*., 2007; Warner *et al*., 1990; Wing and Wolf, 2000]. Below, we highlight five negative externalities of contract growing that are relevant to public health, with specific focus on implications for zoonotic disease emergence and economic solvency of farming communities: 1) waste management; 2) occupational exposures to zoonotic pathogens; 3) peri-occupational and community exposures to these pathogens; 4) farm-level biosecurity; and 5) decline of farm communities.

Waste management

The USDA estimates that confined food animals produce more than 300 billion kg of waste per year, which is more than 40 times the mass of human biosolids generated annually [USDA 2007]. It is estimated that the nine billion broiler chickens grown annually in the US produce between 12 and 23 billion kg of waste per year [Nachman *et al*., 2005]. The management of animal wastes and the disposal of dead birds is the sole responsibility of the grower.

Unlike human wastes, animal manure is subjected to few regulations regarding treatment and none for disposal. Ninety percent of poultry litter (which includes excreta, spilled food, dead animals, and the layer of sawdust or other material spread on the floor of the poultry house) is applied to land or stored in heaps until land application or transport off the farm [Graham 2007]. Many enteric organisms can survive for long periods of time, from days to months, in manure and wastewater [Nicholson *et al*., 2005; Guan and Holley, 2003]. Bacterial pathogens such as *Campylobacter spp, Salmonella spp*, *Clostridium perfringens* and *Listeria monocytogenes* can be present in fresh poultry manure at high levels, and infectious doses are observed even following holding on site [Cole *et al*., 2000]. Additionally, viral persistence in poultry manure poses exposure risks to zoonotic viruses. Infectious titers of avian influenza virus have been recovered from the manure of infected chickens for up to three weeks [Lu *et al*., 2003]. Methods of storage and transport of manure is hypothesized to be a potential source of spread of zoonotic agents [Gilchrist *et al*., 2006; Graham 2007].

Grower exposure to zoonotic pathogens

Growers, catchers and their families are exposed to zoonotic pathogens from occupational contact with live birds and poultry manure. Among these populations, exposure to viral and bacterial pathogens may result from working in the confinement house itself, handling live chickens, cleaning the confinement house and transporting animal waste. Potential exposure pathways include inhalation and ingestion of dusts (inside and near to the poultry house), exposure from lacerations, eye exposure and cross-contamination of drinking water or food on the farm.

While contact between poultry workers and poultry occurs in the absence of a contract growing system, contracting disassociates the integrator from the consequences – both to the individual worker and to the general public – of this exposure. The contracting structure thereby eliminates integrator responsibility for the human health risks of poultry production. Growers are principally responsible for worker health and safety measures taken on the farm, and worker protection from occupational hazards is often limited. In the US, workers are typically not provided clothing or other personal protective equipment when entering the poultry house, and report washing work clothing at home in a recent study [Price *et al*., 2007]. There is typically no cleaning and hygiene facilities provided to these workers. The risks associated with occupational contact with poultry are therefore amplified in this system.

Occupational exposure to broiler chickens has been shown to increase risk of infection with enteric bacteria, including *Enterococci*, *E. coli*, and *Campylobacter jejuni* [van den Boggard *et al*., 2002; Price *et al*., 2007; Wilson 2004]. In an experimental study, Ojeniyi (1989) inoculated chickens with an introduced strain of *E.coli*, and poultry workers in contact with these birds were quickly infected by this strain. The implications of zoonotic bacterial infection are clearly intensified by the presence of antibiotic resistant strains (due to use of antimicrobials in animal feeds), which complicate treatment and may prolong illness. Poultry workers on the Delmarva Peninsula were shown to have 32 times the odds of carrying gentamicin resistant *E.coli* and five times the odds of being infected with a multidrug resistant strain of *E. coli* in a recent study [Price *et al*., 2007].

Confinement workers and growers also have increased risks of exposure to zoonotic viruses, and this is of concern for pandemic influenza in particular, as it poses opportunities for viral evolution and development of human-human transmissible strains. An analysis of human infection with H5N1 in Hong Kong during the 1997-1998 outbreak found that occupational tasks involving direct contact with live poultry were significantly associated with seropositivity to H5N1 [Bridges *et al*., 2002]. In fact, only those occupational tasks which involved handling live poultry were associated with increased risk of infection. In a study of the H7N1 outbreak in the Netherlands in 2003, Koopmans *et al*. (2004) found the highest rates of human seroprevalence in individuals with occupational contact with poultry, including cullers, veterinarians and farmers. Puzelli *et al*. (2005) reported serological evidence of avian-to-human transmission of both high and low pathogenic strains of the H7 viral subtype among Italian poultry workers. Together, these observations indicate that occupational exposure to industrial poultry production, through growing and working with live poultry, poses a distinct and significant risk of infection with avian influenza viruses.

Peri-occupational and community exposure

While growers and poultry workers themselves experience the most direct contact with live poultry and are at highest risk for zoonotic disease exposure, their families and communities are also at elevated risk of exposure and infection. More research is needed to fully illustrate the peri-occupational and community infectious disease risks from confinement facilities, but recent analyses indicate ample reason for concern, particularly for influenza transmission [Graham *et al*., 2008; Gray *et al*., 2007]. In an analysis of the H7N1 outbreak in the Netherlands in 2003, Fouchier *et al*. (2004) identified H7 seroprevalence in family members of farm workers, indicating that peri-occupational pathways of exposure are viable for influenza viruses. Fey *et al*. (2002) documented the case of a farm child infected by ceftriaxone-resistant *Salmonella*, and Gupta *et al.* (2003) identified indistinguishable isolates of ceftriaxone-resistant *Salmonella* in cattle and residents of farm communities. Transmission of methicillin resistant *Staphylococcus aureus* to families of hog farmers has been reported in the Netherlands, with molecular methods confirming the clonality of human and hog isolates [Huijsdens *et al*., 2006]. These studies imply that farm families and communities are a population of elevated risk for infection with farm-based zoonotic pathogens.

Furthermore, community exposures to drug-resistant bacteria emerging from confinement houses are of significant concern for public health. Poor waste management practices contribute to the spread of antibiotic resistant bacteria in the environment near food animal production facilities, putting community members at increased risk of exposure to drug resistant strains through air and water pollution [Chapin *et al*., 2005; Sapkota *et al*., 2007; Anderson and Sobsey, 2006]. The geographic concentration of industrial food animal production intensifies the impacts of these exposures for farm communities [Silbergeld *et al*., 2008].

Growers and their families face the risk of sizable economic burdens from zoonotic illnesses, particularly from drug resistant infections. In the absence of national health care resources in the US, the costs associated with these illnesses (including lost work time and any treatment) are largely borne by growers, workers and their families. As contract employees, growers generally receive few, if any, health benefits from integrators, which may result in reduced access to primary care and delayed identification and treatment of disease. Farm-based practices to reduce grower exposure to zoonotic agents, such as the purchase and use of personal protective equipment, are also the sole financial responsibility of the grower. In these ways, the health conditions and health care costs that result from continuous exposure to a high density of live chickens in a confined environment – an exposure required by the very nature of contract growing for a broiler integrator in the US – remain an externality of production, borne not by the integrator but by the grower and community. If the community resources are impacted by industrial food animal operations, as is often the case [Wing and Wolf, 2000], then the community may be unable to provide these services and the burden of disease may fall more broadly on society.

Investments for biosecurity and biocontainment

Farm-level biosecurity can reduce opportunities for the transfer of pathogens among birds and between poultry and humans. In a vertically coordinated system, integrators generally set company-wide biosecurity standards and guidelines for growers to follow. However, these standards often entail additional costs for the grower – including the purchase of new equipment, disinfectant, or structural adjustments. The integrator does not provide financial compensation for these upgrades, which may reduce the incentive for compliance. In the event of an outbreak of a notifiable disease, growers may also experience significant financial losses from culling or flock loss. Indemnity programs for reportable poultry diseases typically exclude direct payment to contract growers, despite the fact that both integrators and growers have invested resources into the flock [World Bank 2006]. In the US, the USDA and states pay integrators up to 75% of the appraised value of the flock lost due to HPAI. Integrators are encouraged, but not required, to compensate the growers for their losses on the basis of what they would have earned had the flock not been culled [Ott and Bergmeier, 2005]. Yet due to low profit margins in the industry, the established level of compensation is generally not high enough for integrators to cover their own losses as well as those of growers. Costs associated with depopulating and disinfecting growing houses in an outbreak situation, as well as waste management, are not included in the compensation scheme, and these are borne entirely by the grower. Compensation schemes are intended to provide incentives for the early reporting and culling of infected animals to prevent disease spread. Strategies that fail to acknowledge the full financial investment of growers may have the effect of discouraging the early and complete reporting they were designed to facilitate.

Economic impacts of contracting

Industrial poultry production has considerable economic impacts at the community and regional levels. Industrial poultry facilities often bring increased investment to communities, including jobs, tax revenue, and road and utility infrastructure. These local benefits can be significant, especially in low-income rural areas, and for this reason are often welcomed by some individuals. Across the agricultural sector, however, vertical concentration and industrialization are associated with economic and community decline as well as decreased tax receipts and local purchases [MacCannell 1988; Foltz *et al*., 2002; Durrenberger and Thu, 1996]. Property values have also been observed to drop after a confinement house locates in a community [Abeles-Allison and Conner, 1990].

On the individual level, economic returns from contract growing are relatively low, and poultry growers do not earn significant profits through contract relationships. Growers invest approximately 50% of the capital necessary to produce broiler chickens, but earn less than 3% of returns annually on their investment [Morison, 2007]. Off-farm income contributes a large proportion of total income for grower families, ranging from over 80% for small growers to 34% for large growers. The average annual income from poultry among growers in a 2008 survey was US$27,643 [MacDonald 2008]. While farm income for large-scale growers seems quite high (US$86,000 in 2008), these income data exclude information on farm debt and debt payments. Growers often face high levels of debt associated from start-up and refurbishing costs. More than half of growers surveyed in the 1999 study took on US$100,000 or more to finance the operation, and 52% still owed 75% or more on the total farm debt at the time of survey [Farmers' Legal Action Group 2001].

Financial challenges are only one of the issues facing poultry growing communities. In the US, one reason for the geographic location of poultry production is related to community empowerment: the siting of confined animal facilities is disproportionately in non-white, low-income communities, who may not have the political or economic resources to resist the industry or mitigate its health and environmental consequences [Wing *et al*., 2000]. Confinement houses are more likely to be located in communities with high percentiles of African Americans or persons living in poverty [Wilson *et al*., 2002; Ladd and Edward, 2002] and near low-income and non-white schools, compared to middle income white schools [Mirabelli *et al*., 2006]. As a consequence, the presence of confinement houses negatively impacts already tenuous social capital, causing rifts and social gaps between independent and contract farmers, and antagonism and hostility directed towards supporters and opponents of industrial food animal production

[Wright *et al*., 2001]. These studies strongly suggest that the practice of contract growing has important negative connotations for both equity and community cohesion, which are independent factors in community health.

6. Policy Implications

Industrial poultry production brings benefits to consumers through reduced prices, and greater security and availability of food products. Yet many of the negative implications of industrial poultry production to public health and other areas are largely externalized from the production costs borne by the integrators. The practice of contract growing facilitates the outsourcing of negative externalities onto growers, poultry workers, local communities and the general public. This system has local impacts on the health and economic survival of farm communities as well as critical implications for global disease emergence.

As contract growing is adopted by poultry producers in middle and low income countries, attention must be paid to these negative externalities – and also to the system that facilitates them. Policies that shift the financial and regulatory responsibility of waste management, biosecurity and worker health and safety from the contractor-grower to the contractee-integrator are critical to reduce the negative implications of this system. Contractual relationships between growers and integrators are not inherently problematic. Rather, it is the specific manner in which this system has evolved in the US that contributes to its negative impacts. The US contracting system results in transfers of responsibility for the negative byproducts of poultry production – expressed in economic and health terms – from the entity who has control over the conditions of production (the integrator) to one who does not (the grower). The grower is dependent on the contractual relationship, due to high upfront and ongoing costs of poultry production, and therefore largely unable to meaningfully oppose contractual terms.

One glaring example of the implications of this system is the obstacles to improved waste management, which under the US system is the responsibility of the grower. In order to improve animal waste management (to require pretreatment prior to disposal), policies must consider the liability of the integrator. The integrator, not the grower, makes decisions relating to the density of animals on the farm and the input to the feed – factors which contribute to the amount and composition (including pathogens and antimicrobial agents) of poultry waste. This problem exists in swine contract farming as well; in the case of swine production, integrator requirements for housing result in the production of liquid waste streams that are very difficult to manage. Waste liability strategies that fall solely on the resource-constrained grower, who has little to no ability to alter the inputs that affect waste, do not recognize the obstacles to improved management by the grower and may thus contribute to continued problems in the management of animal waste. Shifting legal liability to integrators, or sharing liability between integrator and grower, would better encourage appropriate disposal and treatment. Furthermore, increasing integrator responsibility for waste disposal could incentivize modifications that reduce the amount of waste produced and encourage effective and affordable waste treatment (at either a farm-based or collectivized scale) by aligning profit motives with public health goals.

Even more important in the context of zoonotic disease risks, a realignment of responsibility and liability is critical to support improvements in farm-based biosecurity standards. Costs associated with implementing biosecurity plans should be shared between integrators and growers, acknowledging the shared investment in the flock. Current practices that require growers to pay for biosecurity upgrades themselves – renovations which benefit the industry as a whole – ignore the integrator's substantial stake in ensuring biosecure operations.

Similarly, regulatory standards should require integrators, rather than the growers, to provide personal protective equipment (including goggles, gloves, aprons and boots) to shield growers and poultry workers from zoonotic disease exposure. Growers currently provide their own protective equipment, which can be costly. Regulation of worker health and safety for farm workers in the US is limited, and recommendations for protecting workers from avian influenza exposure lack regulatory force (NIOSH 2008). While the agricultural exemption from occupational health and safety laws disregards the many hazards associated with farm work [Kelsey 1994], the lack of protective standards for poultry workers has egregious implications for public health, particularly as it pertains to avian influenza. While a clear solution would be to end the regulatory exemption for farm workers, a more near-term strategy lies in shifting the cost burden of purchasing protective equipment from growers to integrators, recognizing the shared responsibility for safety in the industry.

Additionally, compensation schemes must be redesigned to reduce unequal burden on contract growers and ensure both fairness and effectiveness. One of the most obvious gaps in biosecurity response is the current indemnity policies for flock loss associated with avian influenza outbreaks. These plans do include direct payment to growers, but rather leaves their compensation to the discretion of integrators. Fair compensation schemes reimbursing growers are vital in setting incentives to report infected birds quickly. Compensation schemes that do not ensure prompt direct payment to contract growers provide the wrong incentives for halting emerging diseases.

Access to health care services for contract growers and farm communities are also necessary to provide front-line surveillance for emerging zoonotic diseases. As contract employees, most growers do not receive health benefits from integrators. In the absence of employer- or state-sponsored health care, this is both a health and a financial risk. Integrators must take on greater responsibility for the health of their workforce by including growers and other contract workers in employer-sponsored insurance programs.

Limited access to health care results in reduced surveillance of grower populations. Active surveillance of poultry worker and community health is a vital component of public health policy in nations with industrial animal production; the lack of health surveillance among growers, poultry workers and their families represents a critical missing link in plans for preventing pandemic influenza [Gray *et al.* 2007]. Public health resources should also be devoted to monitoring the health of these workers, even those who are undocumented, so that emerging diseases are identified quickly. Given that both integrators and the public benefit from intensive animal production, community health monitoring provides a potential opportunity for public/private partnerships that can involve private corporations, governments, universities and non-governmental organizations.

Addressing the socioeconomic impacts of contract growing is a challenging issue that requires regulatory, legal and non-governmental approaches. Laws to strengthen contractor rights within negotiations and assume fair payment schemes can protect workers. Non-governmental organizations, particularly advocacy organizations and unions, play an important role in improving contract conditions for growers. Strategies to include growers as direct employees of the firm would also include them under minimum wage laws and provide health benefits in some situations.

The experience with contract growing in the US provides important insights for other nations who adopt this practice as a component of industrialized poultry production. Contract growing imposes significant health and economic risks on growers and farm communities, as well as the general public. Public health and agricultural policies must consider factors specific to the contracting relationship and the externalities of industrial poultry production in order to successfully mitigate these risks.

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