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# China's hog production: From backyard to large-scale☆

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ABSTRACT

China's hog production has undergone significant structural transition, from the traditional backyard production mode to the large-scale production mode. In this study, we illustrate the linkage between economic development and the transition in hog production mode. Using unique and nationally representative survey data, we find that an increase in farmer wealth motivates them to transition away from backyard hog production. However, the relationship between wealth and herd size among large-scale hog producers is positive. With farmer wealth increasing rapidly, the transition of China's hog production toward the large-scale mode is expected to continue; this will have significant implications for not only hog production, but also the feed sector and many other related sectors.



## 1. Introduction

As the world's largest hog producer, pork consumer, and pork exporter, China is experiencing an important transition, from backyard, household-based production to large-scale production. According to China's national statistics, during the past decade the share of the country's hogs raised by backyard producers decreased from more than two-thirds to about one-third (National Bureau of Statistics of China, hereafter referred to as NSBC, 2013). Correspondingly, large-scale hog producers have dominated China's hog production since 2007 (Gale, Marti, & Hu, 2012).

This transition has had significant implications for not only China's livestock industries, but also the global meat and feed trade markets. In 2013, even though more than 700 million fattened hogs—about one-half of the world's total production—were slaughtered in China, the country still imported 584,000 tons of pork (National Bureau of Statistics of China, 2014; United States Department of Agriculture, 2015). In the feed market, although China has been able to fulfill most of its own domestic

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hog demand, its protein feed needs have largely been met by the international market. In 2013, China imported 63.4 million tons of soybeans in 2013; this amount constitutes about two-thirds of the soybeans traded in the world market (Taylor & Koo, 2015).

Given the importance of these changes, the lack of rigorous analysis on the determinants of this widely observed transition is surprising. Several factors may have simultaneously affected the transition (Gale et al., 2012). However, to the best of our knowledge, no rigorous empirical research based on nationally representative data has attempted to parse the effect of each of these potential factors on a farmer's decision to switch from backyard production to large-scale production.

The overall goal of this study is to gain a better understanding of China's transition in hog production modes, with particular focus on the major factors that have facilitated this transition. Specifically, this study aims to provide empirical answers to two questions—namely, "What are the general trends in the structure of the hog production industry in China?" and "How do various factors, especially farmer wealth, affect farmer participation in backyard versus large-scale hog production?".

The rest of this paper is organized as follows. In Section 2, we review the evolution of hog production in China in recent decades. We also present the dynamics of the various types of hog producer (e.g., backyard producers and large-scale hog producers). Section 3 discusses our sampling approach and data collection methods. In Section 4, we econometrically estimate the effect of farmer wealth and other factors on changes to the hog production model and herd size. Section 5 summarizes our findings and discusses policy implications.

## 2. Transitioning from backyard to large-scale production

Hog producers in China can be classified into one of two types. The first type is the so-called backyard producer. A backyard producer usually raises one or two hogs annually in his or her own backyard (Schneider, 2011). A backyard producer either keeps the hogs in a pen in the backyard or lets the hogs run in the yard or village. For backyard producers, raising hogs is just one of several production activities; they also raise other livestock and poultry and, most importantly, farm crops (Zhang, Li, Liu, & Chen, 2013). As shown in Table 1, as of 1987—after agricultural reforms had been implemented for 10 years—more than 75% of farmers still raised hogs in their own backyards.

The second type of hog producer focuses on hog production as the main, if not sole, source of income. This type of producer can be divided further into specialized hog production households, which usually do not hire laborers, and large-scale producers, which hire laborers. A specialized household's herd size ranges from dozens to hundreds of hogs. In contrast, a large-scale producer's herd size usually ranges from several hundreds to millions of hogs.

Specialized hog production households emerged in rural China during the implementation of agricultural reform in the late 1970s. Before the reform, backyard hog producers faced at least two challenges—namely, credit constraints and policies that discouraged the development of the private economy. Therefore, although almost every household raised hogs, they usually raised only very few hogs (Chen, Liu, Ruth, & Xiao, 2012). The agricultural reform gradually eliminated these antidevelopment policies (Wang & Xiao, 2008). As economic growth accelerated following the agricultural reform, farmer income increased significantly (NBSC, various years). Some backyard producers expanded their herd sizes and became specialized households. As shown in Table 1, in terms of the number of hogs slaughtered, the share of specialized households increased from 3% in 1985 to nearly one-third in 2011.

At the same time, most backyard producers abandoned hog farming, for two reasons. First, the vibrant non-farm labor market absorbed a considerable amount of rural labor, especially female laborers who traditionally had been involved in backyard hog production. Second, as their income increased, farmers increasingly wanted a cleaner environment. A backyard producer must share a small lot, usually less than 1/6 acre, with hogs, other livestock, and poultry. Of course, hog manure is unpleasant. Therefore, as farmer income increased, their reservation price for a cleaner living environment increased. As a result, most backyard hog producers gradually abandoned hog farming (Chen et al., 2012; Chen & Wang, 2013). According to industry reports, the number of backyard hog producers has declined consistently since the mid-2000s (Gale et al., 2012). As shown in Table 1, as of 2011, about 80% of households in China do not raise hogs.

On the other hand, pork demand has increased rapidly as per-capita income has grown. According to China's national statistics (NBSC, various years), since 1978, the real total income of rural residents has increased by more than 12 times, while the real

**Table 1**
Hogs slaughtered by farm size, 1987–2012.

| | | 1987 | 2002 | 2007 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Households (%) | 0 | 24.39[a] | 57.11 | 67.62 | 78.25 | 79.59 |
| | 1–49 | 75.46[a] | 42.46 | 31.49 | 20.72 | 19.36 |
| | 50–499 | 0.15[a] | 0.41 | 0.83 | 0.94 | 0.95 |
| | 500+ | | 0.01 | 0.05 | 0.09 | 0.10 |
| Hogs slaughtered(%) | 1–49 | 95[a] | 73 | 52 | 35 | |
| | 50–499 | 3[a] | 17 | 27 | 29 | |
| | 500+ | 3[a] | 8 | 22 | 36 | |

Data source: National Bureau of Statistics of China (various years).
[a] The 1987 data are calculated based on Chang & Zuo (1988) and National Bureau of Statistics of China (1999).

disposable income of urban residents has increased by more than 11 times.[1] Because pork is the main meat source for most Chinese people, from 1978 to 2012, annual per-capita pork consumption increased from 5.2 kg to 14.4 kg for rural residents and from 13.7 kg to 21.2 kg for urban residents.

Since hog production of the time could not meet the demand, pork prices increased significantly during the 1990s, which spurred the Chinese government to promote hog production (Gale et al., 2012). To promote the hog industry, the government not only removed policies that constrained the development of hog production, but also implemented some policies that encouraged the development of the hog industry. The positive policies included the provision of subsidies, encouraging the integration of farms, and granting tax exemptions (Gale et al., 2012; Xie, 2012).

These preferential policies and increasing pork prices made hog production a profitable business. As a result, large-scale hog farms developed rapidly, especially since the mid-1990s. The herd size of some large-scale hog producers reached the size and scope of U.S. producers. For example, some hog enterprises have produced more than one million hogs annually.

As specialized hog production households and large-scale hog enterprises developed, the share of backyard hog producers decreased consistently. As shown in Table 1, the share of hogs raised by backyard producers was 73% in 2002, but this number dropped to 52% by 2007—a 29% decrease in only five years. Furthermore, by 2011, the share decreased to 35%.

The growth in specialized households and large-scale producers accompanied the smaller number of backyard hog producers. In 1999, specialized households accounted for 14% of total pork production; 10 years later, this share had increased to 30% (Table 1). Compared to the development of specialized households, the development of large-scale producers was every more rapid. In 1985, large-scale hog farms accounted for only 3% of China's total pork production; by 2011, that share had grown to 36%. In other words, specialized households and large-scale producers now dominate hog production in China.

## 3. Data and models

The data collected for this study include hog production information at various levels in the study areas. Specifically, province-level data are from the China Statistical Yearbook (various years), while county-level data are from the provincial statistical yearbooks (various years). Hog production information for townships and villages was collected by interviewing their leaders. These data were used to calculate the weights of non-producers and various types of producer.

### *3.1. Household-level data collection*

The hog production data for various types of producer were collected in 2011 by the Center for Chinese Agricultural Policy, Chinese Academy of Sciences. The samples for this study were selected as follows. First, five provinces were randomly selected as representing China's major agroecological zones. Shandong represents the eastern coastal provinces (Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, and Shandong) and northern provinces (Beijing, Tianjin, Hebei, Shanxi, and Inner Mongolia); Sichuan represents the southwestern provinces (Chongqing, Sichuan, Guizhou, Yunnan, and Guangxi); Guangdong represents the southern provinces (Guangdong, Guangxi, and Hainan); Hubei represents the central provinces (Henan, Hubei, and Hubei) and the northwestern provinces (Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang); and Jilin represents the northeastern provinces (Jilin, Liaoning, and Heilongjiang).

Second, from the five chosen provinces, we selected counties, townships, and villages. Three counties were randomly selected from each province—one from each third of a list of counties sorted by the total number of hogs produced. By using that same procedure, three townships were selected from each county, and three villages were selected from each township.

Third, the sample households were chosen. The leaders of each village were interviewed. The results of these interviews included information on the shares of non-producers and the various types of producer. If a village contained at least one of each type of producer (i.e., backyard producer, specialized household, and large-scale producer), we selected one of each. If a village contained only specialized households and large-scale producers, we selected two specialized households and one large-scale producer. If a village contained only backyard producers, we randomly chose three backyard producers. After selecting the hog producers, we also randomly selected three non-producers from each village.

First, enumerators interviewed township and village leaders, using a questionnaire designed to collect basic socioeconomic information, such as population, labor force, and per-capita income. Detailed questions were asked and recorded about hog production within each township or village. For example, we asked about not only the total number of each type of producer, but also their share of all producers. In order to gain a better understanding of hog production over time, historical information on hog production was collected. We also asked the village leaders about related policies and subsidies.

From each hog producer, the team collected a great deal of information, again by using a detailed questionnaire. In addition to basic household characteristics (e.g., family size, farm size, and asset value), demographic information (e.g., gender, age, education, and marital status) for each individual in the household was also recorded. In addition, the questionnaire included a lengthy section about the work experience of each laborer, especially off-farm work experience.

In addition to the basic characteristics of households and laborers, the questionnaire captured the total number of hogs raised by the sample households each year to (and including) 2004. This information forms the core of this study's analysis. By analyzing

[1] The real incomes are calculated according to the following formula: real income = nominal income / consumer price index, for which the base year is 1978.

**Table 2**
Basic characteristics of the variables.

| | Producer | Non-producers |
|---|---|---|
| Producers dummy (yes = 1) | 0.53 | |
| Herd size of backyard producers (1–9 heads) | 3.55 | |
| Herd size of small-scale specialized hog producers (10–49 heads) | 24.45 | |
| Herd size of medium-scale specialized hog producers (50–499 heads) | 159.13 | |
| Herd size of large-scale hog producers (500-heads) | 1488.07 | |
| Asset value per capita at previous year (10,000 yuan) | 6.05 | 5.72 |
| Consumption asset value per capita at previous year (10,000 yuan) | 3.05 | 4.12 |
| Asset value per capita in 2004 (10,000 yuan) | 5.70 | 5.56 |
| Family size (person) | 4.32 | 4.12 |
| Farm size (mu) | 8.78 | 8.39 |
| Gender (male = 1) | 0.96 | 0.94 |
| Age of household head | 45.54 | 44.29 |
| Education of household head | 7.85 | 7.93 |
| Party member dummy (yes = 1) | 0.19 | 0.21 |
| Cadre dummy (yes = 1) | 0.14 | 0.14 |

Data source: author's survey.

these data, we show the dynamics of hog producers and hog production in China, and thus identify the factors affecting the evolution of the industry. Summary statistics for the main variables used in this study are provided in Table 2.

### *3.2. Hog production by farm size, and the dynamics thereof*

Based on our survey data, we calculated the shares of non-producers and determined the three types of hog producer. As with the number of hogs slaughtered, we then calculated the share of each type of hog producer. As shown in Table 3, in 2010, 82.68% of the farmers were non-producers of hogs, similar to the national share shown in Table 1. We divided the hog producers into four types, based on herd size: backyard producers with a herd size of nine or fewer heads, small-scale producers with a herd size of 10–49 heads, medium-scale producers with a herd size of 50–499 heads, and large-scale producers with a herd size of 500 or more heads. In our sample, about three-quarters of the hog producers were backyard producers (i.e., with a herd size of nine or fewer heads), while only 0.52% (0.09 / 17.32 = 0.52%) were large-scale producers (i.e., with a herd size of 500 or more heads).

However, in terms of the number of hogs slaughtered, backyard producers comprised only 10% of the total. The shares of small-scale producers, medium-scale producers, and large-scale producers were 21%, 34%, and 35%, respectively. The shares of households and of hogs slaughtered in this study are consistent with the national shares shown in Table 1.

To illustrate the dynamics of hog producers and non-producers in China, we follow Quah (1993) and use the hog production data to construct a "mobility matrix." By analyzing the data in each row of the matrix, we can see the sources of each type of hog producer and of non-producers. For example, as shown in Table 4, 82% of the non-producers in 2010 also had been non-producers in 2004, while 13% of them had been backyard hog producers in 2004. Similarly, 74% of the backyard hog producers in 2010 had been backyard hog producers in 2004.

The dynamics of specialized households and large-scale producers are also significant. As shown in the first column of Table 4, 35%, 38%, and 36% of the small, medium, and large-scale producers in 2010, respectively, had been non-producers in 2004. Furthermore, only 3% of the medium-scale producers in 2010 had been backyard producers in 2004, and none of the large-scale producers had been backyard producers in 2004. In other words, backyard producers were more likely to quit hog production than they were to expand their herd sizes and become large-scale producers (see Table 4).

### *3.3. Hog production and farmer wealth*

In this subsection, we link hog production with its potential determinants. Especially, we test whether there is a relationship between farmer wealth and the activity of raising hogs. Because in a developing country per-capita income is not a reliable indicator of farmer wealth, we use per-capita asset value as a measure of wealth (Rozelle, 1996).

When plotted, an inverted U-shaped relationship between household livestock production and the level of economic development is observed from any developing countries. In other words, as the economy grows and farmers become richer, farmers raise more hogs. However, as the economy continues to grow, the expansion of backyard hog production peaks. Finally, most farmers abandon hog production, because off-farm work becomes more attractive than raising a couple of hogs. Evidence of this inverted U-shaped relationship has been observed in many countries (Catelo, Narrod, & Tiongco, 2008; Adams & He, 1995; Rosenzweig & Wolpin, 1993; Devendra, 1993). The relationship has also been documented in China (Qiao, Chen, Carter, Huang, & Rozelle, 2011).

Consistent with these studies, the data in this study show a clear and negative relationship between the herd size of backyard producers and non-producers and the per-capita asset value (Fig. 1, Panel A). In other words, the data show that, as backyard producers become richer, they quit hog production, or at least reduce their herd size. This finding is as expected. China's economy has grown rapidly over the past three decades, and most rural laborers have migrated to cities to engage in off-farm work. As they

**Table 3**
Hog production by different farm size in 2010.

| | Non-hog producers | Hog producers by herd size | | | |
|---|---|---|---|---|---|
| | | 1–9 heads | 10–49 heads | 50–499 heads | ≥500 heads |
| This study | | | | | |
| Percentages of households (%) | 82.68 | 12.59 | 3.71 | 0.93 | 0.09 |
| Hogs slaughtered(%) | | 10.00 | 21.00 | 34.00 | 35.00 |

Data source: author's survey.

have become richer, they have grown more concerned about the environment. As a result, most farmers have abandoned backyard hog raising. In other words, the relationship between herd size and farmer wealth in China has progressed from the left-hand side of the inverted U-shape to the right-hand side.

On the other hand, the relationship between producer wealth and the herd size of specialized producers seems to be positive rather than U-shaped. As shown in Fig. 1, Panel B, as hog producer wealth increases, these medium-scale and large-scale producers raise more hogs. In contrast to backyard producers, medium-scale and large-scale producers focus on hog production. Because hog production is their main or only source of income, they tend to increase their herd size as they become richer.

## 4. Multivariate approach and empirical findings

Taking the analysis a step further than the descriptive statistics as already provided, in this section, we estimate a series of econometric models in order to isolate the effect of farmer wealth on hog production. We do so, because the descriptive results in Section 3 may be misleading, since they do not exclude the effects of other factors that simultaneously affect hog production. To isolate the effect of farmer wealth, we must use an econometric model.

### *4.1. Econometric model*

The relationship between farmer wealth and herd size is different between backyard producers and large producers. For backyard producers, their behavior can be largely explained by an agricultural household model. Raising hogs is just one of several production activities, and they choose these activities to maximize their income (Benjamin, 1992; Singh, Squire, & Strauss, 1985). In addition, farming hogs in a small backyard also brings significant negative welfare. Hence, even though backyard producers would expand their herd sizes as their wealth increases from a low level, most of them would abandon hog production and move to other economic activities after their wealth level reaches a point. In other words, backyard hog production and wealth level have an inverted U-shaped relationship (Qiao et al., 2011). However, specialized medium and large-scale producers are more likely to focus solely on hog production, and their behavior can be explained by the profit-maximizing model, subject to credit constraints being eased if the business owner were to have more wealth (Varian, 1987). Under credit constraints, herd sizes are usually smaller than the economically optimal levels. They would tend to expand their herd size as they become richer or have less credit constraint with an increase in household wealth. Hence, for large producers, there is a positive relationship between herd size and wealth level.

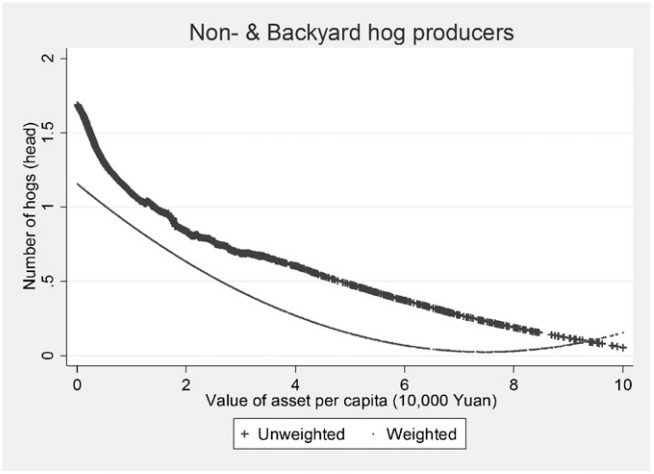
The econometric model for backyard producers and non-producers can be written as follows:

$$\begin{aligned} Hog\_raising_{i,t} = {} & \alpha_0 + \alpha_1 * Wealth_{i,t-1} + \alpha_2 * Wealth^2_{i,t-1} + \alpha_3 * Household_{i,t} \\ & + \alpha_4 * Household\_head_{i,t} + \alpha_5 * Prices_{i,t} + \alpha_6 * Policies_{i,t} \\ & + \alpha_7 * Provinces_{i,t} + \alpha_8 * Time_{i,t} + e_{i,t} \end{aligned} \quad (1)$$

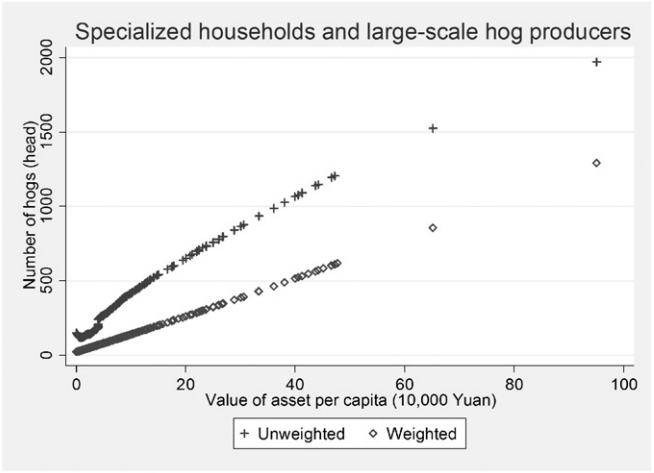
**Table 4**
Hog production scale "mobility matrices" in China, 2004–2010.

| | | 2004 | | | | |
|---|---|---|---|---|---|---|
| | | None | 1–9 heads | 10–49 | 50–499 | ≥500 |
| 2010 | None | 82 | 13 | 3 | 2 | 0 |
| | 1–9 | 19 | 74 | 6 | 1 | 0 |
| | 10–49 | 35 | 14 | 47 | 3 | 0 |
| | 50–499 | 38 | 3 | 16 | 43 | 0 |
| | ≥500 | 36 | 0 | 1 | 35 | 28 |

Note: this table is constructed to illustrate the dynamics of hog producers and non-producers in China. The data in each row of the matrix show the sources of each type of hog producer and of non-producers. For example, the first row shows that 82%, 13%, 3%, and 2% of the non-producers in 2010, respectively, had been non-producers, backyard producers (with a herd size of 1–9), small-scale producers (with a herd size of 10–49), and medium-scale producers (with a herd size of 50–499) in 2004.
Data source: author's survey.




A




B

Data source: Author's survey.

**Fig. 1.** Impact of asset value on hog production.

in which *Hog_raising* is a binary variable equal to 1 if household *i* has raised hogs during year *t*, and 0 otherwise; and *e* is the error term. *Wealth* is specified in one of three ways (used in separate models): per-capita total asset value, per-capita consumption asset value, and per-capita total asset value as of 2004. $Wealth^2$ is the square of *Wealth*. When per-capita total asset value or per-capita consumption asset value is used, it is a lagged measure of wealth (that is, a measure of farmer wealth as of the end of the previous year), which is indicated by the subscript $t - 1$. We do so, because ignoring any endogeneity—such as any degree of reverse causality (i.e., if hog raising is associated with farmer wealth)—may result in overestimation of the effect of farmer wealth on hog raising. The use of such lagged values is a practice seen in other similar studies (Kao & Chiang, 2001).

The model specified by Eq. (1) also controls for other factors. Specifically, *Household* is a vector of household characteristics. We include several variables that measure those characteristics that may account for some of the heterogeneity across households in hog raising. For example, family size and household land endowment are included in the estimation. Similar to *Household*, *Household_head* is a vector of the characteristics of the household head that may account for some of the heterogeneity across households in hog raising. We include several variables that describe the household head. For example, years of education is included as a measure of human capital, and age is included to control for life-cycle effects that may influence the decision to raise hogs. In addition, as in other studies, a gender dummy variable (equal to 1 if the household head is male, and 0 otherwise) and a cadre dummy variable (equal to 1 if the household head is a village leader, and 0 otherwise) are also included.

*Prices* is the ratio of hog price to corn price. Corn price is considered, because corn is the main feed for hogs. In order to control for the effects of some factors that may affect both hog prices and corn prices, we use the hog–corn price ratio. Because of the potential reverse causality and its resulting estimation bias, the lagged value of the hog–corn price ratio is used.

We add two variables to measure the effect of government policies on hog production (*Policies*). First, a subsidy dummy variable (set equal to 1 if a subsidy exists, and 0 otherwise) is added to control for the effect of government policies. Another policy

variable is the hog-raising zone. The hog-raising zone is a location where hog producers receive subsidies in terms of free land or land with a low rental fee, and free technical extension services. In this study, we add *Hog Raising Zone*, a dummy variable that is set equal to 1 if the household is located in such a zone, and 0 otherwise, to consider the effect of government policies on hog production. Finally, provincial dummy variables (*Provinces*) and year dummy variables (*Time*) are added to consider the effects of geography and time.

Similar to the hog-raising model, the herd-size model can be written as follows:

$$\begin{aligned} Herd\_size_{i,t} = {} & \beta_0 + \beta_1 * Wealth_{i,t-1} + \beta_2 * Household_{i,t} + \beta_3 * Household\_head_{i,t} \\ & + \beta_4 * Prices_{i,t} + \beta_5 * Policies_{i,t} + \beta_6 * Provinces_{i,t} + \beta_7 * Time_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (2)$$

in which $Herd\_size_{i,t}$ is the total number of hogs raised by producer $i$ during year $t$, and $\varepsilon$ is the error term. The remaining variables are specified in the same way as for Eq. (1).

However, if we were to simply estimate Eq. (2) for non-producers and backyard producers by using ordinary least squares, we would have a selection bias problem. A farmer will not choose to raise hogs if his or her reservation income is higher than the expected profit from hog production. In practice, however, we observe only those hog producers who earn more than their reservation incomes. Without correcting for selectivity bias, the estimated effect of farmer wealth on hog production may be biased (de Brauw & Rozelle, 2008). Therefore, Tobit models are estimated to correct for the selection bias.

Finally, we estimate the equations with sample weights. As discussed in Section 3, the weights for non-producers, backyard hog producers, and specialized hog producers at the national, provincial, and county levels are obtained from the China Statistics Yearbooks and provincial statistical yearbooks. The weights at the township and village levels are obtained from our field survey of the sample townships and villages. By estimating Eqs. (1) and (2) while using these weights, we obtain nationally representative estimation results.

### 4.2. Estimation results

As discussed in Section 3, the effect of a factor may vary among non-producers and each type of producer. Because specialized households and large-scale producers focus on hog production, and income from hog raising is their main or only source of income, we group them together when we estimate the models. Similarly, we group together backyard producers and non-producers. We first estimate the Tobit models for backyard producers and non-producers; we then estimate the determinants of herd size for specialized producers and large-scale producers. The estimation results are shown in Tables 5 and 6.[2]

#### 4.2.1. Non-producers and backyard producers

The estimation results for the Tobit models for backyard producers and non-producers are shown in Table 5. Replacing lagged per-capital total asset value by lagged per-capita consumption asset value or 2004 per-capita asset value yields very similar estimation results, which demonstrates the robustness of the results.[3] For simplicity, we focus on the estimation results based on the use of lagged per-capita total asset value as an explanatory variable. In general, most of the regression results are consistent with the descriptive analysis from Section 3. Most of the estimated coefficients have the expected signs and are statistically significant. For example, the estimated coefficient on the subsidy dummy variable is positive and statistically significant, indicating that subsidies positively influence hog production. As another example, the existence of a hog-raising zone has a positive effect on participation in hog raising and on herd size (row 5).

More importantly, the results shown in Table 5 help us answer a main question posed in this study: what is the effect of farmer wealth on participation in backyard hog production? As shown in Table 5, column 1, the estimated coefficient on farmer wealth is negative and statistically significant (row 1). In other words, as backyard hog producers become richer, they tend to abandon hog production or raise fewer hogs.

Adding to the model the square of the asset value variable did not change the result. As shown in Table 5, column 2, the estimated coefficient on asset value is still negative, while the estimated coefficient on the square of the asset value variable is positive. In other words, the relationship between farmer wealth and hog production is convex. Further calculation shows that the inflection point of lagged per-capita asset value is 1,853,000 yuan, which is more than 30 times larger than the sample average (Table 2, row 6). In other words, almost all the sample households in this study are on the left-hand side of the convex curve, indicating that, as their wealth increases, they would tend to abandon hog production or raise fewer hogs. In other words, the relationship shown in Table 5, column 2 is consistent with the linear negative relationship shown in Table 5, column 1.

These findings are consistent with our expectations and the descriptive analysis of Section 3. As the economy has grown and off-farm work opportunities have increased in number, farmer wealth has increased significantly. Therefore, their reservation prices with respect to a clean living environment also have increased. Thus, they are less likely to raise hogs in their small backyards. In other words, as they become richer, farmers tend to exit the hog production market.

[2] There could be potential measurement error in calculating weights based on the use of official hog-production statistics, as local officials may overstate hog statistics in order to improve their performance evaluations (Yu & Abler, 2014; Lohmar, 2015). This error, however, is minimal, because the over-reporting issue is a common phenomenon in all provinces. Moreover, we also re-ran the model without the weights, and we found the estimation results to be very similar to those shown in Tables 5 and 6.

[3] For simplicity and to conserve space, the estimated results based on lagged consumption asset value and 2004 asset value are not shown.

**Table 5**
Determinants of non-producers and backyard producers (Tobit model).

| | Non-producers & backyard hog producers | |
|---|---|---|
| Lagged asset value | −0.7586 | −0.7784 |
| | (−4.34)*** | (−4.36)*** |
| Square of lagged asset value | | 0.0021 |
| | | (4.10)*** |
| Lagged hog–corn price ratio | 3.5474 | 3.5484 |
| | (4.07)*** | (4.07)*** |
| Lagged subsidy dummy (yes = 1) | 4.4162 | 4.3976 |
| | (4.33)*** | (4.32)*** |
| Hog raising zone dummy (yes = 1) | 2.2677 | 2.2769 |
| | (0.59) | (0.60) |
| Family size | −0.3007 | −0.3014 |
| | (−1.29) | (−1.29) |
| Own land (mu/household) | 0.0423 | 0.0424 |
| | (1.26) | (1.27) |
| Gender (male = 1) | −1.9840 | −1.9686 |
| | (−0.86) | (−0.85) |
| Age (years) | 0.0874 | 0.0872 |
| | (1.99)** | (1.99)** |
| Household head education (years) | 0.2690 | 0.2686 |
| | (1.75)* | (1.75)* |
| Cadre dummy (yes = 1) | −1.4081 | −1.4041 |
| | (−1.19) | (−1.19) |
| Province dummies | Yes | Yes |
| Year dummies | Yes | Yes |
| Constant | −34.8504 | −34.8386 |
| | (−4.38)*** | (−4.38)*** |
| Sigma | 4.1255 | 4.1246 |
| | (10.14)*** | (10.14)*** |
| Observations | 2923 | 2923 |

Note: robust t-statistics in parentheses, ***p < 0.01, **p < 0.05, *p < 0.1.
Data source: author's survey.

Another interesting finding from Table 5 is that non-producers and backyard producers are very sensitive to market prices. The estimated coefficient on the lagged hog–corn price ratio is positive and statistically significant in both columns of Table 5. In other words, if the market is good (i.e., the hog–corn price ratio in the previous period was high), a non-producer is more likely to begin to raise hogs and a backyard producer is more likely to increase his or her herd size. On the other hand, if the market is bad, backyard producers are more likely to reduce their herd size, or exit altogether.

*4.2.2. Specialized households and large-scale hog producers*

The estimation results for specialized households and large-scale hog producers are shown in Table 6. Similar to the results shown in Table 5 for backyard producers and non-producers, most of the estimated coefficients in Table 6 have the expected signs and are statistically significant. For example, producer education has a positive effect on herd size.

Importantly, the estimation results show that producer wealth and herd size have a statistically significant positive relationship. As shown in Table 5, columns 1–3, the estimated coefficients on lagged per-capita asset value, lagged consumption asset value, and 2004 per-capita asset value are all positive and statistically significant. In other words, the richer a specialized producer is, the larger his or her head size will be.

This finding is consistent with our expectation and descriptive analysis from Section 3. For backyard producers, raising hogs is only a sideline, because their main source of income is farming crops or off-farm work. As they become richer, their reservation prices for a cleaner environment increase, and exceed the income they earn from hog farming. As a result, most of them abandon hog production. However, for the specialized producers, hog production is the main source of income. As they become richer, they would tend to expand their herd size.

Table 6 also shows that, interestingly, the estimated coefficient on the lagged hog–corn price ratio is positive but statistically insignificant (row 4).[4] In other words, specialized households and large-scale hog producers do not adjust their hog production as market prices change. Their response to market price differs from that of backyard producers (Table 5).

There may be a few reasons that specialized households and large-scale hog producers are not sensitive to market price changes. First, they can increase their net profit from hog farming by increasing their herd size. According to the statistical data, the feed conversion ratio (FCR) of backyard producers is greater than that of specialized households and large-scale hog producers (National Development and Reform Commission, various years). Therefore, specialized households and large-scale producers will increase their herd size as long as the FCR effect dominates. In other words, if the market price decreases but the extra benefit

[4] When the models are re-estimated by replacing the lagged hog–corn ratio with both lagged hog price and lagged corn price or with the current hog–corn ratio, very similar results are obtained.

**Table 6**
Determinants of the herd sizes of the specialized households and large-scale hog producers.

| | Herd size (heads) | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| Lagged asset value | 8.6918 | | |
| | (1.93)* | | |
| Lagged consumption asset value | | 7.2374 | |
| | | (1.82)* | |
| Asset value in 2004 | | | 8.6836 |
| | | | (2.03)** |
| Lagged hog–corn price ratio | 0.4516 | 1.0607 | 0.2004 |
| | (0.07) | (0.18) | (0.03) |
| Lagged subsidy per hog | 56.5552 | 61.5971 | 59.0018 |
| | (1.01) | (1.04) | (1.04) |
| Hog raising zone (village level) | 89.6747 | 130.0278 | 112.2501 |
| | (1.28) | (2.23)** | (1.94)* |
| Family size | 1.5528 | 2.4299 | 1.7822 |
| | (0.16) | (0.24) | (0.18) |
| Own land (mu/household) | 0.1545 | 0.0181 | 0.2096 |
| | (0.08) | (0.01) | (0.11) |
| Gender (male = 1) | −50.7347 | −53.4944 | −50.7526 |
| | (−1.93)* | (−1.95)* | (−1.94)* |
| Age (years) | 0.2651 | 0.1388 | 0.2284 |
| | (0.32) | (0.17) | (0.28) |
| Household head education (years) | 7.7633 | 8.0584 | 7.8262 |
| | (2.28)** | (2.33)** | (2.30)** |
| Cadre dummy (yes = 1) | −5.4469 | −10.0330 | −7.0490 |
| | (−0.16) | (−0.30) | (−0.21) |
| Province dummies | Yes | Yes | Yes |
| Year dummies | Yes | Yes | Yes |
| Constant | −37.3779 | −34.5146 | −33.6201 |
| | (−0.39) | (−0.37) | (−0.36) |
| Observations | 1955 | 1955 | 1955 |
| R-squared | 0.300 | 0.272 | 0.293 |

Note: robust t-statistics in parentheses, ***p < 0.01, **p < 0.05, *p < 0.1.
Data source: author's survey.

from increasing herd size can offset the loss associated with declines in market price, specialized producers will continue to increase their herd size.

Second, in contrast to backyard producers, specialized households and large-scale producers experience limited annual adjustment. If the market is poor (i.e., market price is very low), backyard hog producers can abandon hog production immediately. However, even in an unfavorable hog market, as long as the market price is high enough to offset the variable cost—or the expected profit from hog farming is positive in the long run—specialized households and large-scale producers will not completely abandon hog production.

Finally, for a specialized household or large-scale hog producer, the transaction cost of a significant reduction in herd size is high. Because hog farming is only a sideline for backyard producers, they may abandon hog production and engage in other agricultural activities or non-farm jobs. However, for specialized households and large-scale producers who spend all their labor and effort on hog production, the transaction cost of reducing or completely abandoning hog production is relatively high.

## 5. Conclusions

In this paper, we illustrated the transition of China's hog production industry, and its determinants. The results indicate that farmer wealth has had significant effects on the transition of China's hog production. As the economy has grown, most backyard producers have abandoned hog production. At the same time, economic growth has promoted the development of large-scale hog production, which now dominates China's hog production market.

The findings of this study have important policy implications. When setting livestock policies, decision-makers should pay close attention to the market roles played by various types of hog producer during the transition. In addition, policy-makers should pay close attention to China's economic growth rate, changes in farmer wealth, and other drivers of the transition of China's hog production industry.

Although this study focused on the transition of various types of hog producer and the drivers of that transition, it raised many fundamental issues that require further study. For example, as various types of hog producer evolve, how should policies be designed and targeted? What are the environmental consequences of this transition? What are the effects of the transition on China's hog production market and pork market? These issues are possible topics for future research.

## References


Adams, R., & He, J. (1995). Source of income inequality and poverty in rural Pakistan. *Research report no. 102*. Washington, D.C.: International Food Policy Research Institute.

Benjamin, D. (1992). Household composition, labor markets, and labor demand: Testing for separation in agricultural household models. *Econometrica*, *60*(2), 287–322.

Catelo, M., Narrod, C., & Tiongco, C. (2008). Structural changes in the Philippine pig industry and their environmental implications. *IFPRI discussion paper 781*. Washington, D.C.: International Food Policy Research Institute.

Chang, Q., & Zuo, W. (1988). Strategic choice of the optimal regions and scales of pig production in China. *Chinese Rural Economy*, *11*, 44–49,12.

Chen, K., Liu, Y., Ruth, H., & Xiao, C. (2012). Can we relax liquidity constraints in micro-insurance demand? Piloting an innovative design for agricultural insurance. *The final report submitted to ILO Micro-insurance Innovation Facility* (July, 2012).

Chen, K., & Wang, J. (2013). Hog farming in transition: The case of China, *The Pig Site*. (Thursday, February 28, 2013) http://www.thepigsite.com/articles/4262/hog-farming-in-transition-the-case-of-china

de Brauw, A., & Rozelle, S. (2008). Reconciling the returns to education in off-farm wage employment in rural China. *Review of Development Economics*, *12*(1), 57–71.

Devendra, C. (1993). Sustainable animal production from small farm systems in South-East Asia. *FAO animal production and health paper, no. 106*. Rome: Food and Agriculture Organization of the United Nations.

Gale, F., Marti, D., & Hu, D. (2012). *China's volatile pork industry*. Washington, DC: United States Department of Agriculture, Economic Research Service.

Kao, C., & Chiang, M. (2001). On the estimation and inference of a cointegrated regression in panel data. In B. H. Baltagi, T. B. Fomby, & R. C. Hill (Eds.), *Nonstationary panels, panel cointegration, and dynamic panels. Advances in Econometrics*, *Vol. 15*. (pp. 179–222). Emerald Group Publishing Limited.

Lohmar, B. (2015). Will China import more corn? *Choices*, quarter 2. Online at http://choicesmagazine.org/choices-magazine/theme-articles/2nd-quarter-2015/will-china-import-more-corn

National Bureau of Statistics of China Livestock Statistical Yearbook of China, various years, Beijing: Chinese Agriculture Publishing House.

National Bureau of Statistics of China (1999, 2013 & 2014). *China statistical yearbook*. Beijing: Chinese Statistical Press.

Qiao, F., Chen, J., Carter, C., Huang, J., & Rozelle, S. (2011). Market development and the rise and fall of backyard hog production in China. *The Developing Economies*, *49*, 203–222.

Quah, D. (1993). Empirical cross-section dynamic in economic growth. *European Economic Review*, *37*, 426–434.

Rosenzweig, M., & Wolpin, K. (1993). Credit market constraints, consumption smoothing, and the accumulation of durable production assets in low-income countries: Investments in bullocks in India. *Journal of Political Economy*, *101*(2), 223–244.

Rozelle, S. (1996). Stagnation without equity: Patterns of growth and inequality in China's rural economy. *The China Journal*, *35*, 63–96.

Schneider, M. (2011). *Feeding China's pigs implications for the environment, China's smallholder farmers and food security*. Ithaca and Beijing: Institute for Agriculture and Trade Policy and Mindi Schneider.

Singh, I., Squire, L., & Strauss, J. (1985). *Agricultural household models: Extensions, applications' and policy*. Baltimore: Johns Hopkins Press for the World Bank.

Taylor, R. D., & Koo, W. W. (2015). Outlook of the U.S. and world corn and soybean industries, 2014–2024. *Agribusiness & applied economics report no. 741. May 2015. Center for Agricultural Policy and Trade Studies Department of Agribusiness and Applied Economics North Dakota State University Fargo, North Dakota* (Available at: http://ageconsearch.umn.edu/handle/205345. Accessed on August 10, 2015).

United States Department of Agriculture (2015). *Livestock and poultry: World market and trade. United States Department of Agriculture, Foreign Agricultural Service, Washington, DC April 2015*. (Available at: http://apps.fas.usda.gov/psdonline/circulars/livestock_poultry.PDF. Accessed on August 11, 2015).

Varian, H. (1987). *Intermediate microeconomics — A modern approach*. New York: W. W. Norton & Company.

Wang, J., & Xiao, H. (2008). Development of the hog industry and its integration in China. In J. Wang, & M. Watanabe (Eds.), *Pork production in China — A survey and analysis of the industry at a Lewis turning point*. Japan External Trade Organization: ASEDP, Institute of Developing Economies.

Xie, S. (2012). Chinese animal husbandry in 2012: Development and policy focus. *Guide to Chinese Poultry*, *17*, 2–6.

Yu, X., & Abler, D. (2014). Where have all the pigs gone? Inconsistencies in pork statistics in China. *China Economic Review*, *30*, 469–484.

Zhang, Y., Li, C., Liu, C., & Chen, K. (2013). Prevention of losses for hog farmers in China: Insurance, on-farm biosecurity practices, and vaccination. *Research in Veterinary Science*, *95*(2), 819–824.