Coordinating Supply Chains to Maximize Value in the Beef and Pork Industries

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Introduction

There are stark differences between the flow of beef and pork through their supply chains. The pork industry is primarily vertically integrated with a small number of owners controlling the majority of production while the beef industry has many independent decision makers across multiple phases of production (USDA, NASS 2016). Both industries face the challenge of transmitting information up and down the supply chain, but have evolved different levels of vertical coordination and ownership. In spite of differing market arrangements, each industry has shown steady improvements in efficiency with regards to pounds of meat per animal. Figures 1 and 2 show the changes in beef and pork production characteristics from 1991 to 2014. Each industry has achieved steady increases in the amount of weight per animal with the average cattle slaughter weight increasing by over 150 pounds and the average hog slaughter weight increasing by 35 pounds since 1991 (USDA, NASS 2015). In the cattle industry, this increase in slaughter weight has allowed the industry to keep production relatively consistent even though the total number of cattle slaughtered has decreased slightly as shown in Figure 3. An increase in per animal productivity provides benefits for producers (fewer cattle to manage to obtain the same amount of output), consumers (potentially increased beef supply), and the environment (fewer cattle to consume resources).

Each industry has experienced structural changes in the past few decades (Boetel and Liu 2010). These structural changes are likely due to consolidation of smaller firms and the increase in the use of contracts and market agreements, especially in the hog market. Increased linkages between varying stages of production have occurred in each industry. The pork industry has made large steps toward vertical integration (Reimer 2006). The majority of hogs are now produced under contract where hog owners pay producers fees to raise the animals through different phases of production (Key and McBride 2007). Not surprisingly, large operations that specialize in these phases of production have evolved and the number of hog farms has drastically decreased. On the other hand, the beef industry seems to be the lone hold-out among the big three proteins (beef, chicken, pork) with regards to vertical integration. Due to a number of factors, cattle are still exchanged at a few points along the supply chain (Ward 1997). However, marketing agreements, another form of contracting, have become popular in the beef industry and have led to fewer cattle being marketed by the traditional cash-market method. This predominately occurs between the finishing and processing phases of beef production. While ownership of the cattle does generally change hands, these agreements secure supply for meat packers.

Not lost in the structural shifts of the beef and pork industries are the impacts of technological innovation and its effect on the flow of these meats through their respective supply chains. Technology innovations have been a major factor in the changing economics of the beef and pork industries. Improved nutrition, growth promotion technologies, better genetics, and economic conditions have all played a role in livestock becoming more efficient (Rutherford 2013). The value of improved technologies between 1977 and 2012 in the beef and pork sectors have been estimated at $11 billion annually and $7.6 billion annually (Lusk 2013).

The purpose of this article is to synthesize the available information regarding the increased efficiencies of the beef and pork industries. A wealth of knowledge is gathered from published literature that summarizes and describes the flow of beef and pork through their respective supply chains. This article documents the increased efficiency of the beef and pork industries and explores the reasons behind this efficiency boom and the impact on the flow of meat through the supply chain. Specifically, we analyze market structure changes, technological innovations, and quality and grading standards. Research is summarized for each topic and broad views of the beef and pork industries are presented. Next, unintended consequences of the increased meat production per animal are discussed. Finally conclusions are drawn and potential directions for the livestock markets are discussed.

Market Structure

Much of the discussion surrounding the market structures of the beef and pork industries has focused on vertical integration. Vertical integration occurs when one firm participates in multiple adjacent stages of the supply chain (Ward 1997, Carlton and Perloff 1994).

The beef industry generally consists of three points along the supply chain in which a live animal will change ownership: cow-calf to stocker, stocker to feeder, and feeder to processor. At each point, market prices are either used or have an influence on the transaction price. The size of operations increase as the animals are moved along the supply chain. There are many cow-calf producers, fewer stockers and feeders, and very few processors through which cattle flow. The increased concentration of the processing stage has created concern of market power (e.g. Azzam 1997; Koontz and Garcia 1997; Schroeter 1988). While the transactions are market price based, there have been attempts at a more vertically integrated structure through the use of marketing agreements. These agreements are predominately used between the feeder and the processor and secure a certain quantity of cattle to be delivered at a price that will be determined at the time of delivery.

Even with the presence of marketing agreements, the beef industry is easily the least vertically integrated of the big three protein industries. The key reasons for this revolve around the biological makeup of cattle. The biological production cycle is about 2 years which is twice as long as that of hogs. Further, the genetic base of cattle is relatively diverse and is not narrowing (Ward 1997). Alternatively, the pork industry genetic base has narrowed to pinpoint the most efficient hogs for production. Geographical concentration also plays an important role. Cattle are scattered throughout the U.S. due to the required land and forage needed while hog production is centered in the Midwest near the heaviest corn-producing states. These factors create significant barriers to integration in the beef industry. While cattle are overwhelmingly grazed and fed outdoors on vast acreage in the cow-calf and stocker phases of production, there is some movement toward confined cattle production. Large hoop barns are being used in the Midwest to provide a protected environment for cattle during the winter months or potentially year-round confinement (Rutherford 2015).

Much research has discussed the market organization of the hog industry drastically changing from many small producers to fewer large operations (i.e. Key and McBride 2007; Reimer 2006; Ward 1997). Figure 4 shows that the total number of hog operations have decrease along with the number of small hog operations. At the same time, the number of large operations have increased rapidly. Much of this shift occurred between 1992 and 2004 as the number of hog farms decreased by 70 percent and the average hog operation grew from 945 head to 4,646 head (Key and McBride 2007). The overall trend of the pork industry has moved toward large operations that specialize in a single phase of production and operating under contractual agreements and away from the use of cash markets. Approximately 5 percent of hogs were produced under contract in 1992 and this number increased to over 70 percent in 2009 (Key 2014). Not surprisingly, the percentage of hogs sold using the spot market decreased from about 17 percent in 2002 to approximately 3 percent in 2014 (Lawrence 2010; LMIC 2014).

A contract agreement in the pork industry is generally described as an agreement in which the owner of the hogs pays a producer to raise the hogs during a specific phase of production (i.e. birth to weaning, weaning to finish, feeding to finish). Contracting producers are typically paid on a fee-for-service basis and are generally shielded from direct market price fluctuations. This reduction in price risk has encouraged the consolidation of producers into larger operations specializing in specific market phases. Larger operations can better implement technological innovations and exhibit significant economies of scale. These operations are attractive for hog owners as they are more efficient at producing hogs than are smaller operations.

The increase in contract production has led to a divide between hog producers and hog ownership. Table 1 shows that there were approximately 8,100 more hog producers than there were hog owners in 2012 which implies that there were many contracting owners. Even more telling is the 2,000 operations gap between producers and owners in the largest category of 5,000 head or more. This implies that at least 2,000 of the largest producers do not own the hog inventory they raise. The hog inventory was also heavily controlled by the largest owners. There were 145 owners with greater than 50,000 head who accounted for 60 percent of the hog inventory in 2012 (USDA, NASS 2016).

Technological Innovations

Advances in genetics, nutrition, handling practices, and medications have all helped contribute to the increased efficiencies of livestock industries. There have been multiple evaluations of the benefits of technologies in the beef and pork sectors (e.g. Lusk 2013; Capper 2011; Elam and Preston 2004; Lawrence and Ibarburu 2007; Capper and Hayes 2012). Lusk (2013) estimated that 33 percent and 71 percent of the 2012 values of beef and pork production, respectively, could be attributed to factors that improved productivity since 1977 such as technology improvements and genetics. Capper (2011) utilized a simulations approach to estimate that under 1977 technology, it would take 43 percent more cattle and 23 percent more feed to produce the same amount of beef that was produced in 2007.

The technology that is perhaps the most responsible for the increase in livestock productivity and efficiency is the advancement of pharmaceutical technology. Parasite control, ionophores, antibiotics, growth promotant implants, and beta-agonists have been the most widely-used of these innovations. The productivity and economic impacts of these technologies are large. Elam and Preston (2004) discuss each of these technologies in length in their summary of the technological impact in the beef industry. Growth implants are noted to increase rate of gain by 15 to 20 percent and improve feed efficiency 8 to 12 percent while ionophores improve feed efficiency by 6 to 8 percent and increase average daily gain by 1 to 6 percent. Lawrence and Ibarburu (2007) used a meta analysis approach to find estimates for the farm level economic value of these five technologies in the beef industry. They estimated that the cumulative direct cost savings of the technologies was over $360 per head for the lifetime of an animal. Further, they estimated that beta agonists improve feedlot average daily gain by 14 percent and that the combination of implants, ionophores, antibiotics and beta-agonists account for a 37 percent increase in average daily gain in feedlots.

Similar to beef production, many technological innovations have led to increased efficiency in the pork sector. While technological innovations at any level are beneficial, the pork industry is seemingly in prime position to take advantage of new technologies. The growing size of operations coupled with specialization among producers in specific phases of production allow for the costs of technology to be more easily absorbed. Nutritional innovations and pharmaceutical technologies have helped lead to large decreases in the amount of feed needed to produce pork. For a specialized feeder to finish operation, the average quantity of feed required per hundredweight of gain decreased by 44 percent between 1992 and 2004 (Key and McBride 2007). Since 2004, the efficiency gains have flattened with only a 2 percent increase in feed efficiency between 2004 and 2009 (McBride and Key 2013). Similarly, the efficiency of labor use increased by 83 percent from 1992 to 2004 but only 3 percent from 2004 to 2009 (McBride and Key 2013).

Quality and Grading Standards

Grading systems have been used in the beef industry since 1928 when the USDA established the Standards for Graders of Slaughter Cattle. The Prime, Choice, Select, and Standard grades that are used today were adopted through revisions of the standards in 1950, 1976, and 1987 (USDA, AMS, 1996). From the beginning, the goal of the beef grading system has been to facilitate the production, marketing, and distribution of livestock and beef. The grading system facilitates the flow of beef by providing quality estimates to be used by producers and buyers to differentiate between low and higher quality beef products. The beef grading system has become increasingly popular in the U.S. with nearly 90 percent of all beef production being graded (USDA, AMS 2016). Figure 4 shows the amount of beef production graded relative to overall beef production.

While the beef industry has a grading system that is used in the overwhelming majority of production, the pork industry has largely abandoned any efforts of a government administered live hog grading system. The “carcass grade-and-yield” grading system was introduced in 1952 that graded hogs in a similar fashion to cattle. However, due to improved genetics, nearly all market hogs were in the top two USDA hog grades in the late 1980s which left little differentiation ability for the system. Several of the largest meat packers began using a different technology in 1992 dubbed the “Fat-O-Meater.” This technology allowed packers to develop their own pricing grids and the USDA system was abandoned (Martinez and Zering 2004).

A key reason for the lack of a government administered live hog grading system in the pork industry is the market structure. The beef industry relies on the grading system to send market signals upstream, to the livestock producers. If cattle feeders are consistently producing cattle that grade poorly, they are punished by the grading discounts (or they are not rewarded by high-grading incentives). This provides an economic incentive to improve their production strategies and procedures. Conversely, due to the vertically integrated nature of the pork industry, the hog owners discover whether their products are desired by pork-buyers and also have the ability to change production practices through contracting among producers. Thus, the only signal that is truly important in this industry is obtained almost directly from the consumer.

As Tonsor and Schroeder (2013) describe, if the current protocols in the pork industry are providing consumers with a desired product, then the production, processing, and marketing efforts are generally aligned. If not, then the necessary signals are not being sufficiently transmitted throughout the supply chain.

The natural question in the pork industry is whether or not a grading system is needed. Is there a problem with the quality of the pork produced? A grading system is only valuable if quality variation exists and if the lower quality products cannot be differentiated by consumers. Tonsor and Schroeder (2013) find that approximately 20 percent of pork eating experiences involving loin products are likely sub-optimal. Further, the find that little price differentiation occurs between low quality pork and higher quality pork and, thus, consumers often cannot rely on price to signal quality differences. These findings would seem to imply the need for a grading system. However, Tonsor and Schroeder (2013) conclude that when considering the overall feasibility of a grading system, it alone will likely not be able to resolve the quality variation issue.

Accuracy and cost are two key factors that have largely prevented any proposed pork grading system from being implemented. Improved accuracy is related to the time and cost to grade each carcass and therefore would have to provide enough benefit to offset the added costs and decrease in processing plant efficiency. Moeller, Miller, and Zerby (2008) found that shear force measurements of tenderness and the pH level of pork influence consumer perceptions of quality. However, similar to Tonsor and Schroeder (2013), they also conclude that a grading system based on these two measurements is not yet feasible. While a federally implemented grading system similar to the beef industry is not economically feasible, Tonsor and Schroeder (2013) list many private initiatives to improve pork quality.

Unintended Consequences

While the increase in productivity and efficiency of the beef and pork supply chains have had mostly positive impacts on the industries, there are unintended consequences that have arisen. Perhaps the most obvious is directly related to the goal of per animal productivity: carcass size. Increased carcass size has a direct effect on the size of some of the cuts from beef and pork carcasses such as the beef ribeye or pork loin. The increase in size of these cuts has created package price concerns for retailers and plate cost concerns for restaurants. Unlike ground beef or ground pork, the ribeye and loin cannot easily be adjusted for size and consumers may be presented with steaks or pork chops that are larger than they desire. Restaurants are concerned about the size of steaks due to plate cost considerations and the general inability to alter the steak size (they can't just cut it in half; thin slicing is possible but usually not preferred). In fact, the most recent National Beef Quality Audit listed weight and size as one of the top quality challenges faced by the beef industry (NBQA 2011). While it is possible that the overall value of the carcass has increased due to additional pounds, many of the more expensive cuts are likely less desirable.

A key unintended consequence occurring in the hog industry developed from the progression of genetics and narrowing of the genetic pool. Genetic research focused on producing leaner hogs particularly in the 1990s in response to health concerns related to fat and cholesterol (Martinez and Zering 2004). Around this same time, the Porcine Stress Syndrome gene was linked to a pork quality concern called PSE which stands for pale, soft, and exudative which is very lightly colored pork with soft texture and a high degree of drip loss. This stress syndrome gene was found to be carried by some of the leaner genetic lines of hogs and this lead to less attractive pork for consumers. As much as 15.5 percent of U.S. commercial hog slaughter was found to be PSE pork in 2002 which attributed to a $90 million loss in industry revenues. PSE continues to be a common quality deficiency as heavier muscled lean hogs are prone to stress (Van de Perre et al. 2010; Martinez and Zering 2004).

Conclusions

Hogs and cattle are becoming more efficient though the flow of meat though each supply chain looks quite different. Most hogs are owned by a single entity and are contracted from the birth of the piglet to the time which the meat is sold as pork. In contrast, most cattle exchange ownership at least a few times along the beef supply chain. Market signals in the cattle industry are aided in transmission by a quality grading system that sends information upstream to producers while the pork industry relies on vertical coordination to ensure adequate quality.

There are numerous technological innovations to which we can credit for helping to increase beef and pork productivity and efficiency. Elam and Preston (2004) estimated that the combination of research, technology, and innovation increased productivity of the U.S. beef industry by over 80 percent since the 1950s. Likewise, the pork industry has also experienced drastic increases in productivity.

As we look toward the future, the productivity advances of the past few decades provided basis for some important questions. Namely, can each industry continue to become more productive? Can the beef industry keep up with the ever-increasing world population by producing more meat with fewer cattle? Certainly there is some biological limit on how large cattle can be at the time of slaughter. Has the industry neared this limit? Due to land and resource requirements and larger number of production phases, it is not likely that the beef industry will be able to achieve the levels of vertical coordination as we have seen in the pork industry and, thus, likely will not be able to reap rapid improvements in efficiency as were experienced by the pork industry. If the productivity per animal increase for cattle begins to slow, it is likely that the herd size will have to increase to be able to provide for an increase in demand due to a growing population. Similar questions can be posed for pork. If the last few decades of technological advances have taught us anything, it is that there is always room for marginal improvements. However, it is possible if not likely that the largest magnitudes of marginal improvements may have already occurred in the beef and pork industries.

References

Azzam, A. M. "Measuring Market Power and Cost-efficiency Effects of Industrial Concentration." *The Journal of Industrial Economics* 45.4 (1997): 377-386.

Boetel, B. L., and D. J. Liu. "Estimating Structural Changes in the Vertical Price Relationships in US Beef and Pork Markets." *Journal of Agricultural and Resource Economics* (2010): 228-244.

Capper, J. L. "The Environmental Impact of Beef Production in the United States: 1977 Compared with 2007." *Journal of Animal Science* 89(2011):4249–4261.

Capper, J. L., and D. J. Hayes. "The Environmental and Economic Impact of Removing Growth-enhancing Technologies from U.S. Beef Production." *Journal of Animal Science* 90(2012):3527–3537.

Elam, T. E., & Preston, R. L. "Fifty years of pharmaceutical technology and its impact on the beef we provide to consumers." Growth Enhancement Technology Information Team. 2004.

Key, N. "Production Contracts May Help Small Hog Farms Grow in Size." Amber Waves (2014): 1G.

Key, N., & McBride, W. D. "The Changing Economics of U.S. Hog Production." *USDA-ERS Economic Research Report*, 2007(52).

Koontz, S. R., and Philip Garcia. "Meat-packer conduct in fed cattle pricing: multiple-market oligopsony power." *Journal of Agricultural and Resource Economics* (1997): 87-103.

Lawrence, J. D. "Hog Marketing Practices and Competition Questions." *Choices 25*(2)(2010):1-11.

Lawrence, J. D., and Maro A. Ibarburu. "Economic Analysis of Pharmaceutical Technologies in Modern Beef Production." Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. Chicago, IL. 2007.

Livestock Market Information Center (LMIC). 2014. Hogs Sold by Transaction Type. Unpublished data based on USDA-AMS reports.

Lusk, J. L. "Role of technology in the global economic importance and viability of animal protein production." *Animal Frontiers*, *3*(3)(2013), 20-27.

Martinez, S. W., and K.D. Zering. "Pork Quality and the Role of Market Organization." USDA-ERS Agricultural Economics Report, 2004(835).

McBride, W. D., and N. Key. "U.S. Hog Production From 1992 to 2009: Technology, Restructuring, and Productivity Growth." *USDA-ERS Economic Research Report*, 2013(158).

Moeller,S., R. Miller, and H. Zerby. 2008. "Effects of Pork Quality and Cooked Temperature on Consumer and Trained Sensory Perception of Eating Quality in Non-enhanced and Enhanced Pork Loins." National Pork Board Research abstract: #06-139 and #07-005. Available online at: http://www.pork.org/FileLibrary/ResearchDocuments/07-005-MOELLER-OSU-ABS.pdf

National Beef Quality Audit (NBQA). "Executive Summary: The 2011 National Beef Quality Audit." National Cattlemen's Beef Association, funded by The Beef Checkoff. 2011.

Reimer, Jeffrey J. "Vertical Integration in the Pork Industry." *American Journal of Agricultural Economics* 88.1 (2006): 234-248.

Rutherford, B. 2013. "Bigger Cattle; Smaller Steaks." *Beef Magazine.* Retrieved from http://beefmagazine.com/retail/bigger-cattle-smaller-steaks. Accessed 25 March 2015.

Rutherford, B. 2015. "Rabobank report: Confinement or Semi-confinement Cow-calf Production is Feasible." *Beef Magazine.* Retrieved from http://beefmagazine.com/nutrition/rabobank-report-confinement-or-semi-confinement-cow-calf-production-feasible. Accessed 5 January 2016.

Schroeter, J. R. "Estimating the degree of market power in the beef packing industry." *The Review of Economics and Statistics* (1988): 158-162.

Tonsor, G.T., and T. C. Schroeder. "Economic Needs Assessment: Pork Quality Grading System." Prepared for the National Pork Board. July 2013.

United States Department of Agriculture, Agricultural Marketing Service (USDA, AMS). "Standards for Grades of Slaughter Cattle and Standards for Grades of Carcass Beef." Washington, D.C., Government Printing Office, 1996.

____. National Weekly Cattle and Beef Summary. Report LM_XB463. Multiple reports. Accessed 5 January 2016.

U.S. Department of Agriculture, National Agricultural Statistics Service (USDA, NASS). Livestock Slaughter Monthly. ISSN: 0499-0544, multiple reports. Accessed 15 December 2015.

____. Quarterly Hogs and Pigs. ISSN: 1949-1921, multiple reports. Accessed 5 January 2016.

Van de Perre, V., A. Ceustermans, J. Leyten, and R. Geers. "The prevalence of PSE characteristics in pork and cooked ham—Effects of Season and Lairage Time." *Meat Science* 86.2 (2010): 391-397.

Ward, C. E. "Vertical Integration Comparison: Beef, Pork, and Poultry." *Current Farm Economics*. 70(1997): 16-29

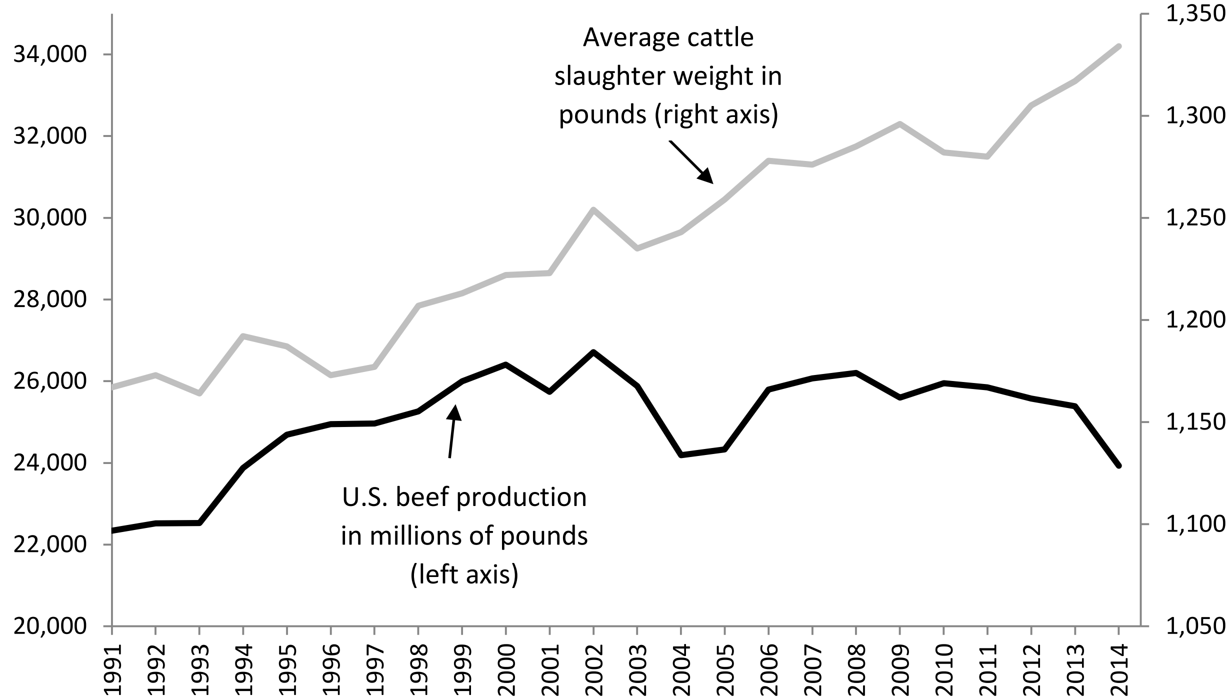

Figure 1. Aggregate U.S. beef production and average cattle slaughter weight from 1991 to 2014.

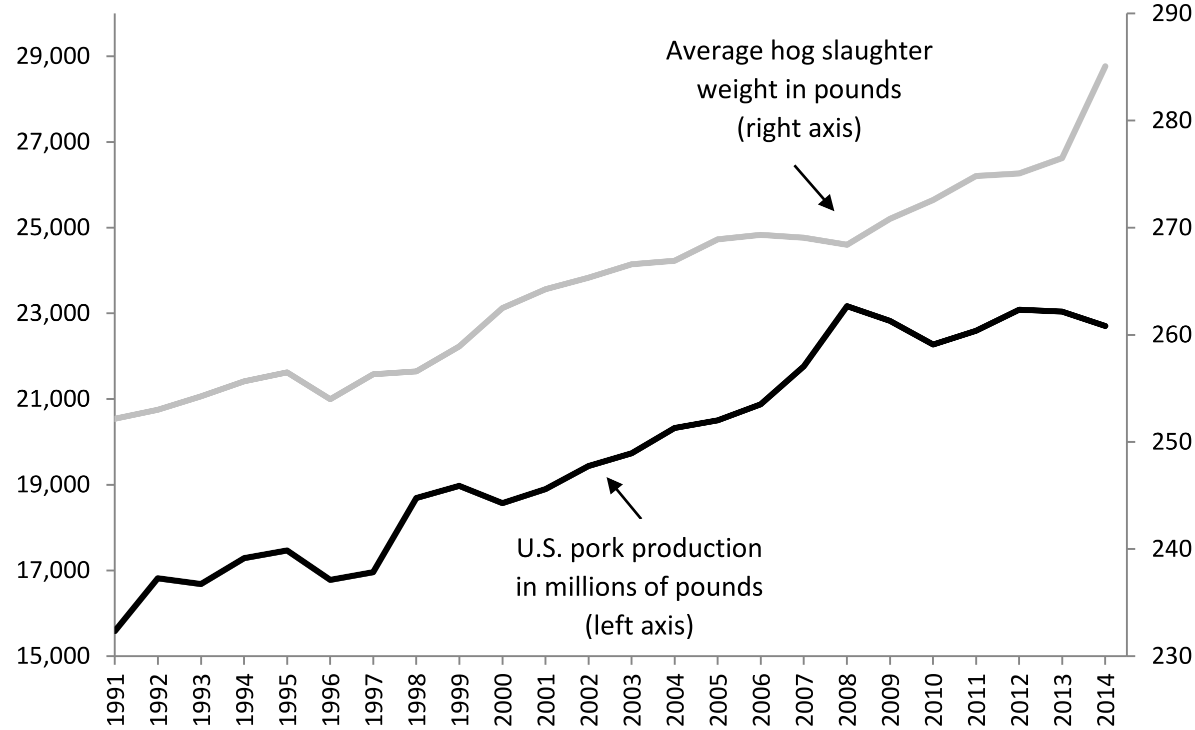

Figure 2. Aggregate hog production and average hog slaughter weight from 1991 to 2014.

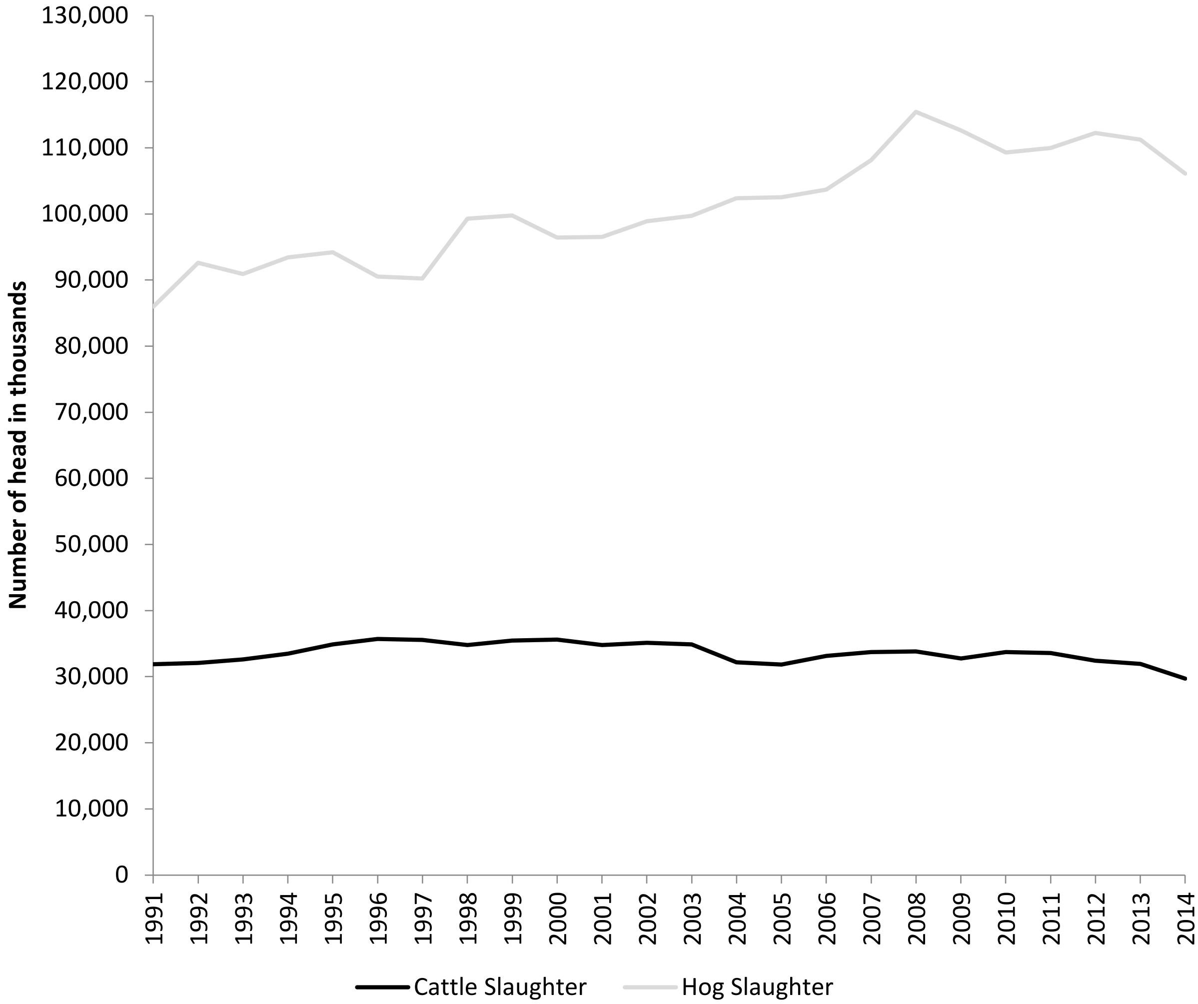

Figure 3. Number of cattle and hogs slaughtered in the U.S. from 1991 to 2014.

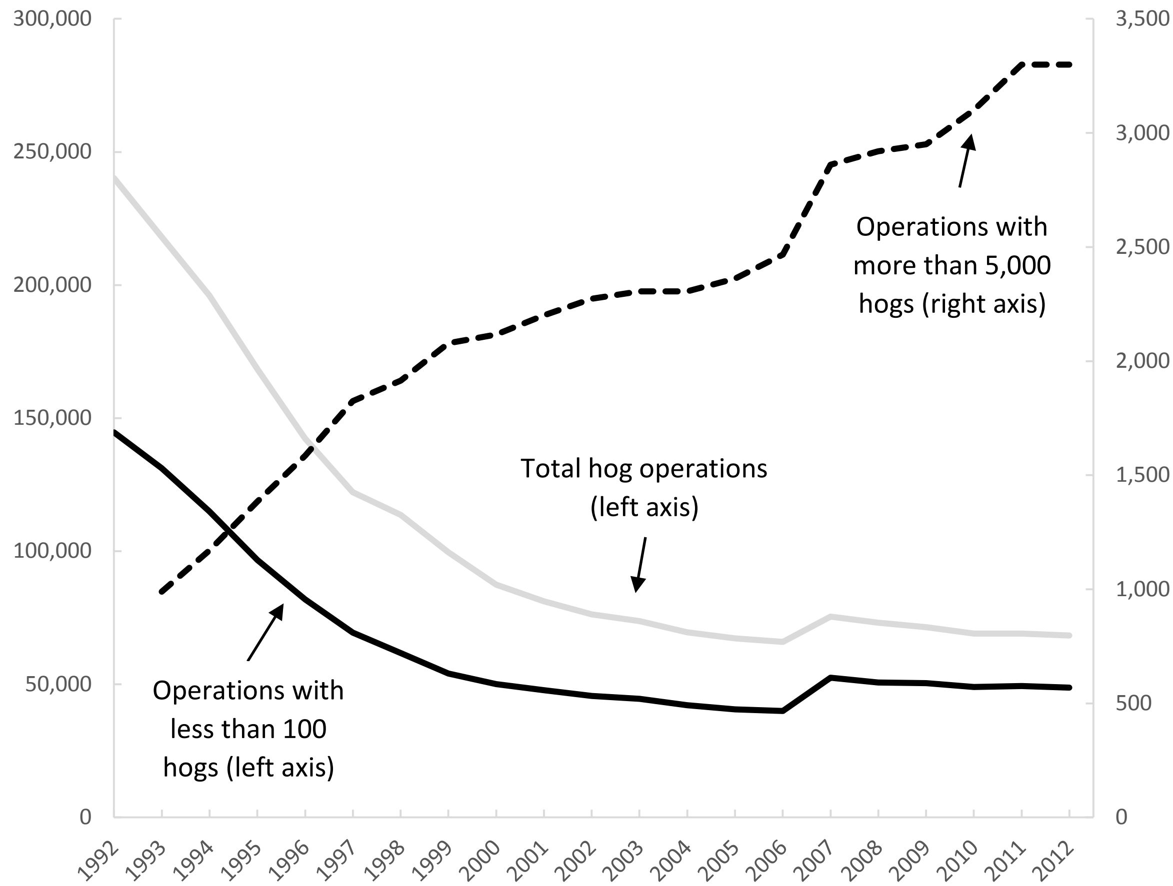

Figure 4. Number of hog operations by inventory level from 1992 to 2012.

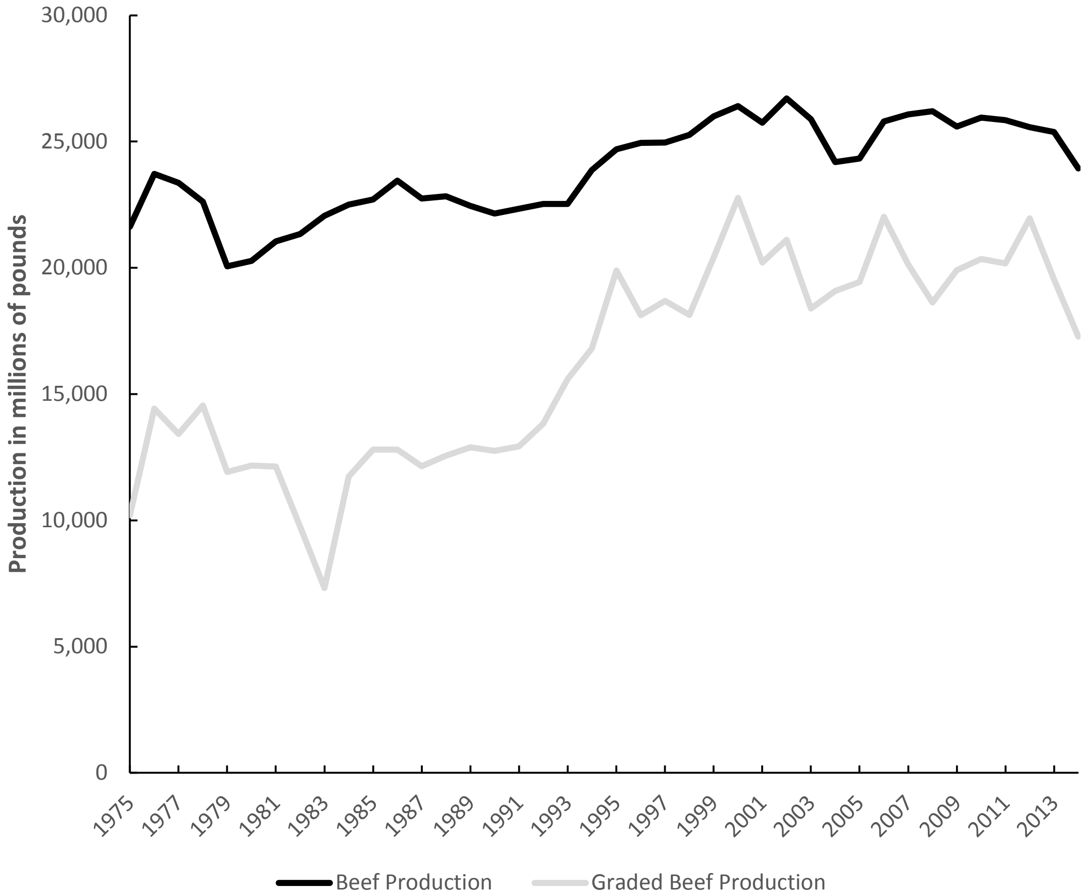

Figure 5. Beef production and graded beef production from 1975 to 2014.

Table 1. Comparison of Hog Producers and Hog Owners in 2012

Size (number of head)	Producer Operations	Owner Operations
1-999	56,000	55,000
1,000-1,999	3,300	1,800
2,000-4,999	5,700	2,100
5,000 or more	3,300	1,300
U.S. Total	68,300	60,200

Source: