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Consumer Demand for Organic Milk Continues to Expand—Can the U.S. Dairy Sector Catch Up?

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The U.S. Department of Agriculture's (USDA) Market News reported widespread concern in 2014 about tightening organic dairy supplies, with supermarkets in many parts of the United States posting signs about organic milk shortages by the end of the year. U.S. food retailers and milk processors have informed customers that they can't meet demands for organic milk a number of times since the organic dairy sector gained traction with consumers over a dozen years ago. The number of certified organic milk cows in the United States increased rapidly between 2000 and 2008—to over 250,000 organic milk cows (3% of the U.S. total)—and then stagnated through 2011, according to USDA's most recent estimate (USDA Economic Research Service (ERS), 2013).

Some organic dairy producers exited the sector in 2009 when processors cut back on organic dairy contracts during the downturn in the U.S. economy. Organic milk demand rebounded quickly, but movement back into organic production is complicated by the three-year transition period required for land that is in conventional production. Expanding milk demand, along with recent drought conditions and high organic feed grain prices, especially in California, are also playing roles in the current shortages.

U.S. milk production began dispersing from its concentration in the Northeast, Upper Midwest, and Central regions—the traditional U.S. milk shed—many decades ago (Jesse, 2002). California is the top conventional dairy state, and also became the top organic dairy state in 2008 with the largest number of certified organic milk cows. Although California had nearly a quarter of the certified organic milk cows in the United States in 2011, traditional milk-shed states still play large roles in organic dairy production.

Organic dairy pastures are beginning to disappear in California due to the devastating drought over the last several years. Organic dairy producers in California are also facing high organic feed grain prices and strong competition for their land from other high-value commodities, which could weaken organic dairy production in that state (Thomas, 2014). Even if California production declines, continuing development of organic dairy production in the traditional milk-shed states, lower feed grain prices, and diversity in the business models used for organic dairy production could support expansion of the U.S. organic dairy sector.

Consumer Base for Organic Dairy Continues to Widen

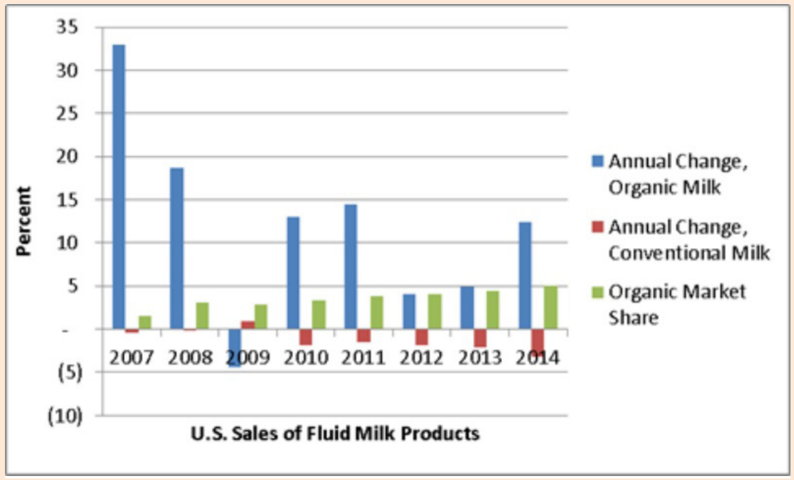
Organic dairy products are now the second leading food category—after fresh fruits and vegetables—for U.S. sales of organic food. Numerous studies have underscored consumer preferences for organically produced food because of their concerns regarding the environment, animal welfare, and their own health. Although nutritionists have not yet reached a consensus about whether organic food offers more nutrients than conventional food, there is evidence that enhanced nutrition is associated with organic dairy products. A recent meta-analysis of studies during 2009-11 comparing the nutrient quality of organic and conventional dairy products found that organic dairy products contain significantly higher protein, α-linolenic acid (ALA, C18 : 3 n-3), total omega-3 fatty acid, conjugated linoleic acid, and other nutrients. The meta analysis concluded that organic dairy farming leads to enhanced nutrient quality due to the higher fresh forage intake of organic cows (Palupil et al., 2012). A subsequent study—the first large-scale, nationwide study of fatty acids in U.S. organic and conventional milk—found that consumption of predominantly organic dairy products may enhance public health by decreasing dietary omega-6 to omega-3 ratios from today's generally unhealthy levels (Benbrook et al., 2013).

Organic products have shifted from being a lifestyle choice for a small share of consumers to being consumed at least occasionally by a majority of Americans. Similarly, mass market retailers, rather than natural food stores, are now the top sales channels for organic food. Walmart, the largest food retailer in the United States, and other supercenters that often target budget-conscious consumers, are continuing to increase their organic food offerings—both Walmart and Target announced new organic food initiatives in 2014. Also, USDA Market News recently reported that a national drugstore chain added organic milk to its cooler section in 2014.

In 1997—the year that USDA published its first proposed rule to establish national organic standards—industry estimates pegged retail sales of organic milk, yogurt, butter, cheese, and other dairy products at $382 million in the United States (Nutrition Business Journal, 2013). Retail sales of organic dairy products more than tripled between 1997 and 2002, to $1.2 billion, and are forecast to reach $5.5 billion in 2014.

In contrast, overall U.S. consumption of milk, yogurt, butter, cheese and other dairy products has fallen from 339.2 pounds per person in 1970 to 275.9 pounds in 2012 (Bentley, 2014), although total milk production increased during this period due to increasing consumption of yogurt, cheese, and other manufactured

Figure 1: U.S. Market Penetration of Organic Milk, 2007-2014



Source: AMS-USDA, Federal Milk Market Order statistics.
Note: Estimates for 2014 are for the first half only.

dairy products which take more pounds of milk to produce. Most of the decline in U.S. dairy consumption is due to the substantial drop in milk consumption during this period, and Americans now consume only about 75% of the amount of dairy products recommended in the Federal dietary guidelines designed to promote health and prevent diseases. The decline in recent years is illustrated by USDA estimates of fluid milk product sales, which show negative annual growth for conventional milk for most years between 2007 and the first half of 2014 (Figure 1).

The organic market share of total fluid milk sales in the United States has increased steadily—from 1.92 percent in 2007 to nearly 5 percent in 2013—although annual growth in organic milk sales has fluctuated. The annual growth in organic milk sales peaked at 33% in 2007. Organic dairy processors had recruited new organic dairy farmers to add capacity and pushed hard for them to transition to organic production before June 2007, when an organic regulatory provision that eased whole herd conversion from conventional to organic production was set to expire. Unfortunately, just as U.S. organic dairy production was ramping up, the downturn in the U.S. economy started in late 2007 and organic milk sales actually declined 4% between 2008 and 2009—the only time in recent years that sales of conventional milk showed positive growth (Figure 1). Consumer demand for organic milk rebounded quickly in 2010, but organic dairy processors had not renewed their contracts with many producers, and conversion back to organic was a slow process.

While the current organic milk shortage also reflects impacts from the widespread drought in 2012 and higher prices for organic feed grains in recent years, growth in the milk sector has routinely been hampered by supply shortages. USDA's ERS conducted a nationwide survey of all certified organic processors and manufacturers in 2004, and inquired about which organic products were in short supply. Among the categories which had shortages—milk, feed grains, produce, and soybeans—milk had the most critical shortage, with 26% of the processors reporting milk shortages (Greene et al., 2009).

Landmark Policy Change on Pasture in 2010

The historical focus of organic agriculture is on ecologically based farming, and the national organic standards, published by USDA in 2000, maintain this focus. USDA regulations require that organic farms be "managed in accordance with the Act and regulations in this part to respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity" (USDA Agricultural Marketing Service, 2000). The national standards virtually exclude the use of synthetic chemicals, antibiotics, and hormones in crop production, and prohibit the use of antibiotics and hormones in livestock production.

The USDA national organic standards also require organic livestock production systems to accommodate an animal's natural nutritional and behavioral requirements, to ensure that dairy cows and other ruminants have access to pasture. However, regulations published in 2000 lacked specific criteria that organic certifiers could use to measure whether organic producers were complying with the law. Although organic processors used images of cows grazing in pasture to sell milk to consumers, not all the organic dairies were providing their cows with pasture. A number of organic stakeholder groups—including organic dairy associations in the Northeast and other traditional milkshed states—urged USDA to add specific enforcement criteria for the use of pasture.

In June 2010, USDA published new rules on organic pasture and required compliance within a year. The pasture rules require that:

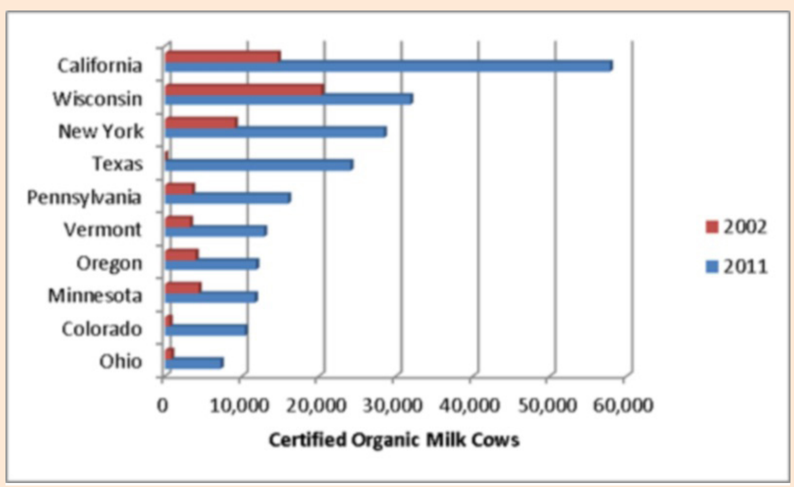
- Animals must graze pasture during the grazing season, which must be at least 120 days per year;
- Animals must obtain a minimum of 30% dry-matter intake from grazing pasture during the grazing season;
- Producers must have a pasture management plan and manage pasture as a crop to meet the feed requirements for the grazing animals and to protect soil and water quality; and,
- Livestock are exempt from the 30% dry-matter intake requirements during the finish feeding period, not to exceed 120 days. Livestock must have access to pasture during the finishing phase.

In announcing the new pasture requirements, Agriculture Secretary Tom Vilsack emphasized that it "will give consumers confidence that organic milk or cheese comes from cows raised on pasture, and organic family farmers the assurance that there is one, consistent pasture standard that applies to dairy products" (USDA Office of Communications, 2010). Small-scale dairy farmers, in particular, had been concerned that they weren't on a level playing field with large-scale corporate dairies. USDA surveyed U.S. organic dairy farmers in 2005, prior to implementation of these requirements, and found that pasture-based feeding was more common on smaller dairy farms and that 4% of organic dairy farms never used pasture (McBride and Greene, 2007).

Organic Dairy Production Still Regionally Diverse

Fast-growing consumer demand and large price premiums for organic milk have made the organic dairy sector a bright spot for many producers over the last dozen years. Researchers at ERS examined milk prices in the mid-2000s, using Nielsen supermarket scanner data, and found that the price for organic milk over conventional milk ranged from 72% above the conventional price in Western states to 126% above the conventional price in the East (Greene et al., 2009). The national average price premium for organic milk was 98% above the conventional price in 2004. Organic milk prices in 2006 varied substantially by fat content, container size, and branding, with organic price premiums for a half-gallon of milk ranging as high as 109% for name-brand organic milk above store-brand conventional milk. In contrast with conventional milk prices, organic milk prices were estimated to increase as the fat content declined.

Figure 2: Top Ten Organic Dairy States Reflect Regional Diversity



Source: USDA, Economic Research Service, based on information from USDA-accredited State and private organic certifiers.

U.S. organic dairy production had just started two decades ago when USDA reported that there were 6,000 certified organic dairy cows nationwide. Over the period between 2002 and 2011—USDA's most recent estimate—the United States expanded from 67,000 organic milk cows to 255,000 organic milk cows, approximately 3% of total dairy cows. USDA's Census of Agriculture reported that organic dairy farms accounted for 5% of total U.S. dairy farms in 2012. Most of this growth took place prior to 2008, when the sector contracted with the downturn in the economy.

California was the top state for both organic and conventional dairy production in 2011. Wisconsin and California traded places between 2002 and 2011 as the top state with the most organic dairy cows (Figure 2). The top 10 states with the most organic dairy cows were still regionally diverse in 2011, and all had substantial increases in the number of organic dairy cows during that period.

Various organic dairy business models are in play in the United States. While the majority of organic dairy farms are small-scale family farms, the United States also has large-scale corporate dairy farms as well. The challenges involved in meeting USDA's strong pasture standard implemented in 2011 may dampen the movement to large-scale dairy farms seen in conventional dairy production.

The three largest organic milk processors in the United States—Organic Valley, Horizon, and Aurora—illustrate different approaches to organic dairy production. Organic Valley is a farmer-owned cooperative, with 1,779 participating farm families in 2014 that sets member-determined pay prices and provides equity ownership in a leading national food brand. Organic Valley indicates that "the central mission of our cooperative is to support rural communities by protecting the health of the family farm—working toward both economic and environmental sustainability."

Aurora Organic Dairy owns and operates 5 organic dairy farms in Colorado and Texas, with a total herd of more than 22,000 organic dairy cows, and an organic dairy processing plant in Plattesville, Colo. Aurora Organic Dairy is the leading producer and processor of store-brand organic milk and butter for U.S. retailers, and develops initiatives "to be a responsible corporate citizen and to be good stewards of our natural resources."

Horizon Organic began processing organic milk 20 years ago and currently sources milk from nearly 700 certified organic family farms in 21 states. Horizon Organic indicates that "our family farmer partners supply 99% of our milk. Horizon Organic also owns and operates a farm in Maryland that supplies 1% of our milk." Horizon Organic also owned large dairy farms in Colorado and Idaho until recently.

Organic Dairies are Much Different than Conventional Dairies

USDA surveyed organic milk producers in 2005 and again in 2010 as part of USDA's annual survey of farm and ranch operators the Agricultural Resource Management Survey (ARMS). These surveys sample organic dairy producers at much higher rates than their occurrence in the population in order to develop sufficient data for a comparison of practices and costs on conventional and organic farms. Organic milk producers usually begin as operators of conventional dairies before undergoing what can be a challenging and costly transition process. Conventional dairy producers need to adjust their approach to dairy herd management during the transition to comply with USDA organic standards.

ERS researchers compared organic and conventional dairy production in 2005 and 2010. The primary difference in the production practices used by organic versus conventional dairies is in the feeding system (McBride and Greene, 2007). In 2005, more than 60% of organic operations reported using pasture-based feeding that provided more than half of seasonal forage (during the grazing months) from pasture, compared to just 18% for other operations. The growth hormone recombinant bovine somatatropin (rbST) is not available to organic producers, but was used by 17% of conventional operations, who also were much more likely to utilize regular veterinary services and a nutritionist. The use of these practices likely contributed to the significantly higher production per cow on conventional versus organic operations. Organic operations averaged about 13,600 pounds of milk per cow in 2005, versus nearly 19,000 pounds on conventional operations.

According to the 2005 ERS analysis of national dairy survey data, total economic costs were significantly higher for organic dairy and soybean operations than for conventional operations. With an average price premium of $6.69 per hundredweight (cwt., which is 100 pounds of milk) for organic milk, organic milk producers covered most of the additional operating costs of organic production in 2005. The value of production minus operating costs was higher for organic producers than for conventional producers in 2005 and 2010, for all size groups (Table 1). However, the premium didn't cover the total costs of organic producers, which includes the opportunity cost of unpaid labor, in either year for any size group. The value of production minus total economic costs was also negative for most size groups in conventional production. Only the largest size groups of conventional producers had positive returns above total economic costs.

Table 1: U.S. Milk Production Costs and Returns per Hundredweight Sold, by Size and Type of Operation, 2005 and 2010

Item	Year	Organic						
Item	Year	Fewer than 50 Cows	50-99 Cows	100-199 Cows	200 or more Cows	500-999 Cows	1,000 Cows or more	All Sizes
		$/Hundredweight Sold						
Value of Production, Minus Operating Costs[1]	2010	8.08	9.16	7.82	10.56	N/A	N/A	9.18
Value of Production, Minus Operating Costs[1]	2005	8.72	8.41	7.65	7.19	N/A	N/A	7.92
Value of Production, Minus Total Costs[2]	2010	-19.38	-11.4	-7.61	-0.43	N/A	N/A	-8.42
Value of Production, Minus Total Costs[2]	2005	-12.91	-8.45	-5.63	-1.2	N/A	N/A	-6.19
Percent of Farms	2010	49	34	12	5	N/A	N/A	--
Percent of Farms	2005	45	42	8	5	N/A	N/A	--
Percent of Milk Production	2010	19	27	20	34	N/A	N/A	--
Percent of milk production	2005	18	33	12	37	N/A	N/A	--
		Conventional						
Item	Year	Fewer than 50 Cows	50-99 Cows	100-199 Cows	200-499 Cows	500-999 Cows	1,000 Cows or more	All Sizes
		$/Hundredweight Sold						
Value of Production, Minus Operating Costs[1]	2010	2.52	3.64	4.16	3.94	5.29	5.63	4.82
Value of Production, Minus Operating Costs[1]	2005	5.57	4.62	5.69	5.94	5.49	6.8	5.93
Value of Production, Minus Total Costs[2]	2010	-20.03	-11.24	-5.72	-3.61	-0.04	1.78	-2.58
Value of Production, Minus Total Costs[2]	2005	-12.22	-7.94	-3.62	-0.67	0.49	2.95	-1.39
Percent of Farms	2010	29	36	19	9	4	3	--
Percent of Farms	2005	31	35	19	9	3	2	--
Percent of Milk Production	2010	4	11	13	14	16	41	--
Percent of milk production	2005	5	14	16	18	15	32	--

N/A = not applicable.

[1]Operating costs include feed, veterinary services, medicine, bedding, fuel, electricity, repairs, certification, and marketing services.

[2]Total costs include operating costs, plus allocated overhead (hired labor, opportunity cost of unpaid labor, capital recovery of machinery and equipment, opportunity cost of land (rental rate), taxes, insurance, and general farm overhead).

Notes: Coefficients of variation (CVs) were checked for the category totals: gross value of production, and feed, operating, allocated overhead, and total costs. All CVs were less than 25 percent.

Source: USDA-Economic Research Service, based on data from USDA Agricultural Resources Management Surveys in 2005 and 2010.

The trend toward larger farms in conventional dairy production was evident in the five years between the two USDA organic surveys. The largest size group for conventional production—1,000 cows or more—represented 2% of conventional dairy farms and had 32% of total milk production in 2005 (Table 1). In 2010, the largest group contained 3% of conventional farms in 2010 representing 41% of total production. Although the larger size groups in the organic dairy sector had higher economic returns, a trend toward concentration of production was not as evident. The largest size group for organic production—200 or more cows—represented 5% of the dairy farms in 2005 and accounted for 37% of total production. The largest organic size group still represented 5% of the dairy farms in 2010, but accounted for a slightly smaller percentage of total production—34%—in 2010.

The Future of Organic Milk Production

As is always the case, the future of organic milk production is largely in the hands of the consumer. Without growing demand, production will not expand. Consumer demand for organic milk expanded rapidly for several decades, jumping from a niche market in natural foods stores to shelf-space allocations in most mainstream food stores. In recent years, even the large retailers, like Walmart and Target, have been responsive to consumer demand for organic milk. While U.S. sales of organic milk have dropped from the double-digit annual increases shown until the general economy experienced a recession, annual sales growth is still in the high single digits. The growing scientific consensus on the nutritional benefits of organic milk, and wider availability in mainstream markets, could help push consumer demand higher.

Another bright note for organic dairy producers is that a recent study of U.S. consumer demand for milk shows that organic milk demand is price elastic, and that the substitution pattern between organic and conventional milk with differing fat content shows greater movement toward organic milk than back to conventional milk (Li, Peterson, and Xia, 2012). With stricter pasture rules raising costs in the organic dairy sector, higher producer prices for organic milk are likely needed to attract more dairy farmers into this sector. Even prior to USDA enforcement of stricter pasture rules in 2011, ERS analysis of the organic dairy sector in 2005 and 2010 found that none of the size groups covered total economic costs in either year. The discrepancy was largest for the smaller farms, partly because they had higher labor costs and lower yields from using more pasture for feed.

Even with stronger USDA pasture requirements, coexistence of organic producers with very different business models is likely to persist in the organic dairy sector to some degree. Some analysts argue that organic sector expansion that includes large-scale farms with lower costs can make organic food—which has less pesticide residue and other positive attributes—more affordable for low-income consumers (Johnson, 2013). USDA's organic regulatory program plays a key role in setting and enforcing strict standards, and ensuring that all producers demonstrate compliance with the rules. These rules provide a framework for future innovations in organic dairy production systems. In particular, research is needed on ways to lower the costs and improve the quality of pasture-based dairy systems in the challenging climates and conditions across the country.

For More Information

Aurora Organic Dairy, Boulder, Colo. Available online: http://www.auroraorganic.com

Benbrook, C., G. Butler, M. Latif, C. Leifert, and D. Davis. 2013. "Organic Production Enhances Milk Nutritional Quality by Shifting Fatty Acid Composition: A United States–Wide, 18-Month Study." PLoS ONE 8(12): e82429. Available online: doi:10.1371/journal.pone.0082429.

Bentley, J. 2014. "Trends in U.S. Per Capita Consumption of Dairy Products, 1970-2012," *Amber Waves*, U.S. Department of Agriculture, June 2.

Greene, C., C. Dimitri, B. Lin, W. McBride, L. Oberholtzer, and T. Smith. 2009. "Emerging Issues in the U.S. Organic Industry," Economic Information Bulletin EIB-55, U.S. Department of Agriculture, Economic Research Service, June.

Horizon Organic, a division of The WhiteWave Foods Company, Denver, Colo. Available online: http://www.horizondairy.com/

Jesse, E. 2002. "Facing up to the Western Dairy Boom," College of Agricultural and Life Sciences, Cooperative Extension, University of Wisconsin-Madison, Rethinking Dairyland Report Series, No. 3, September.

Johnson, J. 2013. "The Wal-Mart Effect on Organics: A Defense of Large-Scale Organic Production," *Duke Environmental Law & Policy Forum*, Vol. XXIV:241-278, Fall.

Li, X., H. Peterson, and T. Xia. 2012. "Consumer Demand for Organic Fluid Milk by Fat Content," *Journal of Food Distribution Research*, Vol. 43, Issue 1, March.

McBride, W., and C. Greene. 2007. "Characteristics, Costs, and Issues for Organic Dairy Farming," Economic Research Report ERR-82, U.S. Department of Agriculture, Economic Research Service.

Nutrition Business Journal. 2013. Table 22—U.S. Organic Food Sales by Product ($Mil) 1997-2008, 2009e-2014e.

Organic Valley, La Farge, Wis. Available online: http://organicvalley.coop.

Palupil, E., A. Jayanegara, A. Ploeger, and J. Kahl. 2012. "Comparison of nutritional quality between conventional and organic dairy products: a meta-analysis," *Journal of the Science of Food and Agriculture*, Vol. 92, Issue 14, pp. 2774-2781. Available online: http://onlinelibrary.wiley.com/doi/10.1002/jsfa.5639/full.

Thomas, M. 2014. "The drought is destroying California's organic dairy farms," *Grist*, September 11.

U.S. Department of Agriculture, Agricultural Marketing Service *Dairy Market News*. Various issues. U.S. Department of Agriculture, Agricultural Marketing Service, https://www.marketnews.usda.gov/mnp/da-home

U.S. Department of Agriculture, Agricultural Marketing Service. 2000. "National Organic Program; Final Rule, 7 CFR Part 205," *Federal Register*, December 21. Available online: http://www.usda.gov/nop.

U.S. Department of Agriculture, Economic Research Service. 2013. "Organic Production Data Product," U.S. Department of Agriculture. Available online: http://www.ers.usda.gov/data-products/organic-production.aspx

U.S. Department of Agriculture, Office of Communications. 2010. News Release. "USDA Issues Final Rule on Organic Access to Pasture," February 12.

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Economics of Antibiotic Use in U.S. Swine and Poultry Production

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Keywords: Antibiotics, Livestock Growth Promotion and Disease Prevention, Drug-Resistance, Livestock Production Costs, Public Health

In the United States today, antibiotics are commonly used in food animals to promote growth and prevent disease, as well as to treat sick animals. The U.S. Food and Drug Administration (FDA) estimates that 14.6 million kg. (32.2 million lbs.) of antibiotics were sold for use in animals in 2012 (FDA, 2014), more than four times the 3.29 million kg. (7.3 million lbs.) of antibiotics sold for human use in 2011 (FDA, 2012). Antibiotics are used primarily in intensive swine, poultry, and feedlot cattle systems, with limited use in dairy cows, sheep, and companion animals.

The extensive use of antibiotics in livestock comes at a cost: it contributes to the increase in drug-resistant pathogens in animals that can potentially be transmitted to humans and negatively impact human health, even if the magnitude of the risk to human health is still debated (You and Silbergeld, 2014). Concerns about increasing antibiotic resistance led to bans on antibiotics for growth promotion (AGPs) in the European Union in 2006. In the United States, AGPs are not banned, but the FDA recently issued guidelines for the industry to voluntarily withdraw medically important antibiotics from growth promotion (FDA, 2013a). For policy makers, the challenge is to evaluate the benefits and costs of animal antibiotics to society. What is the economic value of antibiotics to the livestock industry versus the potential health cost of increasing resistance levels? What are the potential productivity and economic effects of a ban on AGPs for U.S. meat producers and consumers?

Antibiotic Resistance: The Public Health Question

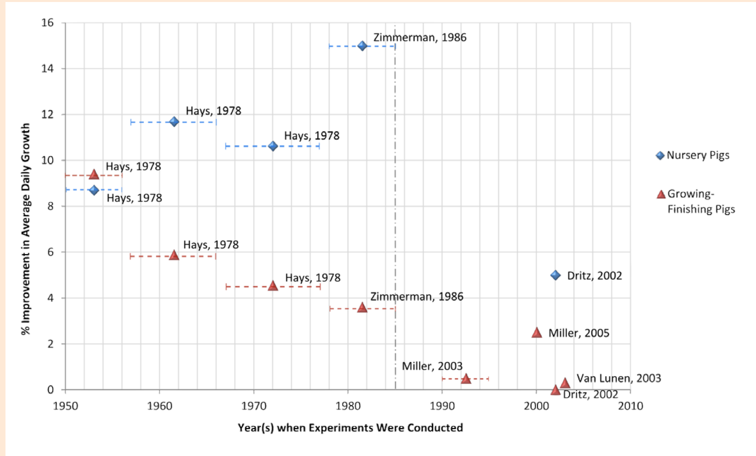
The discovery that antibiotics fed in subtherapeutic concentrations to livestock can hasten their growth and prevent disease (Jukes et al., 1950; and Moore et al., 1946) came just as farmers in the United States were struggling to keep pace with demand for food and animal protein. Antibiotic use for growth promotion and disease prevention soon became an integral part of a new agricultural production model, despite early warnings about the potential risks of developing resistance (Starr and Reynolds, 1951). Numerous studies have demonstrated that food animals on farms using low levels of AGPs harbor a higher percent of resistant bacteria than farms that do not use AGPs (Marshall and Levy, 2011). Increased resistance to certain drugs (such as fluoroquinolones) in both animals and humans coincides with their addition to animal feed and their use in veterinary medicine (Endtz et al., 1991; Bager et al., 1997; and Nelson et al., 2007). Additionally, studies comparing resistance prevalence in both humans and animals before and after AGP bans have documented significant decreases in resistance (primarily in vancomycin-resistant enterococci following the ban of avoparcin as a growth promoter) (Aarestrup et al., 2001; Bager et al.. 1999; Bogaard, Bruinsma, and Stobberingh. 2000; Klare et al.. 1999; Pantosti et al., 1999; and Wegener et al., 1999).

Increasing levels of resistance in bacteria isolated from food-producing animals and retail meat sources have been reported by the National Antimicrobial Resistance Monitoring System (FDA, 2013b). FDA reported that resistance to third-generation cephalosporins rose among isolates from retail ground turkey between 2008 and 2011, and among certain salmonella serotypes in cattle between 2009 and 2011 (FDA, 2013b).

Most important from a public health perspective, extensive research has documented the spillover of resistance genes and resistant pathogens from food animals into human populations via three primary pathways: (1) the release of antibiotic-resistant bacteria into the environment (Campagnolo et al., 2002; Chee-Sanford et al., 2001; and Gibbs et al., 2006), (2) resistance transmission through the food chain (Jakobsen et al., 2010a; Jakobsen et al., 2010b; and Sørensen et al., 2001), and (3) the acquisition of resistant strains through direct contact with food animals (van Cleef et al., 2011a; van Cleef et al. 2011b; Graveland et al., 2010; Huber et al., 2011; Huijsdens et al., 2006; Khanna et al., 2008; Smith et al, 2009; and Voss et al., 2005).

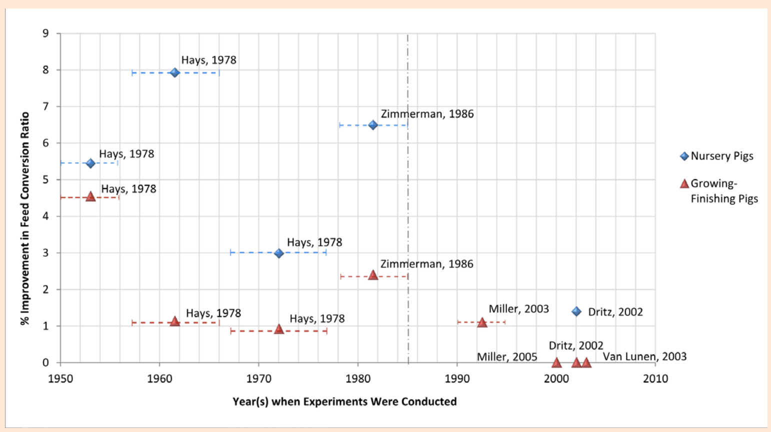
How much these processes contribute to resistance of human pathogens to antibiotics is still unclear. Nevertheless, a report from the Centers for Disease Control and Prevention (CDC) states, "Because of the link between antibiotic use in food-producing animals and the occurrence of antibiotic-resistant infections in humans, antibiotics should be used in food-producing animals only under veterinary oversight and only to manage and treat infectious diseases, not to promote growth" (CDC, 2013).

Figure 1. Percentage Improvement in Average Daily Growth of Pigs Fed Antibiotics over Time



Note: The x-axis refers to the year when the experiments were conducted. Hays, 1978 and Zimmerman, 1986 are reviews of studies conducted over a given time period. The horizontal lines represents the period during which the experiments were conducted. The vertical dashed line separates early vs recent studies as shown in Table 1.

Figure 2. Percentage Improvement in Feed Conversion Ratio of Pigs Fed Antibiotics over Time



Note: Notes associated with Figure 1 apply.

Evidence of Benefits in Swine Production

The major inputs in food animal production—feed, labor, and capital—can be improved on some operations by feeding antibiotics. AGP use can enhance the growth rate and the feed conversion ratio, the rate at which animals convert feed into weight gain (Dibner and Richards, 2005; Hays, 1977; and Zimmerman, 1986), and it can increase labor or capital productivity by substituting for hygiene management in animal housing or transportation (Key and McBride, 2014; and MacDonald and Wang, 2011). Using AGPs could also reduce variability in animal weights and sizes, avoiding financial penalties at markets for animals outside the range suited for mechanized processing (Liu, Miller, and McNamara, 2003).

The effects of subtherapeutic levels of antibiotic feed additives on growth rate and feed efficiency have been reported in cattle, swine, and poultry for more than 50 years (Jukes et al., 1950; Moore et al., 1946; and Salinas-Chavira et al., 2009), but effect sizes vary widely among operations and over time (Figures 1 and 2). Rosen (1995) analyzed a database of more than 4,000 reports from 55 countries and found a high degree of variation for the effects on weight gain and feed conversion in broilers and pigs.

Results obtained in animal-level experiments likely reflect specific nutritional, environmental, and genetic conditions and cannot be generalized. Moreover, most animal-level experimental research on the

Table 1. AGP Effects Found in Newer vs. Older Studies, by Age of Pigs

	Early Studies: 1950–1985 Adapted from Hays (1977), Zimmerman (1986), and Cromwell (2002)			**Modern Production System** Adapted from Dritz et al. (2002)		
Parameter	**Control**	**Antibiotic**	**Difference (%)**	**Control**	**Antibiotic**	**Difference (%)**
Starting Phase						
Average Daily Gain (kg)	0.39	0.45	**16.40%**	0.436	0.458	**5.00%**
Feed Conversion Ratio	2.28	2.13	**6.90%**	1.44	1.42	**1.4% (NSS)**
Growing Phase						
Average Daily Gain (kg)	0.59	0.66	10.60%	n.a.	n.a.	n.a.
Feed Conversion Ratio	2.91	2.78	4.50%	n.a.	n.a.	n.a.
Growing-Finishing Phase						
Average Daily Gain (kg)	0.69	0.72	**4.20%**	0.78	0.778	**0.2% (NSS)**
Feed Conversion Ratio	3.3	3.23	**2.20%**	2.9	2.9	**0%**

Note: The data for 1950–1985 come from a meta-analysis conducted by Cromwell (2002) based on data from Hays (1977) for the period 1950–1977 and data from Zimmerman (1986) for the period 1978–1985. The meta-analysis includes data from 453, 298, and 443 experiments involving 13,632, 5,783, and 13,140 pigs, respectively, for the three phases. The results of the meta-analysis are weighted averages based on the number of replications. The data used in the right panel (modern production system) come from a single study Dritz et al. (2002) involving 3,648 and 2,660 pigs for the nursery and grow-finish phases, respectively.

growth-promoting effect of antibiotics has been performed by the manufacturing and feed industries with relatively few studies by independent research bodies (Thomke, 1998), and most of this research predates 2000.

A meta-analysis of more than 1,000 growth experiments performed in swine between 1950 and 1985 demonstrated that antibiotics in feed improved the daily weight gain in starter pigs (animals weighing 7 to 25 kg. or 15 to 55 lbs.) by an average of 16.4% and the feed efficiency by 6.9% (Cromwell, 2002). Antibiotics were most effective in improving growth in young pigs but were still effective for older growing and finishing pigs (Table 1). One hypothesis is that weanling and starter pigs are more susceptible to stress and subclinical diseases and, consequently, show a greater response to AGPs (Hays, 1977).

Historical experiments have demonstrated that responses to AGPs are lower when production conditions are optimized, with good housing, hygiene, nutrition, and health (Hays, 1977). Early experiments concluded that the degree of response to antibiotics was inversely related to the general well-being of the experimental animals (Coates et al., 1951; Hill et al., 1953; and Speer et al., 1950). Greater antibiotic responses were demonstrated in pigs carrying a high disease load compared with pigs raised in environments with low disease loads, indicating that the growth-promoting effect is at least partially the result of bacteriostatic and bactericidal activity (Zimmerman, 1986). Greater responses were also shown if the antibiotics were added to an inadequate diet (Burroughs, 1959). Nutritional stress and stress associated with relocation (such as movement of feeder pigs) or temperature extremes have been associated with greater responses to antibiotics (Hays, 1977; and Ryan et al., 1961). In addition to improving feed efficiency, adding antibiotics to swine feed was found to reduce the mortality rate by 50% in young pigs (2.0% vs. 4.3%) in trials conducted between 1960 and 1982 (Cromwell, 2002).

Because those results were obtained in animal experiments conducted decades ago, an important question is whether the growth response to antibiotics has changed over time, especially given the increasing levels of resistance among food animals. A review comparing results of animal-level experimental studies led between 1950–1977 and 1978–1985 concluded that the overall effectiveness of AGPs did not diminish between the 1950s and the 1980s (Zimmerman, 1986).

However, for post-2000 studies, the literature suggests that productivity gains from AGPs are lower than indicated by earlier research (Figures 1 and 2). For instance, Miller, McNamara, and Bush (2003) estimated that AGP use increased average daily weight by 0.5% and feed efficiency by 1.1%, much less than the two-digit improvements reported in the 1980s (Cromwell, 2002). Similar results were demonstrated in animal-level experiments, as shown in Table 1 (Dritz et al., 2002; and Van Lunen, 2003). Recent studies tend to show a small, significant growth response to AGPs for nursery pigs, but no significant response for finishing pigs (Dritz et al., 2002; Key and McBride, 2014; and McBride, Key, and Mathews 2008). After controlling for input levels, operator and farm characteristics, farm production practices, and location, a recent study analyzing data from the U.S. Department of Agriculture's (USDA) Agricultural Resource Management Survey estimated that AGP use improved output by 1.0% for feeder-to-finish hog producers, a statistically insignificant improvement (Key and McBride, 2014).

In Denmark, which has an export-oriented, market-driven, and intensive production system, the use of AGPs was banned in finishing pigs in 1998 and in weaning pigs in 2000. The termination of AGPs had no major effect on productivity or feed efficiency in finishers but resulted in some loss of productivity in weaners (World Health Organization (WHO), 2002). Long-term swine productivity improved markedly between 1992 and 2008, suggesting that the ban on AGPs did not harm long-term productivity (Aarestrup et al., 2010). The effects of the ban on AGPs on antibiotic consumption are mixed. Between 1997 and 2008, the total consumption of antibiotics in the Danish swine production industry decreased from 81.2 mg/kg of pork produced to 48.9 mg/kg of pork produced (Aarestrup et al., 2010). Following the AGP ban, total antibiotic use was at its lowest level in recent years in 1999. However, the therapeutic use of antibiotics increased and the total antibiotic consumption for animal production increased by 36% during the period 2001 through 2009 (Jensen and Hayes, 2014). This led the Danish government to impose new restrictions on producers' uses of antibiotics, and total use has started decreasing again after 2009 (Aarestrup, 2012).

The growth response to antibiotics may have decreased over the past 30 years for several possible reasons. First, the growth response to antibiotics is less important when animal nutrition, hygiene, genetics, and health are optimal. The relative improvement in the growth rate resulting from supplementing the diet of pigs with antibiotics has been shown to be inversely related to the growth rate of animals not being fed antibiotics (Braude, Wallace, and Cunha, 1953; and Melliere, Brown, and Rath 1973). With changes in the livestock industry over the past 30 years, all of these factors have improved. Second, increasing levels of resistance in animals could be diminishing the overall effectiveness of AGPs, although data are lacking to evaluate this hypothesis.

The recommended dosage of subtherapeutic antibiotics has increased over time, from 10–20 g/ton in the early 1950s to 40–50 g/ton in the 1970s, and 30–110 g/ton today (Hays, 1977; and Thaler 2010), but there is no demonstrated relationship with increased resistance levels.

Evidence of Benefits in the Poultry Industry

Relatively few studies address the productivity and economic benefits of AGP use in the poultry industry. Table 2 compares three studies on the effects of AGPs on broiler production: one animal-level experimental study of the removal of AGPs on two U.S. broiler farms (Engster, Marvil, and Stewart-Brown, 2002), one farm-level observational study based on a poultry national survey (MacDonald and Wang, 2011), and one observational study with data from before and after the ban on AGPs in Denmark (Emborg et al., 2001).

For the broiler industry in Denmark, the mortality rate, the average weight gain, and productivity (defined as kg of broilers produced/m2 per grow-out) for 1995 to 1999 were not affected by the ban on AGPs (Emborg et al., 2001). The feed conversion ratio did increase, by 0.016 kg/kg from 1995 to 1999, the same magnitude of increase as after the removal of AGPs, in two U.S. broiler farms (Engster, Marvil, and Stewart-Brown,

Table 2. Production and Economic Effects of AGP Restrictions in the Poultry Industry, United States, and Denmark

	U.S. Animal Level Experimental Research (Engster et al., 2002)	**U.S. Farm Level Observational Research** (MacDonald and Wang, 2011)	**Denmark Observational Research Pre (1994-1997) and Post (1998-2000) Ban on AGPs** (Emborg et al., 2001)
Change in feed conversion ratio, value (% change)	Site 1: +0.016 (0.8%*) Site 2: +0.012 (0.6%*)	No HACCP: +0.08 (4%) HACCP: +0.05 (2.6%)	+0.016 (0.9%)
Average weight differential grams (% change)	Site 1: -13.6 g (0.6%*) Site 2: -18.1 g (0.8%*)	2-7% production decline without AGPs when controlling for labor, capital and other inputs, *not statistically significant*	+ 53 g
Mortality rate	Differential: Site 1: -0.2% Site 2: -0.14%	With AGP: 3.95% No AGP, No HACCP: 5.01% No AGP, HACCP: 3.95%	Pre-ban: 4.1% Post-ban: 4.0%
Cost-effectiveness	Cf. Graham et al. study, based on Engster data: Net effect of using AGP = lost value of $0.0093 per chicken (savings in the cost of AGPs more than compensate the decrease in production).	Growers using no AGPs and with HACCP receive 2.1% more fees per kg than growers using AGPs, suggesting higher costs of production in the absence of AGP. Non-AGP premium that would be paid to growers by integrators: $22.5 million.	Calculations suggested that savings in the cost of APG almost exactly offset the cost of the decreased feed efficiency. Potential substantial costs associated with modifications to the production systems (not evaluated).

Note: HACCP = Hazard Analysis and Critical Control Points (a food safety plan).

Sources: Emborg et al., 2001; Engster et al., 2002; Graham et al., 2007; and MacDonald and Wang, 2011.

2002) (Table 2). The end of AGP use in poultry production in Denmark appears to have caused a small decrease in feed efficiency, which was at least partly offset by savings in the cost of AGPs (WHO, 2002).

In the United States, MacDonald and Wang (2011) have demonstrated that suspending AGPs would have no statistically significant effect on production in broiler grow-out operations, once other factors that may affect production (labor, capital, and other inputs) are controlled. However, they also demonstrate that growers who do not use AGPs receive statistically significant higher contract fees than AGP users (+2.1%). These higher fees paid by integrators likely compensate growers for increased costs associated with production without AGPs since broilers produced without AGPs cannot be labeled as antibiotic-free (no antibiotic use at all), limiting the possibility for producers to sell these products for a premium price.

Graham, Boland, and Silbergeld (2007) estimated that the net effect of using AGPs was a loss of $0.0093 per chicken, with the savings in the costs of AGPs more than compensating for the decrease in production. However, this economic analysis does not include veterinary costs or potential costs related to the increased variability in the weight of broiler chickens. Additionally, the added production was valued according to the fees paid to growers which is, in fact, an underestimation of the value of birds to the integrator.

One of the major current benefits of AGP use may be maintaining animal health in older facilities, where hygiene management is less efficient. U.S. farms that produce broilers with AGPs tend to have older houses, with less modern equipment, and are less likely to follow a plan for managing food safety hazards (MacDonald and Wang, 2011). As is the case for swine, AGPs may have smaller benefits when production conditions are optimized: Coates et al. (1951) demonstrated significantly smaller response in chicks to chlortetracycline and penicillin in new environments compared to previously used environments.

In terms of food security, there is a balance to find between using antibiotics to control animal disease and prevent the transmission of zoonotic pathogens from animals to humans, and limiting the emergence and the spread of antibiotic resistance. Some studies highlight that antibiotics added to animal feed or drinking water can decrease the bacterial contamination of animal carcasses and products (Hurd et al., 2008; and Singer et al., 2007). However, improved biosecurity, better hygiene management practices, or vaccinations offer the opportunity to control infectious disease of food animals without increasing levels of resistance.

Potential Economic Cost of a Ban

As described by a few authors (McBride, Key, and Mathews, 2008; and MacDonald and Wang, 2011), a ban on AGPs in the United States would affect producers differentially, according to location, farm size, contracting arrangements, production practices, species, and stage of production. The effect of a ban would also depend on management variables and health and sanitation practices, as shown in studies describing the Swedish experience after that country's 1986 AGP ban (Wierup, 2001).

Table 3. Potential Economic Effects of AGP Restrictions at Animal, Farm, and Market Levels

Potential Economic Effects of Withdrawing AGPs	
Potential Costs	**Potential Benefits**
Potential Animal-Level Effects	
Decreased growth rate, decreased feed efficiency	—
Short term higher mortality rate (especially of young animals), increased morbidity	Long term improvement in health status of animals after investing in biosecurity measures. Potential preservation of antimicrobial efficiency to treat animals.
Fewer animals born per litter	—
Increased variability of product	—
Potential Farm-Level Effects	
Increased time to market and decreased stocking densities	—
Increased input costs: feed (non AGP), young animals purchased	Decreased input costs: saving in AGP cost
Cost of more biosecurity measures and adjustments in housing to compensate for AGP termination	Long term improvement in health status of animals. Decrease in transmission of all diseases, including diseases which are not prevented by antimicrobials (e.g. viral diseases, respiratory tracts infections).
Increased veterinary costs (more treatment of disease)	Decreased veterinary costs (less disease outbreak after having invested in biosecurity measures)
Higher labor costs if alternatives to AGP are more labor-intensive	—
Increased variability of product	—
Potential Market-Level Effects	
Supply side: less output for each level of input, increase in wholesale and retail price of meat, variation in producers revenues (increase or decrease)	Supply side: Potential increase in producers revenues (increase in wholesale price of meat)
—	Demand side: increased consumer confidence and demand for product; increased access to export markets that previously rejected U.S. products because of AGP use

Source: Adapted from Sneeringer, 2014.

Incentives for U.S. food animal producers to use AGPs include improved animal performance and overall health, higher profits, and reduced production risks. Table 3 summarizes the potential economic effects of a restriction on AGPs at the animal, farm, and market levels.

Several studies have sought to estimate the potential economic effect of a ban on AGPs in the U.S. swine industry and found large differences in production cost increases: $0.59/pig and a 9% decrease in net profits (Miller, McNamara, and Bush, 2003); $1.37/pig (Miller et al., 2005); $2.33/pig and a 2% increase in production costs (Brorsen and Lehenbauer, 2002); and $4.50/pig in the first year and a 4.5% increase in overall production costs (Hayes and Jensen, 2003).

An evaluation conducted by a WHO panel on the effects of AGP termination in Denmark estimated the net increase in costs associated with removing AGPs at €1.04 (about the same in 2002 U.S. dollars) per pig produced and zero for poultry. This translates into an increase in pig production costs of just over 1%. Results from a general equilibrium model of the Danish economy suggest that pig production is around 1.4% per annum lower than might be expected and poultry production 0.4% per annum higher. There was no obvious effect on pork prices in Denmark in the years following the ban (WHO, 2002).

Recent USDA estimates of the market-level effects of a ban on AGPs in U.S. hog and broiler production also indicate limited effects (Sneeringer, 2014): the quantity produced would, at most, decrease by 1.08% in the hog industry and 1.12% in the broiler industry (assuming a 3% reduction in supply due to discontinuation of AGPs). The consequent increase in wholesale prices would range from less than 1% to at most 2.6%. The total value of production would increase (0.54% for hogs and 1.45% for broilers), with a gain in value of production for producers not using AGPs before the ban, and a potential loss or gain for producers using AGPs before the ban, depending on assumptions. Since farmers receive about a third of the retail value of pork, consumers would likely see even smaller changes in price. These results are long-term effects; some short-term effects could be negative, as was the case in Denmark after the ban. An AGP ban in the United States could also increase access to export markets that have more stringent regulations on AGPs, such as the European Union, Mexico, and Taiwan (Maron, Smith, and Nachman, 2013).

Policy Issues

The scientific evidence seems to suggest that it is possible for both the swine and the poultry industries to maintain production without AGPs, provided other disease prevention measures are implemented as AGPs are being phased out. Alternative strategies to prevent and control disease in livestock—vaccination, segregation of herds or flocks by age, sanitary protocols, ventilation systems, adjustments in feed rations, and physical biosecurity measures—offer the opportunity to control infectious diseases in food animals without increasing levels of resistance.

Such strategies will incur costs, which could ultimately raise wholesale meat prices. To our knowledge, there are no published estimates of the cost of investing in production systems with better biosecurity and hygiene, and no estimates of the potential benefits of such investments, which are likely to decrease in the transmission of viral diseases and respiratory tract infections, as well as diseases that are prevented by antimicrobials.

A potentially important factor is consumer demand for antibiotic-free meat and poultry. The use of AGPs may be declining in the United States driven, in part, by consumer preferences. Several major companies (including McDonald's, the fast food chain) have mandated the removal of AGPs from broiler production (MacDonald and Wang, 2011). In September 2014, Perdue Foods, the third-largest broiler company in the United States, announced that it had removed all antibiotics from its chicken hatcheries after phasing out the use of AGPs in its chicken production in 2007 (Perdue Foods, 2014). Some estimates indicate that 44% of U.S. broiler production no longer used AGPs in 2006, compared with 2% in 1995 (Chapman and Johnson, 2002; and MacDonald and Wang, 2011). USDA data suggest that the use of subtherapeutic antibiotics in hog production declined between 2004 and 2009—among farrow-to-finish operations, the use of antibiotics fed to finishing hogs for growth promotion dropped from 60% to 40% of market hog production between 2004 and 2009, and from 53% to 40% for nursery pigs (McBride and Key, 2013). However, there is no clear definition for "antibiotic-free" meat and poultry. USDA specifies that the label "no antibiotics added" may be used for meat or poultry products "if sufficient documentation is provided by the producer to the Agency demonstrating that the animals were raised without antibiotics." This ambiguity led to the withdrawal in 2008 of the label "raised without antibiotics," which USDA had approved for Tyson Foods in 2007, after disclosure that the company had used antibiotics for disease prevention in hatcheries.

Definitions of antibiotic use for growth promotion and disease prevention are even less clear. The term "subtherapeutic antibiotics" can include both growth promoters and antibiotics used for disease prevention, since some prophylaxis happens at low doses. Medicated feed additives can be authorized by FDA for different purposes and are classified in two main categories: therapeutic uses and production purposes: "FDA considers uses that are associated with the treatment, control, and prevention of specific diseases to be therapeutic uses that are necessary for assuring the health of food-producing animals" (FDA, 2013a). Since many of the antibiotics approved for use in feed additives in the United States are authorized for both production purposes (growth promotion) and disease prevention, there is a risk that antibiotics could be reclassified from growth promotion to prophylaxis without actual changes in antibiotic use patterns. The Pew Charitable Trusts (2014) reviewed the labels of the 287 antibiotics covered by the FDA guidelines and identified that about one-quarter (66 of 287) of medically important antibiotics can be used in at least one species for disease prevention at levels fully within the range of growth promotion dosages and with no limit on the duration of treatment. Additionally, the FDA guidelines target only antibiotics classified as "medically important antimicrobials;" several antibiotics that are currently not considered medically important may still be used as growth promoters, even though they may indirectly contribute to resistance in human pathogens because of mechanisms of cross-resistance and co-selection.

The voluntary guidelines published by FDA in 2013 may be a first step towards more restrictions on antibiotic use in food animals. In creating the Task Force for Combating Antibiotic-Resistant Bacteria, a White House executive order in September 2014 specified that FDA, in coordination with USDA, "shall continue taking steps to eliminate the use of medically important classes of antibiotics for growth promotion purposes in food-producing animals" (U.S. Executive Office of the President, 2014).

If the benefits of AGPs (in terms of increased productivity) have diminished, then it becomes reasonable to be cautious and avoid the potential public health costs (in terms of increased resistance) rather than wait for a complete understanding of the ecology of gene flow between the animal, the environment, and human reservoirs. The use of antibiotics should principally be the last resort rather than a substitute for biosecurity, hygiene, and other good practices (Wierup, 2001). Antibiotics are not needed to promote growth, but they are essential to treat infectious diseases and maintain animal health. Since new antibiotic classes will likely not be available to veterinary medicine, it is in the best interests of food animal producers to preserve the effectiveness of existing veterinary antibiotics through antibiotic stewardship (Bengtsson and Greko, 2014). The challenge for policy makers is to find that balance between allowing use of antibiotics to control animal diseases and restricting their use to limit the emergence and spread of antibiotic resistance.

For More Information

Aarestrup, F.M. 2012. "Sustainable Farming: Get Pigs off Antibiotics." *Nature* 486:465 – 466.

Aarestrup, F.M., V.F. Jensen, H.D. Emborg, E. Jacobsen, and H.C. Wegener. 2010. "Changes in the Use of Antimicrobials and the Effects on Productivity of Swine Farms in Denmark." *American Journal of Veterinary Research* 71: 726–33.

Aarestrup, F. M., A.M. Seyfarth, H.D. Emborg, K. Pedersen, R.S. Hendriksen, and F. Bager. 2001. "Effect of Abolishment of the Use of Antimicrobial Agents for Growth Promotion on Occurrence of Antimicrobial Resistance in Fecal Enterococci from Food Animals in Denmark." *Antimicrobial Agents and Chemotherapy* 45 (7): 2054–59. doi:10.1128/AAC.45.7.2054-2059.2001.

Bager, F., F.M. Aarestrup, M. Madsen, and H.C. Wegener. 1999. "Glycopeptide Resistance in Enterococcus Faecium from Broilers and Pigs Following Discontinued Use of Avoparcin." *Microbial Drug Resistance* 5 (1): 53–56.

Bager, F., M. Madsen, J. Christensen, and F.M. Aarestrup. 1997. "Avoparcin Used as a Growth Promoter Is Associated with the Occurrence of Vancomycin-Resistant Enterococcus Faecium on Danish Poultry and Pig Farms." *Preventive Veterinary Medicine* 31 (1-2): 95–112.

Bengtsson, B., and C. Greko. 2014. "Antibiotic Resistance--Consequences for Animal Health, Welfare, and Food Production." *Upsala Journal of Medical Sciences* 119 (2): 96–102. doi:10.3109/03009734.2014.901445.

Bogaard, A. E. van den, N. Bruinsma, and E.E. Stobberingh. 2000. "The Effect of Banning Avoparcin on VRE Carriage in The Netherlands." *Journal of Antimicrobial Chemotherapy* 46 (1): 146–48. doi:10.1093/jac/46.1.146.

Braude, R., H.D. Wallace, and T.J. Cunha. 1953. "The Value of Antibiotics in the Nutrition of Swine; a Review." *Antibiotics and Chemotherapy* 3 (3): 271–91.

Burroughs, W. 1959. "Five-Year Summary of More than 400 Experimental Comparisons of Feed Additives in Beef Cattle Rations at College Experimental Stations." American Society of Animal Production Extension Section Meeting, November.

Brorsen, B.W. Brorsen, and T. Lehenbauer. 2002. "Economic Impacts of Banning Subtherapeutic Use of Antibiotics in Swine Production." *Journal of Agricultural and Applied Economics* 34 (3): 489–500.

Campagnolo, E.R., K.R. Johnson, A. Karpati, C.S. Rubin, D.W. Kolpin, M.T. Meyer, and J.E, Esteban. 2002. "Antimicrobial Residues in Animal Waste and Water Resources Proximal to Large-Scale Swine and Poultry Feeding Operations." *The Science of the Total Environment* 299 (1-3): 89–95.

Chapman, H.D. and Z.D., Johnson. 2002. "Use of antibiotics and roxarsone in broiler chickens in the USA: analysis for the years 1995 to 2000." *Poultry Science* 81(3):356-64.

Chee-Sanford, J.C., R.I. Aminov, I.J. Krapac, N. Garrigues-Jeanjean, and R.I. Mackie. 2001. "Occurrence and Diversity of Tetracycline Resistance Genes in Lagoons and Groundwater Underlying Two Swine Production Facilities." *Applied and Environmental Microbiology* 67 (4): 1494–1502. doi:10.1128/AEM.67.4.1494-1502.2001.

Coates, M.E., C.D. Dickinson, G.F. Harrison, S.K. Kon, S.H. Cummins, and W.F.J. Cuthbertson. 1951. "Mode of Action of Antibiotics in Stimulating Growth of Chicks." *Nature* 168 (4269): 332–332. doi:10.1038/168332a0.

Cromwell, G.L. 2002. "Why and How Antibiotics Are Used in Swine Production." *Animal Biotechnology* 13 (1): 7–27. doi:10.1081/ABIO-120005767.

Dibner, J.J., and J.D. Richards. 2005. "Antibiotic Growth Promoters in Agriculture: History and Mode of Action." *Poultry Science* 84 (4): 634–43.

Dritz, S.S., M.D. Tokach, R.D. Goodband, and J.L. Nelssen. 2002. "Effects of Administration of Antimicrobials in Feed on Growth Rate and Feed Efficiency of Pigs in Multisite Production Systems." *Journal of the American Veterinary Medical Association* 220 (11): 1690–95.

Emborg, H., A.K. Ersboll, O.E. Heuer, and H.C. Wegener. 2001. "The Effect of Discontinuing the Use of Antimicrobial Growth Promoters on the Productivity in the Danish Broiler Production." *Preventive Veterinary Medicine* 50: 53–70.

Endtz, H.P., G.J. Ruijs, B. van Klingeren, W.H. Jansen, T. van der Reyden, and R.P. Mouton. 1991. "Quinolone Resistance in Campylobacter Isolated from Man and Poultry Following the Introduction of Fluoroquinolones in Veterinary Medicine." *The Journal of Antimicrobial Chemotherapy* 27 (2): 199–208.

Engster, H.M., D. Marvil, and B. Stewart-Brown. 2002. "The Effect of Withdrawing Growth Promoting Antibiotics from Broiler Chickens: A Long-Term Commercial Industry Study." *The Journal of Applied Poultry Research* 11 (4): 431–36. doi:10.1093/japr/11.4.431.

Gibbs, S. G., C.F. Green, P.M. Tarwater, L.C. Mota, K.D. Mena, and P.V. Scarpino. 2006. "Isolation of Antibiotic-Resistant Bacteria from the Air Plume Downwind of a Swine Confined or Concentrated Animal Feeding Operation." *Environmental Health Perspectives* 114 (7): 1032–37. doi:10.1289/ehp.8910.

Graham, J.P., J.J. Boland, and E. Silbergeld. 2007. "Growth Promoting Antibiotics in Food Animal Production: An Economic Analysis." *Public Health Reports* 122 (1): 79–87.

Graveland, H., J.A. Wagenaar, H. Heesterbeek, D. Mevius, E. van Duijkeren, and D. Heederik. 2010. "Methicillin Resistant Staphylococcus Aureus ST398 in Veal Calf Farming: Human MRSA Carriage Related with Animal Antimicrobial Usage and Farm Hygiene." Edited by Michael Otto. *PLoS ONE* 5 (6): e10990. doi:10.1371/journal.pone.0010990.

Jensen, H.H. and D.J. Hayes. 2014. "Impact of Denmark's Ban on Antimicrobials for Growth Promotion." *Current Opinion in Microbiology* 19: 1-7.

Hayes, D.J. and H.H. Jensen. 2003. "Lessons from the Danish Ban on Feed-Grade Antibiotics." Center for Agricultural and Rural Development Iowa State University. Available online: http://www.card.iastate.edu/publications/dbs/pdffiles/03bp41.pdf.

Hays, V.W. 1977. "Effectiveness of Feed Additive Usage of Antibacterial Agents in Swine and Poultry Production." Lexington: University of Kentucky. Available online: https://archive.org/stream/effectivenessoff00hays#page/n3/mode/2up.

Hill, D.C., H.D. Branion, S.J. Slinger, and G.W. Anderson. 1953. "Influence of Environment on the Growth Response of Chicks to Penicillin." *Poultry Science* 32 (3): 462–66. doi:10.3382/ps.0320462.

Huber, H., N. Giezendanner, R. Stephan, and C. Zweifel. 2011. “Genotypes, Antibiotic Resistance Profiles and Microarray-Based Characterization of Methicillin-Resistant Staphylococcus Aureus Strains Isolated from Livestock and Veterinarians in Switzerland: Further Characterization of MRSA Strains.” *Zoonoses and Public Health* 58 (5): 343–49. doi:10.1111/j.1863-2378.2010.01353.x.

Huijsdens, X.W., B.J. Van Dijke, E. Spalburg, M.G. van Santen-Verheuvel, M.E. Heck, G.N. Pluister, A. Voss, W.J.B. Wannet, and A.J. De Neeling. 2006. “Community-Acquired MRSA and Pig-Farming.” *Annals of Clinical Microbiology and Antimicrobials* 5 (1): 26.

Hurd, H.S., J. Brudvig, J. Dickson, J. Mirceta, M. Polovinski, N. Matthews, and R. Griffith. 2008. “Swine Health Impact on Carcass Contamination and Human Foodborne Risk.” *Public Health Reports* 123 (3): 343–51.

Jakobsen, L., A. Kurbasic, L. Skjøt-Rasmussen, K. Ejrnaes, L.J. Porsbo, K. Pedersen, L.B. Jensen. 2010a. “Escherichia Coli Isolates from Broiler Chicken Meat, Broiler Chickens, Pork, and Pigs Share Phylogroups and Antimicrobial Resistance with Community-Dwelling Humans and Patients with Urinary Tract Infection.” *Foodborne Pathogens and Disease* 7 (5): 537–47. doi:10.1089/fpd.2009.0409.

Jakobsen, L., D.J. Spangholm, K. Pedersen, L.B. Jensen, H.-D.Emborg, Y. Agersø, F.M. Aarestrup, A.M. Hammerum, and N. Frimodt-Møller. 2010b. “Broiler Chickens, Broiler Chicken Meat, Pigs and Pork as Sources of ExPEC Related Virulence Genes and Resistance in Escherichia Coli Isolates from Community-Dwelling Humans and UTI Patients.” *International Journal of Food Microbiology* 142 (1-2): 264–72. doi:10.1016/j.ijfoodmicro.2010.06.025.

Jukes, T.H., E.L.R. Stokstad, R.R. Taylor, T.J. Cunha, H.M. Edwards, and G.B. Meadows. 1950. “Growth-Promoting Effect of Aureomycin on Pigs.” *Archives of Biochemistry* 26 (2): 324–25.

Key, N., and W.D. McBride. 2014. “Sub-Therapeutic Antibiotics and the Efficiency of U.S. Hog Farms.” *American Journal of Agricultural Economics* 96 (3): 831–50. doi:10.1093/ajae/aat091.

Khanna, T., R. Friendship, C. Dewey, and J.S. Weese. 2008. “Methicillin Resistant Staphylococcus Aureus Colonization in Pigs and Pig Farmers.” *Veterinary Microbiology* 128 (3-4): 298–303. doi:10.1016/j.vetmic.2007.10.006.

Klare, I., D. Badstübner, C. Konstabel, G. Böhme, H. Claus, and W. Witte. 1999. “Decreased Incidence of VanA-Type Vancomycin-Resistant Enterococci Isolated from Poultry Meat and from Fecal Samples of Humans in the Community after Discontinuation of Avoparcin Usage in Animal Husbandry.” *Microbial Drug Resistance* 5 (1): 45–52.

Liu, X., G.Y. Miller, and P.E. McNamara. 2003. “Do Antibiotics Reduce Production Risk For U.S. Pork Producers?” 2003 Annual meeting, July 27-30, Montreal, Canada 22026. American Agricultural Economics Association Available online: http://ideas.repec.org/p/ags/aaea03/22026.html.

MacDonald, J.M., and S.-L. Wang. 2011. “Foregoing Sub-Therapeutic Antibiotics: The Impact on Broiler Grow-out Operations.” *Applied Economic Perspectives and Policy* 33 (1): 79–98. doi:10.1093/aepp/ppq030.

Maron, D., T. Smith, and K. Nachman. 2013. “Restrictions on Antimicrobial Use in Food Animal Production: An International Regulatory and Economic Survey.” *Globalization and Health* 9 (1): 48.

Marshall, B.M., and S.B. Levy. 2011. “Food Animals and Antimicrobials: Impacts on Human Health.” *Clinical Microbiology Reviews* 24 (4): 718–33. doi:10.1128/CMR.00002-11.

McBride, W. and N. Key. 2013. *U.S. Hog Production From 1992 to 2009: Technology, Restructuring, and Productivity Growth*. U.S. Department of Agriculture, Economic Research Service, Economic Research Report-158, October.

McBride, W.D., N. Key, and K.H. Mathews. 2008. “Subtherapeutic Antibiotics and Productivity in U.S. Hog Production.” *Applied Economic Perspectives and Policy* 30 (2): 270–88. doi:10.1111/j.1467-9353.2008.00404.x.

Melliere, A.L., H. Brown, and R.P. Rath. 1973. “Finishing Swine Performance and Response to Tylosin.” *Journal of Animal Science* 37: 286.

Miller, G.Y. P.E. McNamara, and E.J. Bush. 2003. "Productivity and Economic Effects of Antibiotics Used for Growth Promotion in Pork Production." *Journal of Agricultural and Applied Economics* 35: 469-482.

Miller, G.Y., X. Liu, P.E. McNamara, and E.J. Bush. 2005. "Farm-Level Impacts of Banning Growth- Promoting Antibiotic Use in U.S. Pig Grower/Finisher Operations." *Journal of Agribusiness* 23 (2). Available online: http://econpapers.repec.org/article/agsjloagb/59680.htm.

Moore, P.R., A. Evenson, T.D. Luckey, E. McCoy, C.A. Elvehjem, and E.B. Hart. 1946. "Use of Sulfasuxidine, Streptothricin, and Streptomycin in Nutritional Studies with the Chick." *Journal of Biological Chemistry* 165 (2): 437–41.

Nelson, J.M., T.M. Chiller, J.H. Powers, and F.J. Angulo. 2007. "Fluoroquinolone-Resistant Campylobacter Species and the Withdrawal of Fluoroquinolones from Use in Poultry: A Public Health Success Story." *Clinical Infectious Diseases* 44 (7): 977–80. doi:10.1086/512369.

Pantosti, A., M. Del Grosso, S. Tagliabue, A. Macrì, and A. Caprioli. 1999. "Decrease of Vancomycin-Resistant Enterococci in Poultry Meat after Avoparcin Ban." *Lancet* 354 (9180): 741–42. doi:10.1016/S0140-6736(99)02395-8.

Rosen, G.D. 1995. "Antibacterials in poultry and pig nutrition." In Wallace R.J. and A. Chesson, ed. *Biotechnology in Animal Feeds and Animal Feeding*. Wiley-VCH Verlag GmbH, Weinheim, Germany. doi: 10.1002/9783527615353.ch8.

Ryan, F.A., L.M. Potter, E.P. Singsen, and L.D. Matterson. 1961. "The Continuous Feeding of an Antibiotic to Laying Hens." *Poultry Science* 40 (5): 1142–51. doi:10.3382/ps.0401142.

Salinas-Chavira, J., J. Lenin, E. Ponce, U. Sanchez, N. Torrentera, and R.A. Zinn. 2009. "Comparative Effects of Virginiamycin Supplementation on Characteristics of Growth-Performance, Dietary Energetics, and Digestion of Calf-Fed Holstein Steers." *Journal of Animal Science* 87 (12): 4101–8. doi:10.2527/jas.2009-1959.

Singer, R.S., L.A. Cox Jr., J.S. Dickson, H.S. Hurd, I. Phillips, and G.Y. Miller. 2007. "Modeling the Relationship between Food Animal Health and Human Foodborne Illness." *Preventive Veterinary Medi*cine 79 (2–4): 186–203. doi:10.1016/j.prevetmed.2006.12.003.

Smith, T.C., M.J. Male, A.L. Harper, J.S. Kroeger, G.P. Tinkler, E.D. Moritz, A.W. Capuano, L.A. Herwaldt, and D.J. Diekema. 2009. "Methicillin-Resistant Staphylococcus Aureus (MRSA) Strain ST398 Is Present in Midwestern U.S. Swine and Swine Workers." Edited by U. Dobrindt. *PLoS ONE* 4 (1): e4258. doi:10.1371/journal.pone.0004258.

Sneeringer, S. 2014. "The Economics of Sub-Therapeutic Antibiotic Use in U.S. Livestock Agriculture." Paper presented at the Antibiotic Resistance at the Animal-Human Interface Workshop, Princeton University NJ, May 13.

Sørensen, T.L., M. Blom, D.L. Monnet, N. Frimodt-Møller, R.L. Poulsen, and F. Espersen. 2001. "Transient Intestinal Carriage after Ingestion of Antibiotic-Resistant Enterococcus Faecium from Chicken and Pork." *The New England Journal of Medicine* 345 (16): 1161–66. doi:10.1056/NEJMoa010692.

Speer, V.C., R.L. Vohs, D.V.Catron, H.M. Maddock, and C.C. Culbertson. 1950. "Effect of Aureomycin and Animal Protein Factor on Healthy Pigs." *Archives of Biochemistry* 29: 452–53.

Starr, M.P., and D.M. Reynolds. 1951. "Streptomycin Resistance of Coliform Bacteria from Turkeys Fed Streptomycin." *American Journal of Public Health and the Nations Health* 41 (11 Pt 1): 1375–80.

Thaler, B. 2010. "Feed Additives for Swine - 2010 National Swine Nutrition Guide." South Dakota State University. Available online: http://bit.ly/1wS9Roc.

The Pew Charitable Trusts. 2014. "Gaps in FDA's Antibiotics Policy." November 30. Available online: http://bit.ly/1uElZLZ.

Thomke, E. 1998. "Growth Promotants in Feeding Pigs and Poultry. I. Growth and Feed Efficiency Responses to Antibiotic Growth Promotants." *Annales de Zootechnie – Animal Research* 47 (2): 85–97. doi:10.1051/animres:19980201.

U.S. Centers for Disease Control. 2013. *Antibiotic Resistance Threats in the United States, 2013*. Available online: http://www.cdc.gov/drugresistance/threat-report-2013/index.html.

U.S. Executive Office of the President. 2014. "Executive Order—Combating Antibiotic-Resistant Bacteria." The White House. Available online: http://www.whitehouse.gov/node/298751.

U.S. Food and Drug Administration. 2012. *Drug Use Review*. Available online: http://www.fda.gov/downloads/Drugs/DrugSafety/InformationbyDrugClass/UCM319435.pdf.

U.S. Food and Drug Administration. 2013a. *Guidance for Industry #213: New Animal Drugs and New Animal Drug Combination Products Administered in or on Medicated Feed or Drinking Water of Food-Producing Animals : Recommendations for Drug Sponsors for Voluntarily Aligning Product Use Conditions with GFI #209.* Available online: http://www.fda.gov/downloads/AnimalVeterinary/GuidanceComplianceEnforcement/GuidanceforIndustry/UCM299624.pdf

U.S. Food and Drug Administration. 2013b. *National Antimicrobial Resistance Monitoring System – Enteric Bacteria: 2011 Executive Report*. Available online: http://www.fda.gov/AnimalVeterinary/NewsEvents/CVMUpdates/ucm409035.htm.

U.S. Food and Drug Administration. 2014. FDA Annual Summary Report on Antimicrobials Sold or Distributed in 2012 for Use in Food-Producing Animals. Available online: http://www.fda.gov/AnimalVeterinary/NewsEvents/CVMUpdates/ucm416974.htm.

Van Cleef, B.A.G.L., H. Graveland, A.P.J. Haenen, A.W. van de Giessen, D. Heederik, J.A. Wagenaar, and J.A.J.W. Kluytmans. 2011a. "Persistence of Livestock-Associated Methicillin-Resistant Staphylococcus Aureus in Field Workers after Short-Term Occupational Exposure to Pigs and Veal Calves." *Journal of Clinical Microbiology* 49 (3): 1030–33. doi:10.1128/JCM.00493-10.

Van Cleef, B.A.G.L., D.L. Monnet, A. Voss, K. Krziwanek, F. Allerberger, M. Struelens, H. Zemlickova. 2011b. "Livestock-Associated Methicillin-Resistant Staphylococcus Aureu S in Humans, Europe." *Emerging Infectious Diseases* 17 (3): 502–5. doi:10.3201/eid1703.101036.

Van Lunen, T.A. 2003. "Growth Performance of Pigs Fed Diets with and without Tylosin Phosphate Supplementation and Reared in a Biosecure All-in All-out Housing System." *The Canadian Veterinary Journal* 44 (7): 571–76.

Voss, A., F. Loeffen, J. Bakker, C. Klaassen, and M. Wulf. 2005. "Methicillin-Resistant Staphylococcus Aureus in Pig Farming." *Emerging Infectious Diseases* 11 (12): 1965.

Wegener, H.C., F.M. Aarestrup, L. Bogø Jensen, A.M. Hammerum, and F. Bager. 1999. "Use of Antimicrobial Growth Promoters in Food Animals and Enterococcus Faecium Resistance to Therapeutic Antimicrobial Drugs in Europe." *Emerging Infectious Diseases* 5 (3): 329.

Wierup, M. 2001. "The Swedish Experience of the 1986 Year Ban of Antimicrobial Growth Promoters, with Special Reference to Animal Health, Disease Prevention, Productivity, and Usage of Antimicrobials." *Microbial Drug Resistance* 7: 183–90.

World Health Organization (WHO). 2002. *Impacts of antimicrobial growth promoter termination in Denmark*. Report WHO/CDS/CPE/ZFK/2003.1, November.

You, Y., and E.K. Silbergeld. 2014. "Learning from agriculture: understanding low-dose antimicrobials as drivers of resistome expansion." *Frontiers in Microbiology* 5:284.

Zimmerman, D.R. 1986. "Role of Subtherapeutic Levels of Antimicrobials in Pig Production." Journal of Animal Science 62 (Supplement 3): 6–16.

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U.S. Implications of the Smithfield Acquisition by Shuanghui

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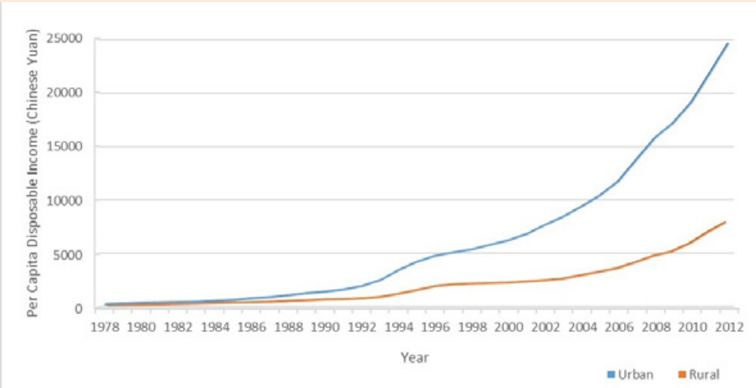
The purchase of Smithfield Foods, the world's largest hog producer and pork processor, by China's top pork products company, Shuanghui International Holdings Ltd., stirred concerns about domestic pork supplies and food safety in the United States. The Smithfield acquisition will cause important changes in U.S. pork exports to China, consumer concerns about food safety of pork products, and competition in Chinese and U.S. pork markets.

U.S. Exports to China

Chinese demand for meat products including pork has continued to increase as the per capita disposable income in China has kept rising over the past several decades (Figure 1a and 1b). In 2012, the per capita pork consumption of Chinese urban residents (21.23 kilograms or 46.8 pounds) was similar to U.S. per capita consumption (45.9 pounds) while Chinese rural residents' per capita pork consumption (14.4 kilograms or 31.75 pounds) was significantly lower than the U.S. consumption level (National Bureau of Statistics of China (NBSC), 2014); U.S. Department of Agriculture (USDA), 2014a). In addition, Chinese consumers have a stronger taste preference towards pork than meat products from other animal origins. Pork accounted for 59% of meat consumption by Chinese urban residents and 69% for rural residents in 2012 (NBSC, 2014). Because the income of Chinese residents will continue to increase and pork is their preferred meat, Chinese demand for pork has significant growth potential. To meet the rising demand, Chinese producers have expanded their production and China has imported more pork from other countries, especially the United States. Figure 2 shows that U.S. pork exports to mainland China have increased from 2.33 million pounds in 1996 to 496.59 million pounds in 2013, and the average annual growth rate is 34.7% (USDA, 2014b). Chinese pork production and consumption increased from 50.71 and 50.8 million metric tons in 2010 to 55.6 and 56.1 million metric tons, respectively, in 2013. Imports accounted for only 0.8-1.4% of Chinese pork consumption during the 2010-2013 period (USDA, 2014c). So China has been satisfying its increased demand primarily through increased domestic production. However, it will be difficult for China to maintain this tradition of self-sufficiency in pork as feed costs rise, and land for additional pork production becomes scarce and expensive (Gale, Marti, and Hu, 2012). China will increase its reliance on imports to satisfy its increasing demand for pork in the future.

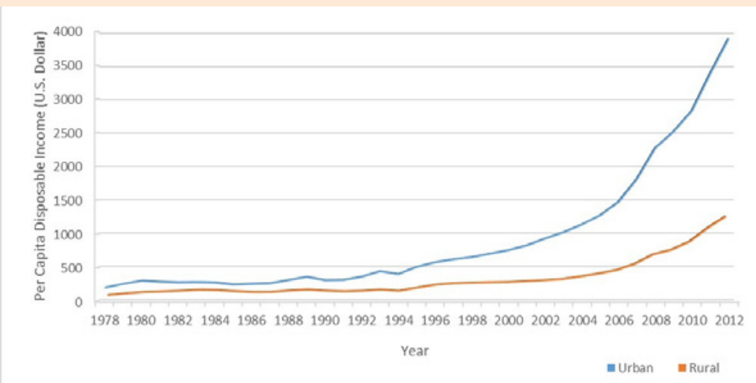
The United States exported 638.8 million pounds of pork to China in 2012, which accounted for 39.7% of Chinese pork imports and 0.54% of Chinese pork consumption (USDA, 2014b and 2014c). Smithfield's pork production accounted for 27.9% of total U.S. production, and about 4.5% of Smithfield's pork products were exported to China in 2012. Smithfield's pork exports to China accounted for 18.2% of total Chinese imports and 0.25% of Chinese pork consumption (Smithfield Foods, 2012; Mattioli, Cimilluca, and Kesmodel, 2013; and USDA, 2014c). Most of Smithfield's exports to China have been offal; one objective of the merger is to boost exports of muscle meat. China bans the use of a feed additive known as ractopamine in pork production. Ractopamine-free pork products account for about 40% of Smithfield's production

Figure 1a: Per Capita Disposable Income of Chinese Urban and Rural Residents (Chinese Yuan, 1978-2012).



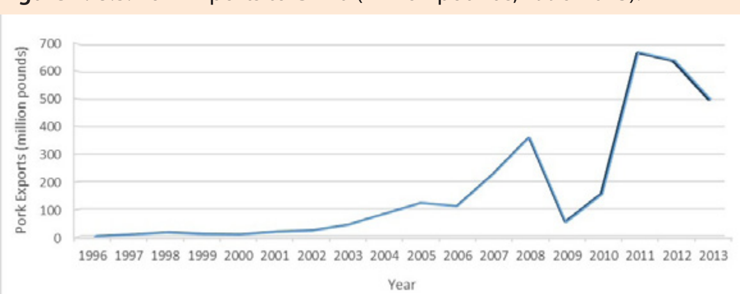
Source: National Bureau of Statistics of China, 2014.

Figure 1b: Per Capita Disposable Income of Chinese Urban and Rural Residents (U.S. Dollar, 1978-2012).



Source: National Bureau of Statistics of China, 2014; Fxtop Company, 2014.

Figure 2: U.S. Pork Exports to China (million pounds, 1996-2013).



Source: U.S. Department of Agriculture, 2014b.

(Bloomberg News, 2013). If Smithfield exports all its ractopamine-free pork products to China, its exports to China will increase by 788% and account for 2.2% of Chinese pork consumption. Collectively, these numbers indicate there is significant potential for Smithfield and other U.S. pork companies to increase their exports to China.

To protect domestic pork producers and maintain food self-sufficiency, the Chinese government has used various measures including import tariffs, regulations as potential technical barriers to trade, and subsidies to support production and limit imports (Hayes, 2013). One import regulation is China's restriction on the use of Codex-approved veterinary drugs in hog production (Stuart and Fritz, 2013). In August 2014, China announced a ban on pork imports from six U.S. processing plants and six cold storage facilities due to the presence of ractopamine in their pork products (Waters and Davis, 2014). Due to high domestic production costs and import protections, hog and pork prices in Chinese markets are usually much higher than in U.S. markets. For example, the hog price in China was 40% to 100% higher than that in the United States during the time period from January 2010 to July 2013 (U.S. Meat Export Federation, 2014).

The acquisition of Smithfield by Shuanghui can lead to more U.S. pork exports to China through four channels.

First, the acquisition can give an incentive to the Chinese government to allow more pork imports from the United States. After Smithfield became a subsidiary of a Chinese company, future pork imports from the United States will be treated as less threatening to the policy goal of Chinese food self-sufficiency and the protection of its domestic producers. Thus, the Chinese government may gradually relax some restrictions and lower import duties on pork imports from the United States.

Second, the major purpose of the acquisition was to bring more U.S. meat products to China. Shuanghui chairman Wan Long indicated this purpose clearly in the announcement of the Smithfield deal (Gara, 2013). Chinese consumers' preferences for taste and freshness of meat products are different from those of U.S. consumers (Anderson et al., 2011; and Oh and See, 2012). However, mostly due to various safety issues and scandals surrounding some Chinese food products, imported food products from developed countries, such as

U.S. pork products, are viewed as higher quality products and receive positive receptions in Chinese markets (Ortega, Wang, and Wu, 2009; Wang, 2012; and Jin and Zhang, 2014). Because Chinese consumers have become increasingly conscious about the safety and quality of food products, the merged company has an incentive to increase the volume and share of the exports of Smithfield's pork products to China and reduce the share of Shuanghui's lower-quality Chinese products in the merged company's total sales in Chinese markets. The coordination of these decisions did not exist before the merger.

Third, Shuanghui's distribution network and market information in China will significantly help increase the sales of Smithfield's pork products in China. Shuanghui is the largest pork producer in China and slaughters more than 15 million pigs a year. Shuanghui has meat processing plants in 18 of 34 province-level administrative divisions and more than 300 distribution and marketing centers in 31 province-level divisions of China. Shuanghui was set up in 1958 and has accumulated tremendous information and knowledge about Chinese consumers (Shuanghui Development, 2014). Smithfield's pork exports to China will benefit from Shuanghui's network and information.

Fourth, more byproducts from pork production will be exported to China after the acquisition. There are huge taste differences of pork byproducts between U.S. and Chinese consumers. Various byproducts such as feet, ears, stomachs, livers, and intestines are widely used in Chinese cuisine. The market values of these byproducts are much higher in Chinese markets than in U.S. markets. After the acquisition, the coordination between the decision on Smithfield's exports to China and the decision on Shuanghui's supply of Chinese products in Chinese markets will also cause the merged company to increase Smithfield's exports of pork byproducts to China. Shuanghui will help Smithfield design the pork byproducts better suited for Chinese consumers so that more of Smithfield's byproducts will be exported to China.

More U.S. exports to China has implications for U.S. producers and consumers. Pork prices in U.S. markets will increase. A potentially interesting aspect is that, when U.S. firms obtain additional revenue from increased sales of pork byproducts to China, they may be more willing to accept lower prices of pork meat products in U.S. markets, compared with the pre-acquisition price levels. However, this negative price effect will be outweighed by the positive effect on U.S. pork meat prices of more exports of U.S. pork products to China. The prices of U.S. pork products in Chinese markets will be affected by more supply of imported products from the United States; more demand due to income growth in China; and the new, coordinated selling strategy of the merged company for two types of differentiated products—higher-quality, imported products from Smithfield and lower-quality, domestic products from Shuanghui's plants in China. The larger supply of imported products from the United States will reduce the prices of U.S. pork products in Chinese markets while more demand due to income growth and the new, coordinated selling strategy of the merged company will raise the prices so that the net price effect will depend on the relative magnitudes of these two opposite effects. However, the prices of U.S. pork products in Chinese markets will continue to be higher than the prices in U.S. markets. Larger total volume of U.S pork products sold in U.S. and Chinese markets—and higher pork prices in U.S. markets—will lead to more demand and higher prices of hogs in U.S. markets. U.S. consumers will be affected by changes in pork prices. More exports of U.S. pork products to China will reduce the pork supply in U.S. markets. However, hog and pork producers in the United States will also respond by expanding their production, which will increase the market supply. So the pork prices in U.S. markets will rise due to more exports to China, but the increase will be limited.

Food Safety

U.S. consumers may have more food safety concerns about pork products, especially Smithfield's products,

Table 1. Four-Firm Concentration of U.S. Pork-Packing Industry and Number of U.S. Hog Slaughter Plants

Year	Four-Firm Concentration (%)	Number of Slaughter Plants
1980	34	
1995	46	
2000	56	
2001	57	
2002	55	175
2003	64	154
2004	64	166
2005	64	163
2006	61	159
2007	65	165
2008	65	126
2009	63	134
2010	65	129
2011	64	136

Source: USDA Grain Inspection Packers and Stockyards Administration, 2012 and 2013.

after the acquisition by Shuanghui. The concerns come from the negative impression of U.S. consumers about China's food industry overall rather than Shuanghui itself. Many food safety incidents have occurred in China since its economic reforms in the late 1970s, and especially in the recent decade. The one receiving the most media attention was the case of contaminated baby formula in 2008. Baby formula produced by a major milk supplier, Sanlu Group, was contaminated by melamine. As a result, six children died and about 294,000 children were sick. Other food safety incidents include poisonous ham treated with the pesticide Dichlorvos in 2003, counterfeit alcoholic drinks in 2009, clenbuterol-tainted pork in 2011, and dead pigs drifting in the Huangpu River after a crack-down on illicit trade of dead meat in 2013. Shuanghui itself was implicated as one of the companies involved in the clenbuterol-tainted pork incident although Shuanghui's responsibility is limited and indirect because the scandal was at the hog-production rather than processing level (Gara, 2013). The negative perception of U.S. consumers is expected to continue as long as food safety in China is perceived not to be significantly improved.

Food safety concerns of U.S. consumers about Smithfield's pork products after the acquisition could adversely affect the sales and prices of Smithfield's products, although the impact is expected to be small and its exact magnitude is a topic for future studies. The negative effect of food safety concerns on the sales and prices of the entire U.S. pork industry will be even smaller because some U.S. consumers will switch to other companies' pork products if they are concerned about the safety of Smithfield's products. In addition, if there are any food safety incidents related to the Chinese meat industry and Shuanghui in the future, the incidents will remind U.S. consumers of the safety concerns and cause some fluctuations in prices and sales in U.S. pork markets.

Market Competition

The four-firm concentration ratio of the U.S. pork-packing industry has increased from 34% in 1980 to 64% in 2012, and the number of hog slaughter plants has declined (Table 1) (USDA, 2012 and 2013). In addition, alternative marketing arrangements including various contracts have been increasingly used to procure live hogs. These trends have raised concerns about the anticompetitive effects of potential buyer power in hog procurements and seller power in pork markets (Zheng and Vukina, 2009). The acquisition of the United States' largest pork producer by the top Chinese pork company has only heightened concerns about market concentration.

Initially, the acquisition of Smithfield by Shuanghui will not change the structure or concentration of either the U.S. or Chinese hog and pork markets. However, over time, the U.S. and Chinese pork markets will become more interdependent. The Smithfield acquisition by Shuanghui and future increased Smithfield exports to China will lead to a higher concentration in Chinese pork markets. Pork prices in China will not necessarily be higher because more imports from a low-price country (the United States) can lower the price in the importing country (China) and this price reduction due to the benefit of trade can offset the price effect of higher concentration. However, when pork markets in the two countries become more interdependent and major companies are selling in both countries, more concentrated and less competitive Chinese pork markets provide an alternative outlet for U.S. pork products and, thus, reduce the competition in U.S. pork markets.

The merged company will implement its within-company coordination of selling strategies of lower-quality Chinese products from Shuanghui and higher-quality imports from Smithfield in Chinese markets in order to compete with other companies. At the same time, Smithfield's selling strategies in U.S. markets will be affected by this merged company's new within-company coordination of selling strategies in Chinese markets. In response to the new selling strategies, other U.S. and Chinese pork companies will adjust their selling strategies accordingly, changing the nature of competition in the markets.

Given the possible increasing concentration in Chinese pork markets, more interdependence between U.S. and Chinese markets, and the coordination of selling strategies, the acquisition will likely lessen competition among companies in Chinese and U.S. pork markets. A major question for the future will be how this reduced competition will play out for U.S. consumers in pork markets.

For More Information

Anderson S., C. Bieroth, G. Tucker, and T. Schroeder. 2011. "Chinese Beef Consumption Trends: Implications for Future Trading Partners." Department of Agricultural Economics MF-3000, Kansas State University. Available online: http://www.agmanager.info/livestock/marketing/bulletins_2/industry/demand/MF3000.pdf.

Bloomberg News, 2013, October 9 "Smithfield to Cut Hog-Feed Additive to Boost Exports to China." Available online: http://www.bloomberg.com/news/2013-10-10/smithfield-to-cut-hog-feed-additive-to-boost-exports-to-china.html.

Fxtop Company. 2014. *Historical Official Exchange Rates*. Available online: http://fxtop.com/en/historical-exchange-rates.php?MA=1.

Gale, F., D. Marti, and D. Hu. 2012. *China's Volatile Pork Industry*. Washington, D.C.: U.S. Department of Agriculture, Economic Research Service, Outlook No. (LDPM-21101), February. Available online: http://www.ers.usda.gov/publications/ldpm-livestock,-dairy,-and-poultry-outlook/ldpm211-01.aspx.

Gara, T. 2013, May 29 "The Smithfield Deal: China Bringing Home the American Bacon." *The Wall Street Journal*. Available online: http://blogs.wsj.com/corporate-intelligence/2013/05/29/the-smithfield-deal-china-bringing-home-the-american-bacon/.

Hayes, D. 2013. "Prospects for US-China Trade in Meat Products and Associated Investment Opportunities." Paulson Papers on Investment: Agribusiness Series, The Paulson Institute, July. Available online: http://www.paulsoninstitute.org/media/103128/us-china_trade_and_investment_in_meat_hayes_english.pdf.

Jin, S., and Y.Y. Zhang. 2014. "The Value of "Made in USA": Impact of Chinese Acquisition of a U.S. Company on Consumer Willingness to Pay." Paper presented at Agricultural and Applied Economics Association annual meeting, Minneapolis, Minn., July.

Mattioli, D., D. Cimilluca, and D. Kesmodel. 2013, May 30 "China Makes Biggest U.S. Play." *The Wall Street Journal*. Available online: http://online.wsj.com/news/articles/SB10001424127887324412604578512722044165756.

National Bureau of Statistics of China. 2014. *China Statistical Yearbook*, 2013. Beijing. Available online: http://www.stats.gov.cn/tjsj/ndsj/2013/indexeh.htm.

Oh, S.H., and M.T. See. 2012. "Pork Preference for Consumers in China, Japan and South Korea." *Asian-Australasian Journal of Animal Sciences* 25: 143–150.

Ortega, D.L., H. Wang, and L. Wu. 2009. "Food Safety and Demand: Consumer Preferences for Imported Pork in Urban China." *Journal of Food Distribution Research* 40(3): 52–63.

Shuanghui Development. 2014. "About Shuanghui." Available online: http://www.shuanghui.net/html/category/about/qyjs.

Smithfield Foods. 2012. *Smithfield Integrated Report*, 2012. Available online: http://www.smithfieldfoods.com/media/12902/smithfield-integrated-report-2012.pdf.

Stuart, B.W., and R.G. Fritz. 2013. "China's Impact on U.S. Poultry and Livestock Sectors." *Choices* 28(1): 1–5.

U.S. Department of Agriculture. 2012. *2011 Annual Report: Packers and Stockyards Program*. Grain Inspection Packers and Stockyards Administration, Washington, D.C., March.

U.S. Department of Agriculture. 2013. *2012 Annual Report: Packers and Stockyards Program*. Grain Inspection Packers and Stockyards Administration, Washington, D.C., March.

U.S. Department of Agriculture. 2014a. *USDA Agricultural Projections to 2023*. Economic Research Service Long-term Projections Report OCE-2014-1, Washington, D.C., February. Available online: http://www.usda.gov/oce/commodity/projections/USDA_Agricultural_Projections_to_2023.pdf.

U.S. Department of Agriculture. 2014b. *Livestock & Meat International Trade Data*. Economic Research Service, Washington, D.C., December. Available online: http://www.ers.usda.gov/data-products/livestock-meat-international-trade-data.aspx#26019.

U.S. Department of Agriculture. 2014c. *Livestock and Poultry: World Markets and Trade*. Foreign Agricultural Service, Washington, D.C., October. Available online: http://www.fas.usda.gov/data/livestock-and-poultry-world-markets-and-trade.

U.S. Meat Export Federation. 2014. "China's Hog, Pork Prices Still Climbing." Available online: https://www.usmef.org/chinas-hog-pork-prices-still-climbing/.

Wang, H. 2012, August 22 "Consumers turn toward imported food." *China Daily*. Available online: http://www.chinadaily.com.cn/business/2012-08/22/content_15694718.htm.

Waters, T., and M. Davis. 2014, August 12 "China halts some U.S. pork imports over feed additive use." Reuters. Available online: http://www.reuters.com/article/2014/08/12/us-china-pork-additive-idUSKBN0GC20Y20140812.

Zheng, X., and T. Vukina. 2009. "Do Alternative Marketing Arrangements Increase Pork Packers' Market Power?" American Journal of Agricultural Economics 91: 250–263.

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The U.S. Gestation Stall Debate

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One of the most contentious and emotional issues in livestock production is that of animal welfare. The welfare of livestock in commercial production systems has been, and continues to be, intensely debated by many groups, including, but not limited to, consumers, animal activists, scientists, legislators, and farmers. Perceptions or misconceptions of welfare issues can have a dramatic effect on livestock production if industries respond by changing certain production practices, if governments react by enacting laws dictating how livestock are produced, or if consumers respond by changing purchasing patterns. A major economic issue in this area spawns from the fact that existing markets may not be well suited for solving the animal welfare debate and imposition of regulatory requirements on production practices could result in significant costs to producers and, ultimately, consumers who pay higher prices for meat.

The concern for animal welfare has particularly targeted the use of gestation stalls—also known as gestation crates—by swine producers. Gestation stalls are metal stalls that house female breeding stock in individually confined areas during an animal's four-month pregnancy. Pork producer organizations suggest that the use of gestation stalls may facilitate more efficient pork production resulting in lower prices for consumers. The use of the stalls is deemed as an animal welfare issue by some because the stalls limit animal mobility (Tonsor, Olynk, and Wolf, 2009). This perception has led to regulatory pressures and agri-food companies considering moving towards policies restricting the use of gestation stalls.

To understand the economic aspects of this ongoing debate, it is helpful to review the structural evolution of the U.S. swine industry, the legal framework underlying provisions of animal welfare in the United States, and adjustments in livestock and meat markets regarding animal welfare claims and protocols.

Changes in Swine Production

The number of swine produced in the United States during the last several decades has remained relatively constant. However, animal production practices have become increasingly concentrated with the major focus being on improved economic efficiency (Fraser, Mench, and Millman, 2001; and Mench, 2008). Once dominated by small operations that practiced crop and swine production, the industry has become increasingly concentrated among large operations. According to the U.S. Department of Agriculture's (USDA) 2012 Census of Agriculture, 63,246 farms, about 3% of the 2.1 million farms in the United States, had a swine inventory in 2012 (USDA National Agricultural Statistics Service (NASS), 2014). Most of these were large operations. Over 95% of farms had a swine inventory of more than 1,000 hogs, more than 90% had more than 2,000 hogs, and over 67% had more than 5,000 hogs (USDA, NASS, 2014).

As the industry has evolved, swine producers have had to adjust the size, organizational structure, and technological base of their operations, or cease production (Key and McBride, 2007). Gestation stalls were an experimental system in the 1950s and, as farms remodeled and were built, gestation stalls became more common amongst newer facilities in the 1970s (McGlone, 2013). In 2012, 75.8% of all gestating breeding stock (38.9% of sites) in the United

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States was housed in individual stalls (USDA, Animal and Plant Health Inspection Service (APHIS), 2014).

These changes in housing—combined with changes in nutrition, health, and genetics as well as the widespread adoption of new technologies—have also led to significant changes in productivity. The efficiency of the U.S. swine breeding herd continues to increase with the average number of pigs per breeding animal continually on the rise. The average number of annual pigs per breeding herd animal (including sows, gilts, and boars) was 20.22 in 2012, up from 10.32 in 1963. This tremendous increase in the average number of pigs per breeding animal is due to the increase in the number of litters per sow per year and the increase in litter rates. Overall, producers have been able to increase pig crops while decreasing breeding herd as a percent of the total inventory.

The pressure for increased production efficiency is driven by many factors, among them the drive to acquire export markets; the availability of competing imports; the low margins paid to producers because of the increased cost of product packaging, distribution, and marketing; technological innovation; and the high cost of skilled farm labor (Appleby, 2005; Appleby, 2006; and Mench, 2008). To remain competitive, producers must continuously maintain or improve production performance. Swine producers are reluctant to change from well-established production practices unless they increase performance or at the very least do not decrease performance. Any production system that has a negative impact on performance will not be widely adopted voluntarily.

Legal Framework in Animal Welfare

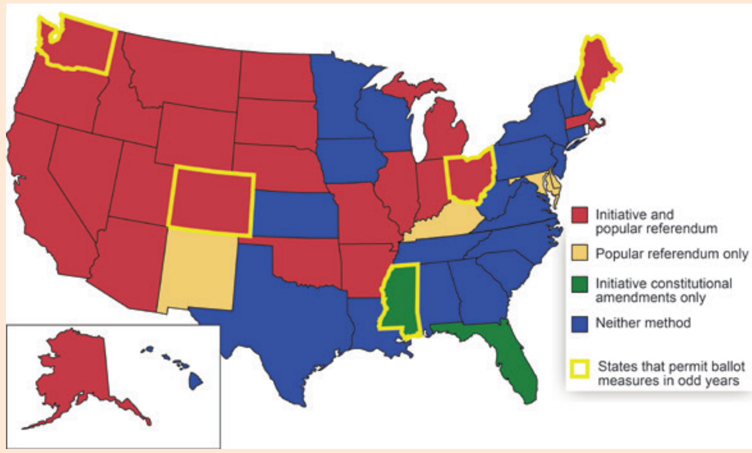
In the United States, there are two federal laws regulating the treatment of farm animals. The Twenty-Eight Hour Law, passed in 1873 (amended in 1994), requires that animals, while in the course of interstate transportation, may not be confined in a vehicle or vessel for more than 28 hours without unloading the animals for feeding, water, and rest (USDA, National Agriculture Library (NAL), 2014a). The Humane Methods of Slaughter Act, originally passed in 1958 (the law that is enforced today was passed as the Humane Slaughter Act of 1978), requires the proper treatment and humane handling of all food animals, excluding chickens and other birds, slaughtered in USDA-inspected slaughter plants (USDA, NAL, 2014b).

There has been almost no change in U.S. federal legislation related to farm animals in the last several decades, even though the treatment of animals in research, exhibition, transport, and by dealers has been extensively regulated since 1966 (amendments in 1970, 1976, 1985, 1990, 2002, 2007, and 2008) under the provisions of the Animal Welfare Act (USDA, NAL, 2014c). The lack of federal legislation governing the housing of farm animals has lead animal activist groups to pressure individual states to enact animal welfare legislation (Mosel, 2001; Uralde, 2001; and Mench, 2008).

Proponents of state legislation claim that stalls (for gestating sows, veal, and other farm animals) or cages (for laying hens) cause cruelty to animals, while the opponents argue that they are merely engaging in normal animal production practices (Rumley, 2009). The debate is intensified by the fact that, while all 50 states have enacted some form of legislation prohibiting cruelty to animals, about 30 states exempt "common," "normal," or "customary" farm animal production practices from coverage under the law (Wolfson and Sullivan, 2004).

In addition to the typical legislative process, there are ballot measures to enact new laws or constitutional amendments or repeal existing laws or constitutional amendments. An initiative is a proposal of a new law or constitutional amendment that is placed on the ballot by petition, that is, by collecting signatures of a certain number of citizens. A referendum is a

Figure 1. State-by-State Initiative and Referendum Provisions



Source: Initiative & Referendum Institute (2013).

Note: This figure shows only the general initiative and referendum provisions for a particular state, not those only specific to animal welfare regulations. Every state has some form of the legislative process which allows the government to place issues on the ballot and so, therefore, is not referenced in the map.

Table 1. States with Bans on the Use of Gestation Stalls and Corresponding Breeding Inven

State	Year passed	Type	Breeding inventory		
			Number	Rank in U.S.	Percent of U.S.
Florida	2002	Ballot Initiative	3,509	30th	0.06%
Arizona	2006	Ballot Initiative	Not Reported	Not Reported	Not Reported
Oregon	2007	Legislation	2,801	32nd	0.05%
Colorado	2008	Legislation	145,140	11th	2.54%
California	2008	Ballot Initiative	8,322	28th	0.15%
Maine	2009	Legislation	1,596	37th	0.03%
Michigan	2009	Legislation	111,983	13th	1.96%
Ohio	2010	Legislation	142,782	12th	2.50%
Rhode Island	2012	Legislation	578	44th	0.01%

Source: States with bans on the use of gestation stalls compiled from Rumley (2009), Natio HSUS (2014). Breeding operations and inventory are as of the end of December 2012; com (USDA NASS 2014).

Note: Any tabulated item that could potentially identify an individual producer or operation Census of Agriculture data and, thus, not available to be reported here.

proposal to repeal a law that was previously enacted by the legislature, and that is placed on the ballot by citizen petition. Currently 24 states have the initiative process and 24 states permit a referendum (Initiative & Referendum Institute, 2013). Figure 1 shows which states have the initiative and referendum process, and what type. These states through the initiative or referendum process have enacted (or have the ability to enact) laws that regulate farm animal production practices. There is no provision for any sort of ballot proposition at the national level in the United States.

Several states have issued bans on sow gestation stalls, veal calf stalls, or conventional cage systems for laying hens. Oregon, Colorado, Maine, Michigan, Ohio, and Rhode Island have already passed legislation and Florida, Arizona, and California have already passed animal confinement laws through a ballot initiative (National Agricultural Law Center, 2014; and Humane Society of the United States (HSUS), 2014). The states slated for elimination of gestation stalls represent a relatively small percentage of the total U.S. breeding inventory (7.30%) and breeding operations (18.89%) (Table 1). However, future regulation in other states could significantly impact a greater percentage of the U.S. breeding inventory and breeding operations. For example, the top three states ranked by breeding inventory represent over 41% of the breeding inventory and over 13% of the breeding operations in the United States - Iowa 917,567 inventory (1,676 operations), North Carolina 896,231 inventory (838 operations), and Minnesota 572,545 inventory (1,133 operations) (USDA NASS, 2014). These states do not have initiative and referendum provisions and currently there is no farm animal confinement legislation being considered in these states.

Smithson et al. (2014) suggest a larger number of states may be favorable to initiatives similar to California's Proposition 2. Proposition 2 prohibits California livestock producers from the "confinement of farm animals in a manner that does not allow them to turn around freely, lie down, stand up, and fully extend their limbs" (California Secretary of State, 2008). The particular species and production segments discussed in Proposition 2 were calves raised for veal, laying hens, and gestating sows and gilts. Importantly, the authors identify a disconnect between these states and the distribution of livestock production highlighting tension that can arise from customer (retailers or other up-stream industry participants) requests not cleanly matching consumer signals for change in the form of observed food purchasing behavior.

Farm Level Costs of Transitioning from Gestation Stalls to Group Housing

The transition from gestation stall housing to group housing is the most common adjustment being made or discussed within the industry. For example, in 2007, Smithfield Foods, Inc., made a decision based on input from its customers to convert to group housing for pregnant sows on all company-owned U.S. farms. Smithfield remains on track to finish its conversion to group housing systems on all company-owned U.S. farms by 2017 and is asking contract sow growers to convert by 2022 with a sliding scale of incentives to accelerate that timetable (Smithfield, 2014).

Gestation stall housing is well defined in the United States because a prototypical system has been installed as the industry has modernized in the past 25 years. In contrast, no prototypical gestation group housing system has emerged, largely because of its limited application at the commercial level which has limited the evolution of systems to fit commercial scale. Group housing has been shown to include large pen systems (greater than 50 sows in a pen) and small pen systems (six or fewer sows in a pen) (Buhr, 2010). Edwards (2008) suggests that the extent to which acceptable economic performance can be realized in alternative housing systems for gestating swine depends on the level of performance which can be achieved in a given system relative to the cost requirement.

The first issue to consider relates to the fixed costs arising from the capital cost of system installation. Several studies have estimated the direct costs of switching from gestation stalls to group pen housing (Lammers et al., 2007; Buhr, 2010; and Seibert and Norwood, 2011). While there is general agreement of increasing costs at the farm level, the magnitude of increase is highly debated. Buhr (2010) defines several factors that will determine transition costs. These include: “(1) the feasibility and cost of retrofitting existing stall facilities into group housed facilities compared to complete construction of new facilities, (2) the remaining useful life of the existing facilities and the useful life of renovating these facilities compared to constructing new facilities, (3) the amount of time available to make the transition if there is a time limitation, (4) any subsequent differences in operation and production net profits after the refurbishment, (5) space allocation requirements for pens versus stall facilities which will determine if new buildings must be constructed to accommodate existing production levels, and (6) the learning curve of management and labor in achieving production results in a new system.”

The second issue relates to the level of reproductive performance which can be achieved in a given system relative to the variable cost requirement. A review of available scientific literature on swine breeding stock housing showed that well managed gestation stalls and group housing produced similar outcomes for gestating swine in terms of physiology, behavior, performance, and health (McGlone et al., 2004). Likewise, a similar scientific literature review concluded that neither stall nor group housing is clearly superior to the other and that each system has advantages and disadvantages (Rhodes et al., 2005). The literature suggests that the method of gestation housing plays an important but not exclusive role in breeding herd productivity. Many factors are shown to influence productivity such as genetics, health, environment, geographic location, worker skill, and management. In reality, swine producers are a heterogeneous demographic and a ban on gestation stalls could affect producers of different sizes, cost structures, and management styles in various ways.

Changes in the Market Place

Consumers are increasingly sensitive to food production processes. Livestock products in particular arouse consumer sentiment regarding livestock treatment and animal welfare (Frewer et al., 2005). The actions of companies that have committed to sourcing pork from producers who do not use gestation stalls or are phasing them out of their own facilities indicate that activism has led to strong market forces to discontinue gestation stall use in the United States (HSUS, 2014). Furthermore, the Food Marketing Institute (FMI) and the National Council of Chain Restaurants (NCCR) support enhanced pork industry guidelines regarding gestation housing systems (FMI and NCCR, 2002).

An argument is typically made that gestation-stall-free pork is demanded by consumers and they will compensate producers by paying higher prices. A number of recent studies have assessed consumer willingness to pay (WTP) for animal welfare attributes in meat products, including gestation-stall-free pork (Grannis and Thilmany, 2002; Tonsor, Olynk, and Wolf, 2009; Tonsor, Wolf, and Olynk, 2009; Olynk, Tonsor, and Wolf, 2010a; Olynk, Tonsor, and Wolf, 2010b; Tonsor and Wolf, 2010; Prickett, Norwood, and Lusk 2010; and Tonsor and Wolf, 2011). However, a general consensus has not been found regarding the magnitude of consumers WTP or if WTP would be large enough to offset a cost increase at the farm level. Buhr (2010) estimates that to fully compensate pork producers would require an additional 25% increase in consumer WTP for U.S. pork products from gestating swine raised in group housing.

Consumer demand for gestation-stall-free pork, or the elimination of gestation stalls, is difficult to identify. With the elimination, one cannot simply say that demand for pork will increase. Previous research has shown that consumers, when directly asked, on average prefer pork produced without gestation stalls. What is unclear is how providing information on gestation stall use would impact aggregate pork demand. For example, consumers may prefer that gestation stalls not be used but, after learning that gestation stalls were used in the first place, may begin to further question animal welfare or other issues in the production of pork which could reduce demand. On the other hand, the ban may appease those consumers concerned about animal welfare and pork demand may increase.

State of Change, Vote versus Buy Difference

It is important to note that gestation stalls continue to be voluntarily used on roughly three-fourths of the inventory (roughly two-fifths of operations). This suggests that actual WTP for stall-free pork products is likely lower when summed across all pork products than what is needed to cover adjustment costs. If this were not the case, one would expect more apparent and voluntary adjustment towards alternative production practices given favorable benefit-cost relationships. This is consistent with points made by McKendree et al. (2013) highlighting the need to evaluate the total premium of stall-free production across the full set of pork products as the cost of producing the entire carcass—not just typically examined pork chops—is impacted given the adjustment occurs during the live-animal segment of pork production.

The situation underpins the controversial setting of animal welfare discussions in the United States as producers are meeting the consumer outside the usual marketplace: in the voting booth. The list of examples where voting residents send signals inconsistent with observed consumption behavior is growing and increasing political tension between producers and consumers. Perhaps the clearest demonstrative and high-profile example is that cage-free eggs hold less than 5% market share in the United States, yet the majority of residents who have voted on related ballots have supported restricting use of laying hen cages (Norwood and Lusk, 2011). Allender and Richards (2010) also note: "Somewhat paradoxically, a majority of California voters elected to regulate cage-free production, even though almost three-quarters of egg consumers are not willing to pay the price difference required" (p. 436). This example is shared as the existing literature is richer in terms of egg research applying scanner data but the same general point holds in the debate of gestation stalls.

Some recent research applied to animal welfare issues suggest several reasons citizens may be more likely to vote to ban practices than they are to regularly buy resulting products in the grocery store. Harvey and Hubbard (2013) outline six reasons including: 1) cheap talk of voting (the costs may be more salient in retail than ballot settings); 2) some people are willing to pay retail premiums only if they are assured of actual improvements in the underlying issue (highlighting the role of group vs. individual decision-making); 3) product labels are not sufficient or reliable to influence purchasing; 4) overall information available to consumers is inadequate or confusing, leading to reduced purchases; 5) the costs of checking information are too high; and 6) other things besides the issue of focus in a voting setting are more important in purchasing environments (for example, safety may trump animal welfare at the retail shelf but not be considered in a voting booth).

Regardless of why this behavior occurs, when voters require practices that shoppers will not fully fund, it has an adverse effect on agricultural producers which, of course, leads to the observed added contention regarding requested production changes that arrive from sources not fully paying premiums to cover adjustment costs.

For More Information

Allender, W.J. and T.J. Richards. 2010. "Consumer Impact of Animal Welfare Regulation in the California Poultry Industry." Journal of Agricultural and Resource Economics. 35:424-442.

Appleby, M.C., 2005. "The Relationship Between Food Prices and Animal Welfare." Journal of Animal Science. 83(Supplement):E9-E12.

Appleby, M.C., 2006. "Animal Sentience in US Farming." In: Turner, J., D'Silva, J. (Eds.), Animals, Ethics and Trade: The Challenge of Animal Sentience. Earthscan, London, pp. 159-165.

Buhr, B.L. 2010. "Economic Impact of Transitioning from Gestion Stalls to Group Pen Housing in the U.S. Pork Industry." Staff paper P10-4. College of Food, Agricultural and Natural Resources, University of Minnesota, St. Paul.

California Secretary of State. 2008. Proposition 2: Standards for Confining Farm Animals. Available online: http://www.sos.ca.gov/elections/elections_j_103008.htm.

Edwards, S.A. 2008. "Balancing Sow and Piglet Welfare with Production Efficiency." Paper presented at the London Swine Conference. April 1-2.

Frewer, L.J., A. Kole, S.A.A. Van de Kroon, and C. de Lauwere. 2005. "Consumer Attitudes Towards the Development of Animal-Friendly Husbandry Systems." *Journal of Agricultural & Environmental Ethics* 18:345–67.

Fraser, D., J. Mench, S. Millman. 2001. Farm animals and their welfare in 2000. Rowan, A. and Salem, D. (Eds.) State of the Animals 2000. Humane Society of the United States Press, Washington, DC.

Food Marketing Institute and National Council of Chain Restaurants. *FMI-NCCR Animal Welfare Program*. June 2002 Report. Available online: http://www.fmi.org/docs/animal-welfare/awnews-advisory62702.pdf?sfvrsn=0.

Grannis, J. and D.D. Thilmany. 2002 "Marketing Natural Pork: An Empirical Analysis of Consumers in the Mountain Range." *Agribusiness*. 18(4):476-489.

Harvey, D. and C. Hubbard. 2013. "Reconsidering the political economy of farm animal welfare: An anatomy of market failure." Food Policy. 38:105-114.

Humane Society of the United States. 2014. "Timeline of Major Farm Animal Protection Advancements." Available online: http://www.humanesociety.org/issues/confinement_farm/timelines/timeline_farm_animal_protection.html.

Initiative & Referendum Institute. 2013. State-by-State List of Initiative and Referendum Provisions. University of Southern California. Available online: http://www.iandrinstitute.org/statewide_i%26r.htm.

Key, N. and W. McBride. December 2007. *The Changing Economics of U.S. Hog Production*. U.S. Department of Agriculture Economic Research Report Number 52.

Lammers, P., M. Honeyman, J. Kliebenstein, J. Harmon. "Impact of Gestation Housing System on Weaned Pig Production Cost." A.S. Leaflet R2235. Iowa State University Animal Industry Report 2007. Available online: http://www.ans.iastate.edu/report/air/2007pdf/R2235.pdf.

McGlone, J.J., E.H. von Borell, J. Deen, A.K. Johnson, D.G. Levis, M. Meunier-Salaun, j. Morrow, D. Reeves, J.L. Salak-Johnson, and P.L. Sundberg. 2004. "Review: Compilation of the Scientific Literature Comparing Housing Systems for Gestating Sows and Gilts Using Measures of Physiology, Performance and Health." *The Professional Animal Scientist*. 20: 105-117.

McGlone, J.J. 2013. Sow Stalls – A Brief History. *Pig Progress*, December 9, 2013. Available online: http://www.pigprogress.net/Home/General/2013/12/Sow-stalls--a-brief-history-1388603W/.

McKendree, M.G.S., N. Olynk Widmar, D.L. Ortega, and K.A. Foster. 2013. "Consumer Preferences for Verified Pork-Rearing Practices in the Production of Ham Products." *Journal of Agricultural and Resource Economics*. 38:397-417.

Mench, J.A. 2008. "Farm Animal Welfare in the U.S.A.: Farming Practices, Research, Education, Regulation, and Assurance Programs." *Applied Animal Behaviour Science*. 113:298-312.

Mosel, A. 2001. "What About Wilbur? Proposing a Federal Statute to Provide Minimum Humane Living Conditions for Farm Animals Raised for Food Production." *University of Dayton Law School.* 27:133-186.

National Agricultural Law Center. 2014. States' Farm Animal Confinement Statutes. University of Arkansas. Available online: http://nationalaglawcenter.org/state-compilations/farm-animal-welfare/.

Norwood, F.B. and J.L. Lusk. 2011. Compassion by the Pound: The Economics of Farm Animal Welfare. Oxford, U.K: Oxford University Press, 2011.

Olynk, N.J., G.T. Tonsor, and C.A. Wolf. 2010a. "Consumer Willingness to Pay for Livestock Credence Attribute Claims." *Journal of Agricultural and Resource Economics*. 35(2):261-280.

Olynk, N.J., G.T. Tonsor, and C.A. Wolf. 2010b. "Verifying Credence Attributes in Livestock Production." *Journal of Agricultural and Applied Economics*. 42(3):439-452.

Prickett, R.W., F.B. Norwood, and J.L. Lusk. 2010. "Consumer preferences for farm animal welfare: results from a telephone survey of US households." *Animal Welfare*. 19:335-347.

Rhodes, R.T., M.C. Appleby, K. Chinn, L. Douglas, L.D. Firkins, K.A. Houpt, C. Irwin, J.J. McGlone, P. Sundberg, L. Tokach, and R.W. Wills. 2005. "A Comprehensive Review of Housing for Pregnant Sows." *Journal of the American Veterinary Medical Association*. 227(10):1580-1590.

Rumley, E.R. 2009. "A Proposal to Regulate Farm Animal Confinement and Overview of Current and Proposed Laws." Drake Journal of Agricultural Law 14:437.

Seibert, L. and F.B. Norwood. 2011. "Production Costs and Animal Welfare for Four Stylized Hog Production Systems." Journal of Applied Animal Welfare Science 14(1):1-17.

Smithfield, 2014. *Smithfield Foods Recommends Its Contract Growers Convert to Group Housing for Pregnant Sows*. January 2, 2014. Available online: http://investors.smithfieldfoods.com/releasedetail.cfm?releaseid=817511.

Smithson, K., M. Corbin, J.L. Lusk, and F.B. Norwood. 2014. "Predicting State-Wide Votes on Ballot Initiatives to Ban Battery Cages and Gestation Crates." *Journal of Agricultural and Applied Economics*. 46:107-124.

Tonsor, G.T., N. Olynk, and C.A. Wolf. 2009. "Consumer Preferences for Animal Welfare Attributes: The Case of Gestation Crates." *Journal of Agricultural and Applied Economics*. 41(3):713-730.

Tonsor, G.T., C. Wolf, and N. Olynk. 2009. "Consumer Voting and Demand Behavior Regarding Swine Gestation Crates." *Food Policy*. 34:492-498.

Tonsor, G.T. and C. Wolf. 2010. "Drivers of Resident Support for Animal Care Oriented Ballot Initiatives." *Journal of Agricultural and Applied Economics*. 42(3):419-428.

Tonsor, G.T. and C.A. Wolf. 2011. "On Mandatory Labeling of Animal Welfare Attributes." *Food Policy*. 36(3):430-437

U.S. Department of Agriculture, Animal and Plant Health Inspection Service. 2014. *Swine 2012, Part I: Baseline Reference of Swine Health and Management, 2012*. National Animal Health Monitoring System. Fort Collins, CO #663.0814.

U.S. Department of Agriculture, National Agriculture Library. 2014a. *Twenty-Eight Hour Law*. Available online: http://awic.nal.usda.gov/government-and-professional-resources/federal-laws/twenty-eight-hour-law.

U.S. Department of Agriculture, National Agriculture Library. 2014b. *Humane Methods of Slaughter Act.* Available online: http://awic.nal.usda.gov/government-and-professional-resources/federal-laws/humane-methods-slaughter-act.

U.S. Department of Agriculture, National Agriculture Library. 2014c. *Animal Welfare Act.* Available online: http://awic.nal.usda.gov/government-and-professional-resources/federal-laws/animal-welfare-act.

U.S. Department of Agriculture, National Agricultural Statistics Service. 2014. *Census of Agriculture*. Available online: http://www.agcensus.usda.gov/Publications/2012/#full_report.

Uralde, J. 2001. "Congress' Failure to Enact Animal Welfare Legislation for the Rearing of Farm Animals: What is Truly at Stake." *University of Miami Business Law Review*. 9:193-214

Wolfson, D.J. and M. Sullivan. 2004. Foxes in the hen house. In Cass R. Sunstein and Martha Craven Nussbaum (eds.), Animal Rights: Current Debates and New Directions. Oxford University Press. 205--228.

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