Structural changes of hog farming in China: good or bad? A case study of Wuxue City in Hubei Province

***Zhao Liange*[1] *& Han Hongyun*[2]**

1 College of economics, Zhejiang Gongshang University, Hangzhou Zhejiang 310035, China

2 corresponding author: Center for Agricultural and Rural Development Zhejiang University, 866 Yuhang Tang Road, Qizhen Building, ZijinGang Campus, Zhejiang University, 310058 Hangzhou, Zhejiang, P.R.,China, China. Email: Hongyunhan@zju.edu.cn

Abstract

China's hog sector is undergoing the shift from family farming system to commercialized intensive production. The empirical analysis indicates that middle-size hog farms ($100<Q\leq1000$) have outperformed other hog farms in the pursuit of environmental conservation and economic efficiency; however, 45.5% of sampled hog farms are small farms with less than 100 head. To achieve the win-win situation of economic efficiency and environmental conservation, it is critical for the Chinese government to facilitate the evolution of structural changes of small hog farms via contracting production, specialization of the piglets, and establishment of association of hog farming.

Key words: *Manure Management Practices, Hog Farming, Structural Changes*

0. Introduction

As industrialized farming has rapidly displaced production dominated by single family production(Geisler and Lyson, 1991), intensive hog farming becomes a major focal point of environmental management (Ribaudo and Agapoff, 2005). One view is that adverse environmental effects of hog production occur with structural changes of livestock operations (Bontems et al., 2004) due to reduced opportunities for scope economy (Huang and Magleby, 2001; Metcalfe, 2002) and the separation of animal production from crop production (Thorne, 2007; Gollehon et al., 2001); another opposing view is that intensive hog production is environmentally friendlier than small farms because they can afford technologically advanced waste management systems (Vukina, 2003). Gaps exist in the understanding of the effects of hog operations on environment (Meyer, 2000). More importantly, little is known about actual manure management practices of small farms (Poe et al., 2002). It is unclear whether hog industrialization will improve or degrade environmental quality.

Hog production is regarded as a means to improve farm household incomes in China. Reflecting structural changes elsewhere in the world, China's hog industry has undergone a shift from family farming system to large-scale production units as a response of government intervention, technology advancement, favorable business climates (Gillespie et al., 1995), changing environmental liability and consumer preferences (Reimer, 2006). Many commercialized hog operations are spreading out in the peri-urban areas of big cities in China (Huaitalla et al., 2010; Somwaru et al, 2003), hog production has become the main contributor of environmental degradation because more than 90% of livestock farms have no sewage treatment facilities (Zhu et al., 2005), this situation poses a urgent demand on the examination of the impacts of structural changes of hog farming on economy and environment.

In China, few previous studies focus on production efficiency of hog farming, failing to provide highlights on the relationship of alternative production practices with environmental quality and economic efficiency. Understanding the driving forces against structural changes of hog farming are urgently needed for government policy design to encourage farmers' voluntary conservation activities while pursuing economic efficiency (Horan et al., 1999). What is the exact impact of structural changes of hog farms on environment? Do hog producers benefit from the structural changes of hog production? If yes, how to facilitate the evolving process of structural changes? Based on field surveyed data, by examining how hog production practices of hog farms change with varying farm sizes, this paper aims to clarify the impact of structural changes of hog farms on environment and economic wellbeing of hog producers.

1. Study area and date collection

1.1 The structural change of China's hog sector

Chinese government's priority for food security has led to the commitment of considerable resources to agricultural research, which has produced some promising new options for feeds, fish species, and farming practices. Technology advancement and favorable hog price (Gillespie et al., 1995) have facilitated fast growth of hog production in China. As a result, among nine countries contributing more than 50% of the world's total slaughter, China ranked the first and the volume of slaughtered fattened hogs accounted for 46.4% of that in the whole World in 2008 (See Table 1).

Table 1: *Hog production in selected countries in 2008*

	Slaughtered fattened hogs / (10,000 head)	***Breading stock at year-end/ (10,000 head)***	***Slaughter rate (%)***	***Hog production (10,000 tons)***	***Average carcass weight (kg/head)***
The whole World	131451.7	94128.2	139.7	10319.0	78.5
China	61016.6	46291.3	131.8	4620.5	76.0
America	11201.6	6590.9	170.0	1046.2	93.4
Danish	2079.4	1273.8	163.2	170.7	82.1
Canada	2171.1	1381.0	157.2	194.1	89.4
Japan	1622.1	974.5	166.5	124.9	77.0
Netherlands	1451.2	1202.6	120.7	131.8	90.8
Germany	5489.8	2668.7	205.7	511.1	93.1
France	2529.9	1480.6	170.9	202.9	80.2
Spain	4187.5	2629.0	159.3	348.4	83.2

Source: FAOSTAT, Statistical Data of China from China statistical Yearbook 2009.

In response to government support, favorable business climates (Gillespie et al., 1995), changing environmental liability and consumer preferences (Reimer, 2006), since 2002 China’s hog sector has undergone dramatic structural changes with an increase in large commercialized farms, hog operations with more than 50 animal units jumped from 165,982,000 in 2002 to 479,736,400 in 2008 at an annual average rate of 19.35%; the volume from large hog operations increased by about 65.4 %. However, unregulated small hog farms with less than 50 units were up to 44.05 % in 2008(See Table 2), this made manure management of hog production a challenge issue to environmental management in China.

Table 2: *Development of large-scale China's hog production from 2002 through 2008*

	2002	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*
Number of scale slaughter over 50 head (10000 head)	16598.2	18907.41	23394.09	28257.6	31846.4	38938.99	47973.64
Ratio to total hog slaughter (%)	29.28	31.94	37.85	42.75	43.00	48.46	55.95

Source: "The Yearbook of Chinese Animal Husbandry" from 2002 though 2009.

Even though hog farming is still dominated by small producers in China, hog production has become concentrated in large commercialized operations. Increased concentration of animals on fewer farms has effects on manure management practices (Ribaudo and Agapoff, 2003). The exact impacts of structural changes of hog farms on the society deserve special attention from researchers and policy-makers in China facing a challenge between economic development and environmental conservation.

1.2 Study area and date gathering

To gather micro-data for empirical analysis, field survey was conducted in Wuxue city of Hubei Province in 2009. Located on the northern shore of the Yangtze River, a subtropical humid monsoon climate with hot summer makes Hubei Province suitable for agriculture, forestry, animal husbandry, and fishery. As the fifth big contributor of slaughtered hogs in China, animal husbandry plays a crucial role in rural development.

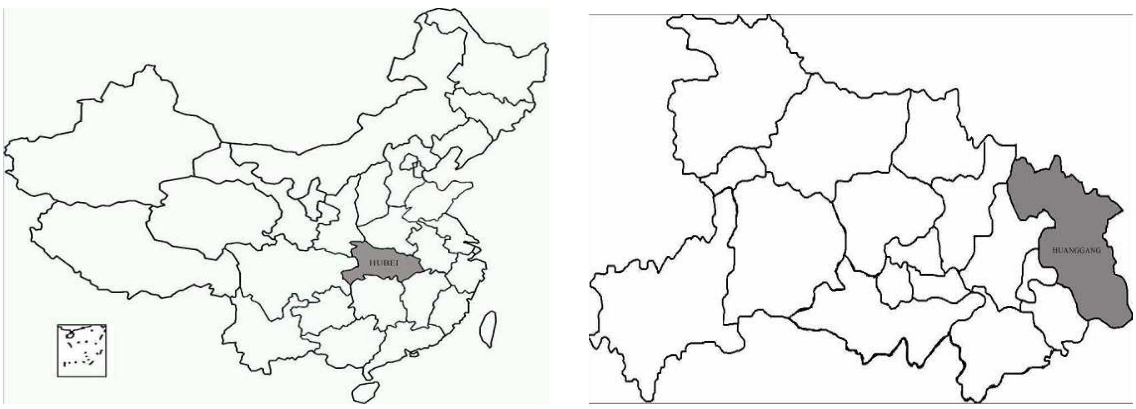


Figure 1: *Study site*

Wuxue has been chosen as study site mainly due to following considerations: firstly, hog farming has become the dominant industry in Hubei Province with 34.2% of total agricultural value; secondly, commercialized hog farms have begun to take shape rapidly with rising large hog breeding farms, the number of hog farms with over 1000 head has jumped from 78 in 2005 to 163 in 2008 in Wuxue city (See Table 3).

Table 3: *Structural changes of hog farming in Wuxue city*

Year	***Number of hog farms***				***Total***
	50-99 head	***100-499 head***	***500-999 head***	***Over 1000 head***	
2005	650	660	80	78	1468
2006	710	530	75	76	1391
2007	785	621	78	110	1594
2008	987	1410	91	163	2651

Source: Wuxue city Bureau of Animal Husbandry Statistics.

Wuxue is a county-level city of Huanggang city, located in the east-north of Hubei Province. There were four districts in Wuxue city, 8 towns with total 1246 square km area and 34,733 hectares arable land, the total population was 740,000 persons in 2009, of which agricultural population was 588,578.

The survey covers a cross-section of hog operations and collect information on production costs, business arrangements, production facilities and practices, and farm operator and financial characteristics, as well as information about manure storage and handling, and manure disposal. The questionnaire consists of five components.

The first section is characteristics of hog producers, including personal characteristics, income composition and other economic and social feature of households; the second is characteristics of hog operations; the third is the characteristics of hog farms, including farm location, construction cost, hoggery infrastructure, farming technology, production scale and so on; the fourth is manure management practices of hog operations, including farmers awareness of environmental pollution, modes of waste pretreatments and final disposals; the fifth is the information of costs and benefits of hog operations.

After a pre-interview with local officials in August 2009, formal survey was carried out in October 2009. Four townships of Wuxue city were randomly selected, and a total of 140 hog producers were interviewed face-to-face. In total, 134 valid questionnaires were gathered, effective rate was 95.7%.

1.3 Categorizing hog farms in China

To examine the effect of structural changes of hog farming, it is necessary to categorize hog farms. According to the *Technical Standards for Livestock Farms*, single farm of more than 3000 slaughtered head, production district over 6000 head is termed as intensive hog farms. According to the *Approaches of Livestock Pollution Control Management* issued by Chinese Environmental Protection Administration in 2001, hog farms providing year-round breeding stock of 500 head and over are treated as intensive hog farms (See Table 4).

Table 4: *Technical classifications of intensive livestock production (inventory year-end)*

Items	Grade of class	Hog (head, over 25 kg)	Chicken (head)		Cattle (head)	
			Layers	Broiler	Adult cows	Beef
Livestock operation	I class	≥ 3000	≥ 100000	≥ 200000	≥ 200	≥ 400
	II class	500 ≤ Q < < 3000	15000 ≤ Q < < 100000	30000 ≤ Q < < 200000	100 ≤ Q < < 200	200 ≤ Q < < 400
Livestock park	I class	≥ 6000	≥ 200000	≥ 400000	≥ 400	≥ 800
	II class	3000 ≤ Q < < 6000	100000 ≤ Q < < 200000	200000 ≤ Q < < 400000	200 ≤ Q < < 400	400 ≤ Q < < 800

Note: 1 hog =30 layers, 1 hog=60 broilers, l adult cow=10 hogs, 1 beef=5 hogs.

The *China Animal Husbandry Yearbook* terms 50 hog units as the lower end of a scale hog farm. *National Agricultural Cost-benefit Analysis* further attribute a farm with 30 head and below to a backyard farm, farms with slaughtered hogs of 31-100 and 101-1000 head are attributed into small-scale and middle-scale hog farms, farms with 1001 head and over are large-scale hog enterprises.

Hog operations could be broadly clarified into three groups of "backyard hog farms, specialized hog operations, and commercialized hog production enterprises" (Somwaru et al., 2003 p.5). Taking into consideration of small farms in China, the classification system of National Agricultural Cost-Benefit Analysis is employed in our study. Backyard hog farms include very small hog production of rural households.

During the field survey in August 2009, 134 effective questionnaires were gathered. Except for 11 backyard hog farms with less than 10 head, 6 producers just raised hogs less than 30, and 44 farms could be attributed to the group of specialized small hog farms, 73 farms were middle-scale hog farms (See Figure 2).

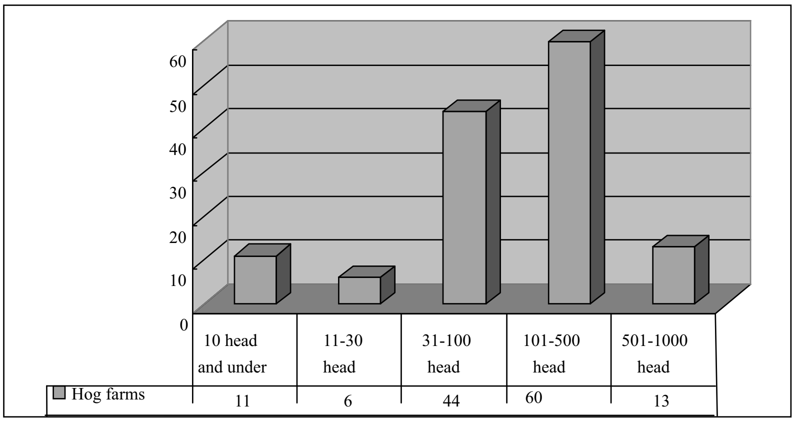


Figure 2: *Distribution of hog farms*

Besides raising hogs, small rural households in China also undertake other activities, such as raising small number of chickens and goats, and crop production activities. Rural households in this category often save some portion of the slaughtered hogs for home consumption and use traditional feeding methods, such as table scraps, vegetables, green fodder, and unprocessed grains and oilseeds. These small hog producers raise 8 head per household per year.

The second category is the specialized rural hog households or specialized hog farms. Family members are chiefly engaged in hog production. The share of these operations in China's hog production is increasing, and their production capacity is beginning to dominate some of the rural markets in China due mostly to the government's marketing promotion policy. These hog operations on average annually raise over 67 head.

The third category, commercialized hog production enterprises, includes state or collectively owned hog farms, as well as privately owned in the form of sole proprietorship or partnership, with share rent or contract arrangements with state farms or local collectives. Some larger operations have produced several hundred head of hogs per year. These operations are characterized by large capital investment and the breeding technologies, feeding methods, and disease prevention practices in this category are advanced and modern.

The rapid structural changes of livestock sector has led to the loss of technological diversity, dependence on wage labor, centralized control (Geisler and Lyson, 1991), coordinative activities (Kliebenstein and Lawrence, 1995), less control of land receiving manure (Lorv et al., 2004), and runoff of pollutants (Thorne, 2007). The knowledge on the impacts of structural changes of hog farms is urgently needed for policy formation of nonpoint pollution control.

2. Structural changes of hog farming: good or bad?

2.1 The economic consequence of scaling hog farms

It is farmers who decide on production practices (Wossink et al., 2001), storage method (Babcock et al., 1997), manure disposal (Bosch et al., 1998), and provides land, housing facilities, and labors, and typically responsible for compliance with environmental laws (Vukina, 2003). Hog farms will adjust their operations to take advantage of scale economies and to make the most efficient use of accessible resources. As a resource use indicator relative to economic efficiency, production efficiency can be measured by the maximum output at given inputs, or by the minimum level of factor inputs to achieve a fixed output.

Suppose $F(Y, X_n)$ is the production function, given a fixed number of input elements, D^i is the distance function of hog farm i measured by the actual maximum output level: $D^i(Y, X_n) = Max\{\tau : (X/\tau) \in F(Y, X_n)\}$

Where, Y is live hog weight gained, accounting for the difference in the weights of feeder and finished hogs across operations; X_n is the vector of inputs such as expenses of labor, baby animals (feeder hogs), fine feed, beans, succulents and coarse fodder, additives, and other feed expenses.

Here, labor cost is measured by the amount of persons employed times the number of working days times wage rate (Yuan per day). Indirect cost includes depreciation of fixed assets, maintenance expenditures, and miscellaneous fixed expenses per farm.

Table 5: *Input-output analysis of surveyed households on an average*

	Average scale	***Labor cost (X_1)***	***Marginal net weight (Y)***	***Feed input (X_2)***	***Water fee (X_3)***	***Electricity fee (X_4)***	***Medical cost (X_5)***
Unit	Head	days/head	kg/head	Yuan/ head	Yuan/ head	Yuan/ head	Yuan/ head
Backyard (Q≤30)	8	262.1	122.6	673.5	5.0	16.0	75.0
Small scale (30<Q≤100)	67	201.8	135.6	1140.9	2.8	11.0	38.7
Middle scale (100<Q≤1000)	344	206.3	143.0	1169.7	3.0	7.5	28.4

Animal cost is the expense of feeder hogs purchased times the animal weight per head. Cost of fine feed includes annual expenditures on mixed feed, grain feed, bran, oilseed cakes, and bean dregs per head.

Cost of succulents and coarse fodder includes expenditures on rice chaff, millet bran, fodder, and succulents per head. Cost of additives includes expenditures on additives. Other variable expenses include costs of feed processing, fuel, water fee for cleaning pig houses, and electricity, the cost of veterinary fees, and the cost of other direct fees per farm.

Technical efficiency is estimated by the ratio of potential efficient input use to the actual observed utilization; scale economies is measured by identifying variations in the input and output ratios at different scales when variable scale returns are allowed. Employed FRONT2.1, estimated technical efficiencies of hog farms at different scales are given in the Table 6.

Table 6: *Technical efficiency of hog breeding at different scales*

	Overall efficiency (CE)	***Technical efficiency (TE)***	***Scale efficiency (SE)***
Backyard (Q≤30)	0.721714	0.757143	0.952
Small scale (30<Q≤100)	0.817295	0.867432	0.939295
Middle scale (100<Q≤1000)	0.823384	0.870438	0.945781

While overall efficiency increases with a growing farm size, backyard hog producers had the greatest scale efficiency (See Table 6). It is proved that the pure scale economies increase for backyard and specialized hog farms and decreases or exhibits constant returns for commercialized hog operations (Somwaru et al., 2003). So do for hog farms in Wuxue City.

Hog farms with 100 to 1000 head achieve the highest profit, while feed cost accounted for 64.3, 87.0, and 83.8 % of the total costs of backyard, small-scale, and middle-scale farms, respectively. Labor cost, energy consumption and raw material of middle-scale farms are far below those of backyard hog producers, advantage over hog price helps middle-scale farms achieve higher efficiency than small-scale farms (See Table 7).

Table 7: *Cost-benefit analysis of hog farming at different scale (unit: Yuan/head)*

	Backyard (Q≤30)	***Small scale (30<Q≤100)***	***Middle scale (100<Q≤1000)***
The cost of hog feeding per head	1046.6	1311.4	1395.8
1. Piglet price	328.5	272.7	316.2
2. Feed	673.5	1140.9	1169.7
3. Medical	75.0	38.7	28.4
4. Water fee	5.0	2.8	3.0
5. Electricity	16.0	11.0	7.5
6. Employed labor cost	0	0	6.6
7. Training cost	0	0	0.5
8. Rent for hog house	0	9.4	1.8
9. Cost of mechanical repair	0	0	0.5
10. Tax	19.6	0.7	0.4
11. Interest rates for loan	6.3	2.5	8.1
Benefit of hog feeding per head	1549.1	1612.2	1737.1
1. Hog price	1542.9	1604.7	1732.4
2. Benefit of side-product sale	2.1	3.7	2.3
3. Government subsidy	4.0	3.7	2.5
Net benefit	502.4	300.8	341.3
Average net benefit of hog farms	502.4*8 = = 4019.2	300.8*67 = = 20755.2	341.3*344. = = 117407.2

A further look at table 8 indicates that the difference comes from the technical efficiency of middle-scale hog operations. In 2008, the main advantage of scale hog farms was the shortened hog breeding cycle and the cut of medical and utility cost. Commercialized middle-scale farms had a shorter average cycle of 139 days to fatten a baby hog, it was 30 days shorter than that of backyard households. Meanwhile, commercialized hog farms had an overall downward trend in hog feed conversion ratio from 2002 through 2008, backyard household's hog feed conversion ratio rose with an average annual growth rate of 1.52% (See Table 6). In the U.S, the conversion ratio in 1980 ranged from 3.7 to 3.8 kg of feed per kg of meat (Thorne, 2007), there is a room for the improvement of management efficiency of China's hog production.

Table 8: *Technical efficiency of hog farms of different scales from 2002 though 2008*

Year	Large-scale hog farming				Backyard hog farming			
	Labor cost (Yuan/ head)	Average feeding days	Increased net weight per day (kg)	Feed-meat conversion ratio	Labor cost (Yuan / head)	Average feeding days	Increased net weight per day (kg)	Feed-meat conversion ratio
2002	35.16	142.00	0.56	3.20	127.60	184.00	0.48	2.74
2003	39.91	142.00	0.57	3.25	135.52	185.00	0.48	2.84
2004	56.07	143.00	0.58	3.14	151.52	186.00	0.48	2.84
2005	55.69	142.00	0.61	3.03	167.11	174.00	0.52	2.87
2006	59.17	141.00	0.61	3.06	175.08	179.00	0.52	2.80
2007	63.93	139.00	0.63	3.09	176.53	173.00	0.53	3.01
2008	69.83	139.00	0.66	3.09	187.13	169.00	0.56	3.00

Source: national costs and benefits of agricultural products.

2.2 The environmental impact of structural changes of hog farms

The changing structure of hog farms is altering manure management practices. Problems with hog production occur from runoffs and leaching from the application of manure to cropland, spills and leaks from waste storage facilities, and direct ambient air pollution from feedlots and storage facilities (Mctcalfe, 2000; Vulkina, 2003). The Chinese government is aware of the environmental impact of structural changes of hog farming and has developed a range of laws and regulatory rules to tackle the adverse environmental impact of animal production, including "Discharge standard of pollutants for livestock and poultry breeding" (GB18596-2001), "Technical standard of preventing pollution for livestock and poultry breeding" (HJ/T 81-2001).

To further standardize the intensive livestock and poultry industry waste management, on September 30 of 2009, "Technical specifications for livestock and poultry breeding industry pollution control" was approved as the national standard, which developed the technical requirements for engineering design, construction, operation and maintenance. In addition, the government subsidizes farmers who recycle to use animal waste and apply organic fertilizer, local governments also prescribe zoning for livestock to reduce the risk of pollution from livestock manure.

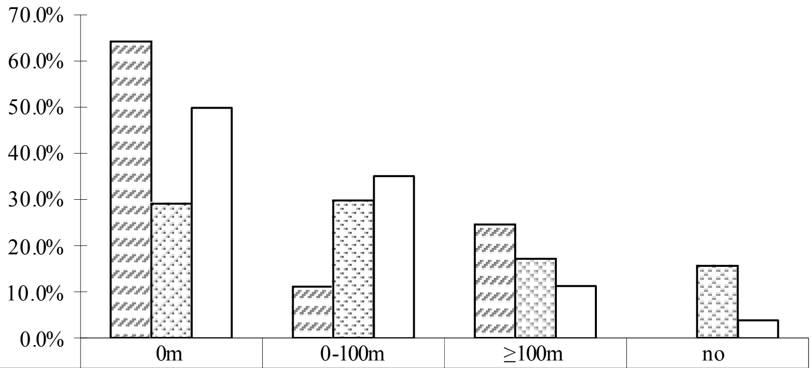
Although there are technical standards for livestock farms to meet certain wastewater discharge standards, at present, only large-scale farms with more than 3000 head and a district with 6000 head and over are demanded to construct pollution control facilities to meet the regulatory rule of synchronized infrastructure principles. There is no law related to hog operations under 500 animal units or intensive livestock and poultry parks under 3000 animal units. The share of surveyed hog farms under 500 animal units in Wuxue city is up to 90.3 % (See Figure 2). Uncontrolled discharge of residuals of scattered farms nearby residence poses an urgent threat to human and animal health.

Adjustments to meet a manure disposal policy, including changes in cropping patterns, feed rations, manure disposal methods, and disposal locations, are determined by the characteristics of farm resources and management choices (Dou et al., 2001). Any measures adopted to deal with environmental issues are determined by farmers' perception towards benefits against costs, as well as farmers' attitude towards environmental impacts. Farmers' options of waste management practices at different scales, including selection of hog houses, manure production, collection and storage, treatment and application, exert different effects on local environment. A detailed examination based on micro-data could provide highlights for environmental impacts of structural changes of hog farming.

2.2.1 Farm size and site location

The optimal manure-forage system will depend on the farm characteristics and specific local conditions (Newton et al., 2003). Factors affecting the choice of site location include aspects of market access, raw material access, input and product transportation, labor, climate, governmental regulations, and community attributes. In China, big and middle-size hog production enterprises are mostly located near residential areas of big- or middle-size cities (Somwaru et al., 2003).

In order to get raw material and land for animal waste application easily, 85.1 % of hog farms locate within 100 m away from arable land. Among all 134 hog farms, 113 farms are just in residential areas, accounting for 84.3% of the total samples. Among them, 86 hog farms locate in the vicinity of residential areas, accounting for 64.2% of samples, and hog farms less than 100 m away from residential areas and water bodies account for 11.2% and 29.9 %, respectively. According to Technical Standards of Preventing Pollution for Livestock and Poultry Breeding approved on April 1 in 2002, the distance no less than 500 meters from residential areas and origins of drinking water bodies is required for the construction of hog houses. In total, 75.4 % of surveyed hog farms locate within 100 meters, failing to meet the technical requirement (See Figure 3).



	0m	0-100m	≥100m	no
distance to residential areas	64.2%	11.2%	24.6%	0.0%
distance to water bodies	29.1%	29.9%	17.2%	15.7%
distance to arable land	50.0%	35.1%	11.2%	3.7%

Figure 3: *The distance of feedlots from neighbors*

In the U.S, relocation is often proactively pursued as an effective way to increase profitability of hog production with a consideration of labor and transportation costs (Stirm and St-Pierre, 2003), and the availability of land for spreading manure (Ribaudo and Agapoff, 2003; Lorv et al., 2004). In China, relocation is urgently required as an adaptive response to regulatory technical standards. A look at Figure 4 indicates that 14.3 % of backyard farms are willing to relocate piglets, middle-scale farms tend to relocate their hog houses, to adapt feeding time with cropping season, as well as to adopt pollution control technologies.

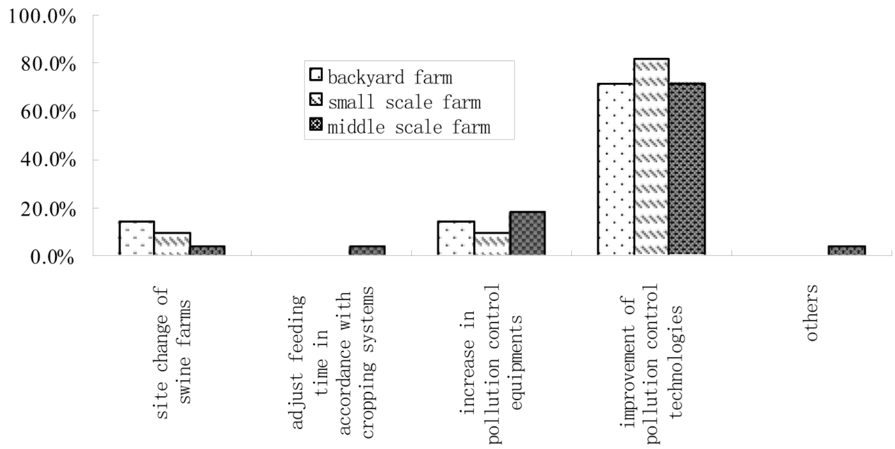


Figure 4: *Hog operations' willingness to improve waste management*

2.2.2 Farm size and manure production

Changes in cropping patterns, feed rations, manure disposal methods, and disposal locations are determined by the characteristics of farm resources and management choices (Dou et al., 2001). Once waste handling and storing technology are fixed, the amount of pollution is determined by nutrient content in animal manure generated by a particular type of animal(Bontems et al., 2004). Agronomic measures of nutrient balance (Lanvon, 1994), for example, phytase can reduce the phosphorus content of manure (Bosch et al., 1998).

An obvious solution to manure management problem is the source reduction by changes of feed composition. Middle-scale farms are characterized by large capital investment and production capacity considerably surpass those of the specialized hog farms. The breeding technologies, feeding methods, and disease prevention practices in this category are advanced and modern (Somwaru et al., 2003). These operations outperform other hog farms in terms of utilization of feed additives, conservancy method and improvement of hog houses (See Table 9).

2.2.3 Farm size and manure storage

Solid wastes of backyard and small-scale hog farms are often composted, sometimes in combination with other agricultural residues. In general, liquid wastes are stored in deep pits for anaerobic decomposition before applied to the farmland as fertilizer. A mixture of urine, waste water and small parts of solid manure are flushed into open lagoons for a simple sedimentation before being discharged into natural water bodies. Construction of storage facilities is important for environment conservation.

According to the field survey, only 56 hog producers accommodate the manure storage pits with an average volume of 11 m^3; 78 hog farms have no waste storage facilities, accounting for 58.2 % of total sampled hog farms (See Table 10). Middle-scale hog

Table 9: *Farmers' actual and expected measures of emission reduction*

Measures to reduce emissions	***Number of hog farms adopting different measures***			
	Backyard (Q≤30)	***Small scale (30<Q≤100)***	***Middle scale (100<Q≤1000)***	***%***
Optional feed	0	4	4	6.0
Precision feed	0	0	1	0.7
Use of feed additives	2	20	23	33.6
Conservancy method	7	13	28	35.8
Use of disinfectants	6	42	23	53.0
Improvement of hog houses	3	6	13	16.4
others	1	0	1	1.5
no measures	3	0	0	2.2
	Number of hog farms willing to adopt various measures			
Optional feed	1	2	7	7.5
Precision feed	0	0	0	0
Use of feed additives	0	7	6	9.7
Conservancy method	9	10	22	30.6
Use of disinfectants	5	33	48	64.2
Improvement of hog house	3	5	10	13.4
others	0	0	0	0
no measures	0	0	0	0

Table 10: *Volume of storage pits*

Volume of storage pit	***0 m^3***	***0-5 m^3***	***5-10 m^3***	***11-15 m^3***	***Over 15 m^3***	***Total***
Backyard (Q≤30)	11	4	0	0	2	17
Small scale (30<Q≤100)	28	3	6	0	7	44
Middle scale (100<Q≤1000)	39	5	6	5	18	73
Number of hog farms	78	12	12	5	27	134
%	58.2	9.0	9.0	3.7	20.1	100

farms perform better in terms of storage facilities. Discharge of liquid wastes from small and backyard hog farms pose a big threat to local water bodies.

2.2.4 Farm size and manure pretreatment and disposal

With regard to manure pretreatment, only 40 (26%) hog producers have adopted pretreatment measures before the discharge of animal wastes. Among 40 farms who conduct pretreatment, 62.5% of farmers choose sediment filter, 27.5% use storage fermentation, 5.0% and 2.5% use chemical additives and wet and dry separation, respectively. Ninety four hog producers have not adopted any pretreatment measures (See Table 11).

With regard to waste disposal, 52.2% of households tend to sell or give away freely to other farmers, 18.7 % of hog farmers adopt biogas fermentation, and 21.8% choose aerobic compost or fish ponds (See Table 11). A sedimentation tank can basically minimize environmental pollution, but many medium-scaled hog farms cannot afford con-

Table 11: *Waste pretreatment of Households*

	Modes	*Households*			*Total*	*%*
		Backyard (Q≤30)	*Small scale (30<Q≤100)*	*Middle scale (100<Q≤1000)*		
Pretreat-ment	Sediment filter	1	11	13	25	62.5
	Separation of wet from dry residual	0	0	1	1	2.5
	The use of chemical additives	0	0	2	2	5.0
	Storage fermentation	1	5	5	11	27.5
	Others	0	0	1	1	2.5
Waste disposal	Direct discharge after pretreatment	11	0	0	11	8.2
	Direct sale	2	19	49	70	52.2
	Straw compost or fish	3	10	15	28	20.9
	Fermentation biogas systems	1	15	9	25	18.7

struction cost. According to the field survey, it is found out that all sediment filter and storage fermentation are in the open air. It is likely to cause leakage of waste overflow, which will result in water pollution (Newton et al., 2003).

By contrast with other modes of waste disposal, biogas technology is a relatively secure way of manure disposal, but with a relative high cost. The energy resource potential of manure organic matter may be sufficient to stimulate some farms to employ fixed-bed anaerobic reactors for the combined benefits of energy recovery (Horn et al., 1999). In addition, the Chinese government is well aware of biogas potential of animal waste treatment in rural areas. During 2003 to 2006, the Central government provided a total subsidy of 5.5 billion RMB to 5.7 million households for biogas digester production (Yuhuan agricultural information, 2009). Each household got 1000 RMB for biogas digester construction in Wuxue city. Unfortunately, the relatively high construction cost constrained farmers' option of biogas systems.

Seventy rural households tend to sell or give away to other farmers in the manner of waste disposal. Small farms can not guarantee for daily acquisition of swine manure to sell, the daily cleaning of solid waste have to been piled up in storage pits or a fixed region. In this regard, middle-scale hog farms have advantages over small and backyard farms.

3. Policy implications for facilitating structural changes of hog production in China

The hog prices rose sharply in 2007, to support standardization hog production, the State Council provided breeder subsidies to large-scale hog farms (Zhang et al., 2006).

Even under government policy support, there is a big portion of small farmers. According the filed survey, the average size is 210 breeding head, 61 hog farms had hogs less than 100 head, accounting for 45.5% of sampled households who fail to achieve overall efficiency; only 13 hog farms have more than 500 units (See Figure 2).

Middle-scale farms outperformed other types of farms in terms of waste management and economic efficiency. The coexisting of efficient middle-scale farms and backyard farms contradicts the economic rationality assumption that farmers would be reasonable to exploit available resources to maximize their profits, this creates a need for incentive policy design to facilitate the structural evolution of hog operations to pursue scale economies.

3.1 Facilitate structural changes through specialization of hog production

"The greatest improvement in the productive powers of labor, and the greater part of the skill, dexterity, and judgment with which it is anywhere directed, or applied, seem to have been the effects of the division of labor"(Smith, 1776 p.5). Hog sector, like many other agricultural activities, is moving toward a greater level of coordination and specialization (Kliebenstein and Lawrence, 1995). According to the field survey, 32.8% of surveyed hog producers engage in hog production, 90 also engage in other activities, such as fish and crop farming, accounting for 67.2%. Low professional specialization is impeding the structural evolution of hog farms in China (See Figure 5).

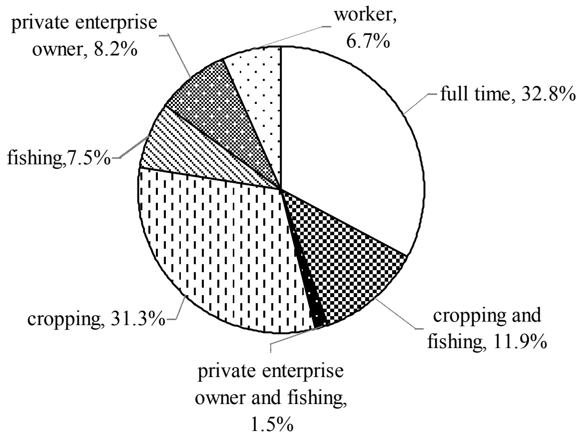


Figure 5: *Level of specialization of surveyed hog operations*

Moreover, specialization of piglets will facilitate the process of structural evolution of hog farms. Hog production could be divided into four phases of breeding and gestation, farrowing, nursery, and finishing. Specialized feeder hog-to-finish operations became increasingly common, while farrow-to-finish operations became less prevalent in the U.S (Key et al., 2008). This has not happened in China. From the field survey, 49.3 % of hog farms complete the whole process of hog feeding, 32.1% of sampled households buy baby hogs from local market, 11.1% of hog farms carried out the whole process and buy baby hogs when they fail to produce enough baby hogs (See Table 12).

Table 12: *Farm size and membership of association*

	non membership	***Member-ship***	***Farrow to finish***	***Farrow to finish or buy***	***Feeder hog -to-finish***
Backyard (Q≤30)	7	0	3	0	4
Small scale (30<Q≤100)	36	8	28	3	13
Middle scale (100<Q≤1000)	64	9	35	12	26
Total	117	17	66	15	43
%	87.3	12.7	49.3	11.1	32.1

3.2 Promote moderate scale of hog farms through contracting production

There is a trend of contracting production in livestock sector in the World (Rhodes, 1995). Coordination activities in hog production are growing rapidly, ranging from the totally integrated system through ownership to various arrangements that link input supply, production, processing, and merchandising (Kliebenstein and Lawrence, 1995). Risk sharing is one of the mostly widely cited reasons for contracting, which can reduce price risk and might make it easier for farmers to obtain financing for setting up or expanding hog production(Key and McBride, 2003;Vkina, 2003), stable contract between hog producers and providers of piglets can reduce the risk of quality of piglets. Secondly, contracting may raise farm productivity by improving the quality of managerial inputs, by speeding the transfer of technical information to growers, thereby permitting the adoption of more efficient technologies (Key and McBride, 2003). Thirdly, contracting production could be a help of enhancing education level and providing occupation training to hog producers.

Last but not least, contracting firms are often the facilitators of hog association in China. Although association of hog farms or cooperatives could provide services of disease prevention and control, feed wholesale, introduction of improved varieties, only 17 hog farms are members of those organizations, all were small-scale and middle-scale farms; 87.3% of surveyed households are not member of hog association. Most farmers believe that these organizations are still in its infancy with limited services(See Table 13). Low level of self-organization hinders structural changes of hog farms.

4. Conclusions

Small-scale hog farming is under increasing pressure either to evolve or to disappear because of changing technology of hog production (Cozzarin and Westgren, 2000), hog production in China is undergoing the shift from family farming system to intensive production. The changing structure of hog farms is altering manure management practices and economic performance of hog production. The findings suggest that middle-scale operations have outperformed other hog operations in terms of economic efficiency and environmental conservation. However, low level of specialization and lack of self organization of hog farms do hamper the process from backyard farming to moderate scale operations of hog production. Specialization of the piglets and development of association of hog farms could facilitate the structural evolution of small hog farms into middle-scale hog farms.

To realize the win-win situation of middle-scale hog farms, it is necessary to advocate appropriate scale of specialized hog operations by the promotion of contracting production and self-organization of hog farms. The increasing concentration of hog production on large operations is expected to continue due to its economic efficiency, meaning that manure management will continue to be an important issue to the hog industry, it is urgent to improve farmers' understanding of environmental effects and enhance the environmental awareness by publicizing hog pollution cases such as air pollution and water pollution.

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