Market Emergence and the Rise and Fall of Backyard Hog Production in China

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1. Introduction

In developing countries, per capita demand for livestock products tends to increase with economic development. To ensure that supply meets rising consumer demand, policy makers must formulate policies either to increase domestic livestock production or to rely more on imports. If neither an increasing reliance on imports nor the use of a high domestic price to assure supply and demand balance is a desired policy option, policies makers have to seek other means to increase total livestock supply. The increased livestock supply generally comes from one of two sources: either by encouraging increased production from traditional backyard production or by fostering large commercial livestock enterprises.

Policies to encourage growth in backyard livestock production are different from those that would facilitate the expansion of large-scale commercialization. If decision makers only consider policies to foster commercialized operations when they project the shortage in the livestock supply, they may waste valuable fiscal resources and policy effort. Such policies could also lead to inefficient investment by private individuals. For example, during the 1980s in China, concerns that livestock production would not be sufficient to feed its citizens led to a series of government-initiated programs, most of which sought to encourage the establishment of large commercialized livestock operations in suburban regions of large cities (Pan, 2000). The government subsidized many of these commercial enterprises. By the late 1990s, however, many of the operations went bankrupt. During the same time period, with little encouragement from policy makers, livestock supplies from backyard operations expanded dramatically to the

point that competition from backyard operations may well have driven some of the commercialized operations out of business.

Thus, to make better policy decisions, it is important for policy makers to understand the pattern of backyard livestock production and the fundamental economic factors that contribute to the observed pattern in backyard hog production during different phases of economic development. In fact, many different economic factors may have provided backyard producers with a competitive edge and facilitated their expansion at a certain stage of economic development. The economic literature has suggested that risk (Rosenzweig and Wolpin, 1993; Kurosaki, 1998), off-farm wage rates (Benjamin, 1992; Skoufias, 1994), and family structure may affect household production behavior. No one, however, has linked the emergence of markets with the pattern of livestock production, despite the fact that the emergence of markets was one of the main features that characterized economic transition in China during the time that its livestock sector underwent dramatic changes.

In examining the case of China, the absence of well-functioning markets may be one factor behind the dynamics in Chinese hog production. The economic literature shows that agricultural input, output, and labor markets were poorly developed in China, especially at the beginning era of economic reform in the 1980s (Parish, Zhe, and Li, 1995; Park, Jin, Rozelle, and Huang, 2002; Rozelle, Taylor, and De Brauw, 1999). Markets remain underdeveloped in some poor areas and inland regions as of today. Institutional barriers have affected labor markets, preventing farm families from moving to locations that promise them higher returns (Nyberg and Rozelle, 1999). Poor grain and feed markets can force farm households to rely heavily on their own grain production in

their livestock operations. The imperfections in grain markets can be caused by local geographic and transportation conditions or by government grain policies. Zhang (1999) shows that farm households in poorer regions relied as much as 90 percent on their own farm's grain for their livestock operations. Swings in China's grain procurement policies in the past two decades probably disrupted the development of grain markets (Park, Jin, Rozelle and Huang, 2002).

Over the last two decades, however, markets have emerged. In the 1980s, farm households purchased less than 20 percent of their inputs in the free markets. By the middle 1990s, more than half of the factors of production were purchased through markets (Chen and Rozelle, 1999). While markets have generally improved in all regions in China, market development is still uneven across regions. For instance, the share of goods allocated by free markets and the percentage of farm labor working off-farm is significantly lower in the poor, inland regions than in the rich, coastal regions.

While policy makers correctly predicted that backyard hog production would fall in the rich, coastal regions, they might not have fully understood the relationships between market development and backyard hog production in poor areas. The increases in backyard hog production from less wealthy, inland provinces clearly surprised officials. Furthermore, the increased supply in the inland provinces in conjunction with better livestock markets in the 1990s appears to have made the commercial hog sector in the coastal areas less competitive.[1]

[1] Generally, the livestock markets in China might operate more efficiently than the grain markets. If we use the commercialization rate as a measure of the level of market development, data from a comprehensive farm household survey conducted by Research Center for Rural Economy (to be discussed in detail later in the paper) shows that on average more than 80 percent of hogs produced by farm households were sold in the market; while only 25 percent of grain was sold in the market. This might be partly due to the fact that there was more government intervention in the grain sector than in the livestock sector over the past two decades.

In this paper, I directly investigate the effects of market development on farm household hog production. I find that that grain and labor markets development can explain a significant portion of the observed expansions of hog production in poor, inland areas and contractions in rich, coastal areas during the past two decades in China. For poor households in the inland areas, it is generally difficult to find off-farm employment (especially at the early stage of the economic reform in the 1980s), and thus the opportunity cost of labor is low; when facing the right conditions, they are willing to use their labor to produce hogs. However, when areas are at their poorest, their hog production is often constrained by the limited available grain and feed supply. When development begins, the emergence of grain and feed markets facilitate household access to less expansive feed grain from the market and allows them to utilize their low cost labor in hog production to earn additional income.

For relatively richer households in the coastal areas, I find that the effects of labor market development dominate the decision making process. Better labor markets increase the opportunity cost of labor and encourage farm households to send more family labor to off-farm labor markets and use less in hog production. In the meantime, improvements in grain markets encourage hog production of commercial operations, however this expansions occurs only for a few specialized households. For most households in the coastal areas, their production of hog falls.

To further examine the dynamics of China's hog production and understand the implications for the implementation of more effective policies, the rest of this paper is organized as follows. In Section 2, I document the ways in which trends in market development appear to correspond with observed trends in household hog production.

This suggests that the level of market development might be a key factor contributing to the observed relationship between household hog production and income in China. I also discuss the data set used for the paper. In Section 3, I provide a theoretical explanation of the linkage between markets and household hog production. I construct a farm household model to demonstrate theoretically that labor and grain market development, in conjunction with changes in other economic factors, could contribute to the formation of the observed relationship between livestock and income. In Section 4, I econometrically estimate the effects of labor and grain market development on household hog production. The results indicate that grain and labor market development can explain a significant portion of the rise and fall in China's backyard hog sector over the past two decades. Section 5 summarizes findings, draws policy implications and suggests directions for future research.

2. Market Development and Livestock Production

2.1. The Inverted-U in Household Livestock Production

Economic studies indicate that the relationship between backyard livestock production and the level of economic development might not be monotonic. Instead, backyard livestock production may follow a nonlinear relationship as the economy develops. In the early stages of development, poor farm households tend to expand their livestock production when their income increases.[2] However, after their income levels

[2] For instance, richer farm households in Pakistan raised more livestock than poorer households (Adam and He, 1995). As economies developed in the 1980s and 1990s, poor countries in Southeast Asia, such as Cambodia, Indonesia, Laos, Myanmar, Philippines, and Vietnam, increased their livestock production, and most of this increase came from small farms expanding production (FAO, 1999).

reach a certain level in the later stages of economic development, livestock production for many farm households appears to fall.[3]

Although the data sources I have assembled are quite different in their geographical and temporal coverage and level of aggregation, they all illustrate the non-linear relationship. Data from Mexico, South Africa, and Taiwan all show an inverted-U relationship between backyard livestock production and the stage of development (Appendix A). In each case, I observe that the path of backyard livestock production initially expands and then contracts as household incomes improve. Comparisons across countries also indicate that the farm households that produce the most backyard livestock have higher than average income, but they are not the richest households. In other words, in all of the sample nations, farm households expand their herd sizes until they are somewhat above the median income level. After that point, households begin to give up raising livestock in their backyards.

To examine the relationship between backyard hog production and income in China, I use a data set collected by the survey department of the Rural Center for Rural Economy, a research unit affiliated with China's Ministry of Agriculture (hereinafter referred to as the RCRE data). In the RCRE survey, each sample household is required to record all daily activities in the form of a "diary." The information is aggregated and available on an annual basis, covering a range of subject areas including labor allocation, agricultural production and marketing, income from on-farm activities and off-farm employment, land use, asset ownership, savings and access to credit. In addition to the household survey, village accountants are also responsible for collecting a community-

[3] For example, the number of hog producers in Korea in 1999 was only 3 percent of the 1970 level (Korea Ministry of Agriculture, Forestry, and Water Resource, 2000).

level data set. The community data set includes information on variables that cover total village agricultural output and sales, allocation of land and employment of labor in local enterprises. With access to a portion of the RCRE data, my sample includes 670 households in 29 villages from nine different provinces for all survey years from 1986 to 1999. The main data to be analyzed, hog production, come from the section of the RCRE data set that reports major outputs of farm products in both value and quantity terms.[4]

Nonparametric analysis, based on a Lowess estimator, demonstrates that, similar to other nations, there is also an inverted-U relationship between income and livestock production in China (Figure 1). Low-income farm households produce the fewest hogs per household. When per capita income improves, they tend to increase hog production until income reaches approximately 850 *yuan*, a level somewhat above the median. A further increase in per capita income, however, is associated with a decrease in household hog production.[5]

2.2. Household Hog Production and Market Development

The RCRE data illustrate that market development, especially in the case of grain and labor markets, is one of most important features that characterize rural economic development in the past two decades in China. Like Sadoulet, de Janvry and Benjamin (1996) and Giles (2000), I use the percentage of the village labor force working in nonagricultural sectors as an indicator of labor market development. Similarly, the percentage of grain sold in the market (or the grain commercialization rate) is used as an

[4] In the RCRE data, hog output is reported in kilograms rather than in animal units.
[5] Chen (2003) showed that this relationship appears whether I use parametric or nonparametric methods, whether I use Lowess estimator or Kernel estimator. Also, it appears in each sample province and each sample year.

indicator of grain market development.[6] I assume that a better labor or grain market is represented by a higher percentage of the village labor force working in off-farm sectors or a higher grain commercialization rate.

To demonstrate that farm households in different stages of economic development face markets of different levels of development, I divide the sample into income terciles (low, median, and high income subgroups). My assumption is that farm households in the low-income subgroup represent those at early stages of economic development, while the high-income group reflects those at relatively advanced stages of development. Examining the data in this way, I can show that labor and grain markets are better developed for the higher-income subgroups than lower ones (Table 2). The share of nonagricultural labor accounts for 40 percent of the village labor force in high-income groups while it is only 26 percent for the low-income groups. The grain commercialization rates also are higher for the high-income subgroups. In addition, farm households in the medium- and high-income subgroups are more likely to be from plains areas (rather than hilly or mountainous areas) and have access to better transportation infrastructure (Table 1, columns 6 and 7). In other words, in richer areas farm households might have better grain markets because they face lower transportation and other transaction costs when marketing grain.

[6] Ideally, the total grain transactions in the market, including both grain purchasing and selling activities, would give more precise information on the level of grain market development. Unfortunately, the RCRE village surveys did not contain information on grain purchases. For villages that were mainly grain buyers in the market, using the percentage of grain sold in the market might underestimate the level of market development because a better grain market would not cause the these villages to sell more grain. However, the RCRE data show that, even for those poorer villages, the grain commercialization rate did increase over time. This indicates that this measurement, though imperfect, can still capture the general trend of grain market development. In the later empirical analysis, I also use a group of variables that have tight linkage to grain transaction costs to measure the grain market development. The merits and weakness of both indicators are discussed in more detail in the later empirical part of this paper.

A similar pattern linking markets and hog production is found over time. I find that labor and grain markets improve gradually over the survey period for all three income subgroups (Table 1, rows 4 to 15 and rows 1 to 3). For labor markets, the share of non-agricultural labor in the village labor force increased by about 10 percent from 1986 to 1999 for all income subgroups. For grain markets, taking the low-income subgroup as an example, the rate has more than doubled from 14 percent in 1986 to 30 percent in 1998 (Table 1, column 5, rows 4 to 7).

The shifts in markets also are correlated with those of hog production. Using a Lowess estimator, the nonparametric analysis traces out the inverted-U shape relationship between hog production and grain and labor market development (Figure 2). I find that when grain markets are poor, farm households produce few hogs. As grain markets develop, household hog production begins to increase. Household hog production continues to increase until the grain commercialization rate reaches a level of about 20 percent (or when the share of non-agricultural labor in the village labor force increases to 35 percent). Further improvements in grain or labor markets, however, are associated with decreases in hog production.

The changing relationship between grain and labor market development and hog production over the course economic development might be a result of the complex interactions among many economic factors, including grain and labor market development, the farm household's own-grain production capability and other economic factors. For example, households living in relatively poor, inland areas often confront poor grain markets and at the same time these households are often constrained in their household hog production decision by the lack of access to sufficient grain and feed

supplies. Using the criterion of whether a household needs to purchase grain to meet its own food consumption needs, I find that more than 62 percent of the RCRE households in the low-income tercile are grain deficit. In contrast, only 39 percent of medium-income households and 31 percent of high income households are grain deficit.[7] Thus, it is possible that a grain market development might help these households overcome the grain and feed supply constraints and allow hog production to expand. In the meantime, for poor households the initial positive relationship between hog production and labor market development could be due to the fact that that as labor markets emerge, they could help farm households overcome credit constraints.

At the more advanced stage of economic development, however, after grain and labor markets develop to certain levels, additional market development may have the opposite effect. It is likely that the effects of labor market development might eventually dominate. The increasing opportunity cost of farm labor may encourage farm households to send more family labor to the off-farm labor markets and use less in hog production, causing the fall in hog output. While a few households may take advantage of better grain markets to purchase grain and feed from markets to specialize in hog production, most households would sell their grain in the market and contract their hog production because of simultaneous changes occurred in other economic factors.

In summary, the descriptive analysis suggests that there is a linkage between market development and household hog production. However, the analysis so far is

[7] It is very likely that the percentage of households in the low-income tercile being grain deficit might be even higher than the above percentage, because some of poor households cannot purchase grain simply due to reasons like credit constraints, even if they want to. On contrary, the actual percentage of farm households in the high-income tercile being grain deficit might be lower, because their decisions to purchase grain from the market might not be necessarily related to the grain adequacy, but to additional choices of food varieties.

mostly descriptive in nature and is mostly based on simple correlations without fully considering the complexity of the farm household economy. In the following sections, I explain the linkages between market development and household hog production, and develop a series of testable hypotheses and use our data to test how market development affects hog production.

3. Households Models with Imperfect Grain and Labor Markets

In this section, I start by discussing the representation of market development in the farm household model. I stress the importance of having a model that can explicitly represent the emergence of labor and grain markets as gradual processes (rather than ones that are only able to examine two extreme market conditions: perfect markets and missing markets). Next, I construct a household-level computable general equilibrium model (CGE). To illustrate that market development might have different effects on hog production for farm households with different levels of income, I construct two baselines: one that examines a poor farm household and the other a relatively rich household. With the model, I first simulate how grain and labor market development encourage the expansion of hog production directly. I also show that grain and labor market development, in conjunction with changes in other economic factors, can also encourage wealthier farmers to reduce their hog production and create the inverted-U relationship between income and hog production. The last subsection concludes with a list of hypotheses to be tested in the econometric section.

3.1. Transaction Costs and Market Development

In developing a model of a farm household economy, I choose to use the level of transaction costs to represent the different levels of market development, an approach that is consistent with the one taken by de Janvry, Fafchamps, and Sadoulet (1991). Transaction costs typically consist of the costs of accessing markets, mark-ups by traders, the costs of imperfect information, such as those expenses incurred during the search for the best prices and costs of negotiation and bargaining. De Janvry, Fafchamps, and Sadoulet (1991) demonstrate that transaction costs result in a price wedge between the household's buying and selling price. They suggest that great distances to the marketing venues, poor infrastructure, less competitive marketing systems and poor information could lead to a large gap between buying and selling prices.[8] When there are no transaction costs, the farm household is assumed to operate in perfect markets. In contrast, when transaction costs are insurmountable, farm households are essentially operating in an "autarky" situation.[9]

While the case of imperfect markets may be most prevalent in the context of farm household economies, studies on market development typically tend to assume the existence of either perfect markets or completely missing markets (e.g., de Janvry,

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[8] For example, using data collected in a national survey of *Ejido* sector conducted in 1994 by the Mexican Ministry of Agrarian Reform, Key, Sadoulet, and de Janvry (1999) reported that the average selling price for corn was about 75 percent of the average buying price in 1994. Ejido land represents about one-half of all arable land in Mexico.

[9] According de Janvry, Fafchamps, and Sadoulet, a market fails when a transaction through market exchange creates disutility greater than the utility gain that it produces. They suggested to use different levels of transactions costs to measure the levels of market development. Empirically, we can use the development of infrastructure as an indicator of market development. However, as discussed above, transactions costs can be associated with many other thing, such as the competitiveness of a market. These costs cannot be captured completely by infrastructure variables. On the other hand, as suggested by de Janvry et al, and also shown in the later part of this paper, transactions costs have a direct bearing to the level of market transactions. Higher transactions costs restrict the level of market transactions, while better markets stimulate them. Therefore, empirically, we also use grain commercialization rates to proxy for the level of grain market development.

Fafchamps, and Sadoulet, 1991). When one looks only at the two extreme cases, it is impossible to trace out a continuous relationship between agricultural production and market development. Specific to the study of backyard hog production in China, the approach of focusing on the two extreme cases may not be able to trace out the complete pattern in hog production--especially when we have good reasons to suspect that the relationship between output and grain and labor market development is nonlinear.

To provide a more complete picture of the relationship between hog production and market development, I construct a farm household CGE model that explicitly incorporates the different levels of market development as a continuous variable. To do so, I use different levels of transaction costs to represent the different levels of market development, ranging very high (which mimics the missing markets case) to very low and near zero (the perfect markets case). In my analytical approach, the farm household economy is modeled as a mixed complementarity problem (MCP), where the farm household only sells (buys) grain and labor when the shadow prices of grain and labor are equal to prices it would receive (pay) in the market. If the shadow prices are between selling and buying prices, or within the price bands created by transactions costs, no market transactions occur. For example, if the buying and selling prices for grain are 1.2 and 0.8 *yuan* per kg respectively, the farm households would buy grain only when its shadow price of grain is equal to 1.2 *yuan* per kg and sell grain only if the shadow price of grain is equal to 0.8 *yuan* per kg.[10] However, when the shadow price is between 1.2 *yuan* and 0.8 *yuan*, the farm household would neither purchase nor sell grain in the

[10] Please note that the household's grain shadow price would never be greater than 1.2 *yuan* per kg, because the household can continue to purchase grain from market until the shadow price equals 1.2 *yuan* per kg. Similarly, the shadow price would never be lower than 0.8 *yuan* per kg. If the household values grain less

market. More detailed discussion on the formulation of MCP is given in the later part of the section.[11]

3.2. Farm Household Simulation Model

I assume that a typical farm household attempts to maximize its utility from consuming grain (X_g), commodities purchased from markets (X_m), and leisure (X_l):

$$U(X_g, X_m, X_l) \tag{1}$$

subject to an income and a set of complementarity constraints. The household budget constraint can be written as:

$$\begin{aligned} & p_p Q_p(L_p, C_g, M) + ip_g[Q_g(L_g, A) - X_g - C_g] + ip_l(T - X_l - L_g - L_p) \\ & + E - p_m X_m \geq 0 \end{aligned} \tag{2}$$

where p_p and p_m are the prices of the market-purchased commodities and hogs, and ip_g and ip_l are shadow prices of grain and labor that are different from their market prices, because grain and labor markets are assumed to be affected by some levels of transactions cost. The shadow prices of grain and labor also have to satisfy additional conditions (as is specified in Equation 3 and will be discussed in detail later). The variables, Q_g and Q_p, are the household's grain and hog outputs, respectively; C_g is the amount of grain crop used to feed hogs; $Q_g - X_g - C_g$ is the grain marketed surplus. When marketed surplus is positive (negative), the farm household is a net seller (buyer)

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than the selling price, it would continue to sell. In equilibrium, the shadow price would be equal to the selling price.

[11] I choose not to include risk in the farm household model, mainly because of the complexity of the farm household model itself. Inclusion of a risk factor would make the model so complex that it would not converge. Omitting the risk factor is also supported by the fact that risk might not be the dominating factor in the hog production decision-making process in China. For example, using the same RCRE data, Giles (1999) examined how various components of household income contribute to farm household income risks. The study found that volatilities in grain prices have minimal effects on income variations in China. Thus, the effect of using hog production to diversify grain price risk is negligible. Furthermore, Park (1999) found that farmers most frequently rely on informal credit, not livestock accumulation, to smooth consumption. The risk factor, however, will be explicitly included in the later econometric analysis.

of grain. The variable, T, is the total stock of household time; L_g and L_p are labor inputs in grain and hog production. $T - X_l - L_g - L_p$ is the household's net labor supply to the market, and when it is positive, the household is a net supply of labor; E is the initial endowment of income. Finally, M and A are the fixed assets used in hog and grain production. In sum, this constraint requires the farm household to maintain a balanced full-income budget.

In addition, I specify a set of complementarity conditions that have to be satisfied. These are needed since from the perspective of a farm household, when grain markets are imperfect, the shadow price of grain is always bounded by its purchasing price and selling price. In other words, if the shadow price of grain is less than its purchasing price, the household would not purchase any grain from market. Similarly, if the grain shadow price is higher than its sale price, it would not sell in the markets. The following conditions define this relationship between shadow prices and market transactions

$$\begin{aligned} & p^s{}_i \le ip_i \le p^b{}_i \\ & p^s{}_i > 0;\ p^b{}_i > 0\ ; i = g, l \end{aligned} \tag{3a}$$

$$Q^s{}_i(ip_i - p^s{}_i) = 0; \quad Q^b{}_i(ip_i - p^b{}_i) = 0 \tag{3b}$$

$$p^s{}_i = p^m{}_i - T \quad and \quad p^b{}_i = p^m + T \tag{3c}$$

Using grain as an example, we can see the role of these constraints in hog production in an environment that is characterized by imperfect markets. In formulating a mixed complementary problem, the household's perceived grain price (ip_g) has to be bounded by its selling price ($p^s{}_g$) and purchase price ($p^b{}_g$) as shown in equation 3a. The household only sells grain ($Q^s{}_g$>0), when its perceived grain price (ip_g) is equal to $p^s{}_i$ (Equation 3b), which is the grain market price (p^m) less the grain transaction costs (T--Equation 3c). In

other words, if the household values grain at an amount no more than what it can earn from selling the grain in the market (the difference between the market price and transaction cost), it would sell grain into the market and it would receive a price equal to p^s_i, which is equal to $p^m - T$. Similarly, if the household values grain at an amount more than the market price plus grain transaction cost, it would purchase grain at a price equal to p^b_g, or $p^m + T$. However, when ip_g is between the price band of $p^m - T$ and $p^m + T$, the household would neither purchase nor sell, and it would remain self-sufficient.

Because Equation 3 introduces a discontinuity in the optimization problem, the usual maximization procedures that derive closed-form analytical solutions based on the first-order conditions cannot be solved for. Thus, in this application, I use the PATH procedure in the GAMS package to solve the MCP problem. PATH has been used by many to solve MCP problems in economic applications (Rutherford, 1995; Arndt, Schiller, and Tarp, 2001; Komen and Peerlings, 2001).[12]

In formulating this simulation model, I use two Cobb-Douglas functions to represent the farm household production and consumption behavior. The key parameters for the model are reported in Appendix B.[13] In situations where I do not have sufficient information to estimate parameters directly, I use the parameters from literature, such as those used in de Janvry, Fafchamps and Sadoulet (1991).

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[12] Typically, Newton's method has been used in practice to solve the square systems of nonlinear equations. The basic idea is to construct a local approximation of the nonlinear equations around a given point, x_k, solve the approximation of the nonlinear equation around a given point, $x_k+1=x_N$, and repeat until a solution to the nonlinear system is found. A linear search between x_k and x_N is also used to reinforce a sufficient decrease on an appropriately defined merit function (Ferris and Munson, 2000). The Core algorithm is a nonsmooth Newton method to find a zero of the normal map $F[\pi(x)]+x-\pi(x)$ associated with the MCP. Here $\pi(x)$ represents the projection of x onto $[l,u]$ in the Euclidean norm. If x is a zero of the normal map, then $\pi(x)$ solves the MCP (Ferris and Munson, 1998). Refer to paper for detail. PATH uses a generalization of this method on a non-smooth reformulation of the complementarity problem.

[13] For example, I assume that a 1-percent increase in feed usage in hog production would increase hog production by 0.35 percent.

3.3. Simulation Results

Direct Effects of Market Development

To examine how grain market development might have different effects on hog production decisions for households at the different stages of economic development (or different income), I have two benchmark scenarios: one representing a poor farm household operating in the early stages of economic development with limited grain production capability, little access labor market (or facing high transactions costs in the labor market); and the other representing a relatively rich household that possesses higher yielding grain production technology and has better access to labor market. We assume that when richer farmers are in the labor market, they face no significant transactions costs).[14]

Simulation results confirm that the development of grain markets has different effects on household hog production for the poor and rich farm households. When grain transaction costs decrease at a rate of 5 percent of its market price per period, from 55 percent of market price (Period 1) to zero at Period 12, the simulation results demonstrate that the fall in grain transactions costs reduces the shadow price of grain.[15] For the case of poor households, the shadow price becomes the same as the price in which it is able to purchase grain because the poor household is a net grain purchaser. Decreases in the shadow price of grain in turn lead to the expansion of the use of grain in hog production. Simulation results also show that hog output increases continuously from about 140 kg in

[14] For instance, the poor household is calibrated as the one that, under perfect market conditions (without any transaction costs in grain and labor transactions), would annually purchase 587.5 kg of grain from the market, with 500 kg used for human consumption (in addition to its own grain production of 1,000 kg) and 87.5 kg used for feed grain. In equilibrium, the farm household produces 100 kg of hogs per year and sells 938 of its 3,200 man-hours of labor in the off-farm labor market.

Period 1 to 280 kg in Period 12 (dotted line, Panel A, Figure 3). In the case of rich households, however, the same grain market development increases the selling price of grain, resulting in increases in the sale of grain directly onto markets and decreases hog production from about 230 kg in Period 1 to 100 kg in Period 12 (solid line, Panel A, Figure 3).[16]

In the meantime, decreases in labor transactions costs show a negative effect on hog production for both poor and rich households. For both rich and poor households, when transactions costs in labor markets decrease, the shadow price of labor increases. For the poor household, when the transactions costs of entering the labor market decrease to 35 percent of its market wage rate, the farm household starts to sell more labor in the market and use less labor in hog production. The fall in transaction costs in the labor market triggered a reduction in hog production, from about 150 kg in Period 1 to less than 50 kg in Period 12 (dotted line, Panel B, Figure 3). Similarly, in the case of the rich farm household, a better labor market also would encourage the household to allocate more of its labor in to the off-farm labor market and use less in hog production, resulting in contractions in hog production.[17]

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[15] I found that if grain (or labor) transactions costs reach 50 percent of their market prices, no market transaction would occur. For the purpose of simulation, I use these high transactions costs to emulate the condition of missing markets. In reality, transactions costs could be lower.

[16] The simulation can further show that if transactions costs in labor market remain high, the poor farm household might continue to expand hog production by purchasing additional feed from market following a grain market development, irrespective of its overall grain balance situation.

[17] The simulation results can also show that for the rich household, the effects of labor market development on hog production hinge upon the relative profitability between labor income and hog income. If hog production is more profitable, especially for those specialized hog producers with better production technologies, the simulation can show that a better labor market might induce an increase in labor hiring, and spur the specialization in hog production.

Indirect Effects of Market Development

Grain and labor market development also affects hog production indirectly. Economic development is often accompanied by a series of changes in other economic factors, including rising wage rates, continuous improvements in grain production technologies, increasing investment in hog production, and contraction in family size.[18] I investigate the impact of these factors on household hog production under the scenarios of perfect markets (i.e., no TCs), missing grain markets (very high TCs), missing labor markets, and both missing grain and labor markets (Table 2). The analysis suggests that the presence of imperfect markets makes household grain yields and family size relevant factors in hog production. For example, grain yield improvement has no impact on hog production under the perfect grain markets scenario. However, it has a significant and positive effect on hog production when grain markets are missing. Without grain markets, the only way a farmer can increase the amount of feed that can help him expand hog production is to grow it himself. Similarly, family labor endowment would have no effect when labor markets are perfect. When labor markets are missing, however, a contraction in household labor size could have a significantly negative effect on hog production.

Overall Effects of Market Development

The simulation exercise up to now only investigates how a change in a single economic factor would affect hog production, holding all other factors equal. Economic development, however, is more likely to be associated with simultaneous changes in many economic factors. To show this, we examine how hog output would change

[18] Based on the RCRE data, Appendix C summarizes how these economic factors change over the low-, medium-, and high-income subgroups.

following a simultaneous change in the following factors: a.) grain and labor transaction costs decrease at a rate of 0.05 *yuan* per period;[19] b.) grain yield increases at 2 percent per period;[20] c.) other capital inputs used in hog production increases by 10 percent per period;[21] d.) wage rate increases by 5 percent per period; and e.) the family labor endowment of the household decreases by 2 percent from its initial labor endowment (Figure 4).

Under the multi-dimensional, "economic development" scenario, hog production clearly displays an inverted U pattern over the entire simulation period. Hog production increases steadily from 158 kg in Period 1 to 240 kg in Period 8 (about 40 percent increase from Period 1). However, when the economy further evolves, hog production starts to contract. In Period 12, the farm household only produces 199 kg (about 10 percent decrease from Period 8). This magnitude of changes in hog production is largely consistent with the observed changes in average hog production across terciles in the RCRE households (second row from bottom, Appendix C). Sensitivity analysis shows that that this inverted-U relationship is robust to my assumption of the initial levels of grain and labor transaction costs, the growth rate in grain yield and any expansion in fixed assets in hog production (Appendix D, Scenarios 1, 2, 4 and 5). In contrast, if we

[19] The RCRE data do not provide direct information on grain and labor transaction costs and how they change over time. I assume that grain transaction costs are 30 percent of its market prices at the early stages of development (Period 1), because studies of farm household economy in other developing countries suggest that grain transaction costs can be as high as one-third of grain market price (Key, Sadoulet, and de Janvry, 2000).

[20] With the RCRE data, I use a regression approach to generate estimates of the growth rates of off-farm wage rates, grain yields and labor endowment. I find that rural wage rates and grain yield increase at the rates of 5 percent and 2 percent respectively, while the family size decreases by nearly 2 percent each year.

[21] Other capital inputs in hog production include expenses incurred to maintain and upgrade hog raising facilities and expenses in veterinary services. I assume that the capital inputs increases by 10 percent per period which is consistent with the observed increases in investment by Chinese farm household during this period by de Brawn (2000). In addition, I test the robustness of the results by either including or excluding this improvement in fixed assets.

assume that grain and labor markets are perfect without any transaction costs, simulation results show that hog production continues to decrease over the entire 12 periods, and the inverted-U relationship is not present (Appendix D, Scenario 3). These results indicate that grain and labor market development plays a pivotal role in the observed inverted-U relationship between hog production and economic development.

In summary, the simulation exercise creates the following hypotheses that can be tested in the econometric model:

> *Hypothesis 1*: In the case of poor, grain-deficit, the emergence of grain markets has a positive effect on hog production; its effect on richer, grain-surplus households is negative;
>
> *Hypothesis 2:* Labor market development increases the opportunity cost of farm labor and has a negative effect on the hog production of both poor and rich farmers; and
>
> *Hypothesis 3*: Increases in the off-farm wage rate and contractions in farm household size would make labor tighter when households are considering expanding hog production; however, improved grain production technologies would have a positive effect on household hog production. The theoretical model shown that these factors affect household hog production and supplement the forces of market emergence, contributing to the inverted-U relationship between development and hog production.

4. Empirical Model

In this section, I construct an econometric model to directly test these three hypotheses. If I can find evidence that the linkages between market emergence and hog production behave in a manner consistent with the three hypotheses, then we have a market emergence and maturation based explanation for the inverted U relationship between development (or income) and livestock production. To test the hypotheses, I first specify our econometric model and construct the variables. Next, I discuss the estimation strategy. Finally, after presenting the results, I use the coefficients to demonstrate that

grain and labor market development can explain a significant portion of rise and fall of China's backyard hog sector over the past two decades.

4.1. Basic Model and Variable Construction

The basic econometric model is:

$$Hog_{ijt} = \beta_1' M_{ij} + \beta_2' R_{ijt} + \beta_3' Z_{ijt} + u_{ijt} + \varepsilon_{ijt} \ . \qquad (4)$$

In equation (4) the dependent variable, Hog_{ijt}, is measured as the quantity of hog output in kilograms that is produced by household *i* in village *j* during year *t*. Three groups of factors are assumed to explain hog production, market development (M_{jt}), risk preferences (R_{ijt}) and other determinants (Z_{ijt}).

Our main variable of interest in equation (4), M_{jt}, measures the extent of market development, and it includes two indices, one representing grain market development and the other representing labor market development. To test the effects of labor market development on hog production, I use the share of non-agricultural labor in the village labor force as an indicator of labor market development. If β_1 is negative and significant, then as labor markets develop hog production falls, which is our test of hypothesis 2.

The grain market development index is included to test hypothesis 1. I utilize two approaches in the test. First, I use a set of variables that are related to grain transactions costs, including the distance to a major road, the value of the vehicles that are owned by the household and two dummy variables, which hold constant if the village is in a suburb of a city and if village is in a remote mountainous region. The matrix of variables that measure the transactions costs associated with grain markets are henceforth referred to as *grain market indicator 1*. Alternatively, I can use the percentage of the village grain output sold in the market, a measure of grain commercialization rates. This variable

henceforth is referred to as *grain market indicator 2*. In my subsequent analysis, I test for the validity of hypothesis 1 by examining if β_1 is positive for low-income households and negative for high-income households.

There are advantages and disadvantages associated with both indicators. Many empirical studies use grain market indicator 1 to measure transactions costs and market development (Key, Sadoulet, de Janvry, 2000; Goetz, 1992; Wik, Taylor, and Holden, 2000). This set of indicators has the virtue of being exogenous in a conceptual sense and directly associated with grain transaction costs. However, these variables may not capture all aspects of local market performance or pick up all of the costs associated with grain transactions. In other words, these variables might underestimate grain market development.

On the other hand, grain commercialization rates can proxy for the level of grain market development, or grain market indicator 2. Based on a similar logic in specifying the measure of labor market development (the other variable of interest), the literature provides evidence suggesting that agricultural commercialization rates are linked to the level of market development and may be a good proxy (Ahmed, 1994; Von Braun, 1994). The strength of using grain commercialization rates is that, unlike grain market indicator 1, it may be able to capture a broader set of transactions costs and other factors that make up market development. The weakness of using grain commercialization rates, however, lies in the fact that grain commercialization rates can be endogenous. Specifically, it may be that grain commercialization rates are affected by unobserved factors that affect both grain sales and hog production. If so, then the coefficient of the grain commercialization rate, β_1, could be biased due to endogeneity. To address this issue, I need to use

statistical methods to control for the endogeneity. Because no one indicator is without limitations, in the empirical analysis, I use both indicators to test the effects of grain market development on hog production.

I also include several other variables in the estimation model to test Hypothesis 3 and help isolate the effects of market development on hog output. The household wealth level is used to capture farm household risk preferences, R_{ijt}, although I recognize that wealth also is associated with other, sometimes offsetting, determinants, such as changes in liquidity and preferences for cleanliness. Other economic factors included in Z_{ijt} that might affect hog production consist of wage rates, farm household size, grain yields, hog and grain prices, the farm household education level, and the share of industrial revenue in the total village revenue.[22] The first component of the error term, u_{ijt}, captures other unobserved household and village characteristics that may affect the household's hog production decision-making process. It is possible that u_{ijt} may be correlated with the market indicator variables. The second component of the error terms, ε_{ij}, is uncorrelated shocks to hog production.

4.2. Estimation Strategies

4.2.1.Tobit Model

Because a farm household either produces a positive number of hogs or no hogs, the dependent variable, hog output per farm, is truncated at zero. A tobit model is suitable for the empirical estimation and can be specified as:[23]

[22] The wage rates and grain yield are computed at the village level. Village grain yield is computed as the ratio of aggregate village grain output to sown areas in the village.

[23] However, if we believe that the factors determining whether a farm household would raise hogs are different from factors affecting the number of hogs to raise, the Heckman Selection Model might be preferred. In this study, I cannot find obvious factors that affect one but not the other.

$$
\begin{aligned}
y_{ijt} &= x_{ijt}\beta + \varepsilon_{ijt} \quad if\ x_{ijt}\beta + \varepsilon_{ijt} > 0; \\
&= 0 \qquad\qquad if\ x_{ijt}\beta + \varepsilon_{ijt} \leq 0; \\
where\quad y_{ijt} &= Hog_{ijt}\ and\ x_{ijt} = [M_{ijt}, R_{ijt}, OD_{ijt}, u_{ijt}]
\end{aligned} \tag{5}
$$

ε_{ijt} is an independently distributed error term and assumed to be normal with zero mean and constant variance σ^2. Thus, the model assumes that there is an underlying stochastic index equal to $(x_{ijt}\beta+u_{ijt})$, which is observed only when it is positive.[24] The marginal effects of a change in x_{ijt} on y_{ijt} (the censored dependent variable) and y_{ijt}^* (the observations above censoring points) are not equal to β_I, instead they are equal to:

$$\partial E[y_{ijt}^*]/\partial x_i = \beta_i[1 - zf(z)/F(z) - f(z)^2/F(z)^2] \tag{6}$$

$$\partial E[y_{ijt}]/\partial x_{ijt} = F(z)\beta_i \tag{7}$$

4.2.2. Unobserved Effects

To answer how the differences in grain and labor market development, both across villages and over time, would contribute to the different levels of hog production, I choose to mainly rely on a tobit random effects model.[25] The consistency of the random effects model, however, requires that unobservable household and village characteristics

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[24] Tobin further shows that the expected value of y in the model is $Ey = x\beta F(z) + \sigma f(z)$,where z=xb/s, f(z) is the unit normal density, and F(z) is the cumulative normal distribution function. The expected value of y for observations above the limit (y*) is:

$$
\begin{aligned}
Ey^* &= E(y \mid y > 0) \\
&= E(y \mid u > -x\beta) \\
&= x\beta + \sigma f(z)/F(z)
\end{aligned}
$$

Thus, the relationship between the expected value of all observations, Ey, and the expected value conditional upon being above the limit, Ey*, is $Ey = F(z)Ey^*$.

[25] Because a fixed effect model is essentially a within-groups estimator, it does not capture the effects across households and villages. A fixed effects model depends solely on the deviations of the dependent variables and explanatory variables from their respective group (farm household in this study) means, and it makes no use of the fact that the group means are in general different for different groups (Davidson and

(u^{ijt} that could also affect hog production) be uncorrelated with other explanatory variables in the estimation equation. This requirement might not hold. For example, as mentioned above, grain commercialization rate, as the indicator for grain market development, might be endogenous, thereby causing bias.

Our main strategy to try to control for the covariance between the residual in Equation 4 and the grain market development is to use an instrumental variable approach. In the estimation, I assume that grain quotas and transactions costs affect the endogenous variable (grain market development) but does not affect the outcome variable, (hog production), except through the effects of market development. The logic of this strategy relies on the exogeneity of national grain quota policy. As long as officials assign quotas to villages without consideration of their status as a livestock producer, and if the size of the quota in an economy like China could affect the development of the local grain market, I should have a valid instrument. The same logic is used for transactions costs.

I also used several other approaches to correct fixed effects and minimize the possible endogeneity bias. First, I use Honre's fixed effect tobit model to demonstrate how results might change using a fixed effects model. While such a model would account for all non-time varying fixed effects, according to Deaton (1997), it is possible that the presence of measurement error could offset the gains from the reduction of the bias that would come from eliminating the fixed effects. Second, in my empirical models, I lag most of the explanatory variables to minimize the contemporary correlation between u^{ijt} and explanatory variables.[26] Finally, I generate many explanatory variables

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Mackinnon, 1993). Thus, the differences across different households and villages are entirely ignored in the estimation.

[26] The unobserved household effects at one period are generally thought to be uncorrelated to explanatory variables in the previous period.

from village-level surveys instead of household-level surveys. For example, grain yields, wage rates and grain and hog prices are all based on data from the village-level surveys. This has two benefits in controlling the covariance between the error term and explanatory variables. Since the data for the left and right hand side variables come from different survey instruments, there is less reason to believe there are correlated errors from the data collection process. In addition, using explanatory variables constructed from village level data eliminate the presence of unobserved household effects. In summary, after specifying my variables in this manner, I assume the I have accounted for most of the unobserved heterogeneity and so the empirical analysis will rely mainly on the random effects tobit model. Since it is difficult to control for all unobserved heterogeneity, however, I supplement the analysis with IV and fixed effects estimators.

While controlling for potential econometric problems, I proceed with my tests of the three hypotheses. First, I begin my test of Hypothesis 3 by running the regressions with a random effects tobit model using the *entire* sample observations. I am particularly interested in examining the coefficients on the grain yield, family size and wage variables. According to the theory, these variables may reinforce the expansion and contraction of hog production as an economy develops from underdeveloped stage to more developed stage. I test the robustness of the results by including different control variables and using different grain market indicators. I also use these coefficients in the later decomposition exercise.

Next, I begin to directly test the market emergence hypotheses. According to the data and theory, market development could have different effects on hog production as the economy develops (or as household incomes increase). Consequently, I divide the

sample into three income terciles (or low-, medium-, and high-income subgroups). Using these subsets of data, I conduct separate regression analyses and test different parts of the hypothesis. For example, I use the lower income subgroup to test whether or not backyard livestock production rises as grain markets emerges (first part of Hypothesis 1). I then use the higher income subgroup to test whether or not grain market development (second part of Hypothesis 1) and labor market development (Hypothesis 2) lead to falling hog production.

4.3. Estimation Results

Almost all the models analyzing the effects of labor and grain market development on household hog production perform well and produce robust results that largely confirm our hypotheses. Many coefficients of the control variables are of expected sign and statistically significant. For example, an increase in wealth is associated with a decrease in hog production for all income subgroups (Tables 3.4 and 3.5), indicating that an improvement in wealth may be enhancing household's tolerance of risk.

The estimation results are also consistent with Hypothesis 3. I find that family size, grain yields, and wage rates all have separately significant effects on hog production. The F-test on the joint significance of these variables is also significant. The effects from these factors are also robust whether I use the entire sample (Table 3), use different indicators to measure grain market development, or divide the sample into three income subgroups (Tables 3.4 and 3.5). For example, family size has a significant and positive effect on hog production; one fewer family member results in a decrease of as much as 11 kg in hog output (about 11 percent, row 8, Table 4). Similarly, grain yields

are shown to have a positive effect on hog production for all three income subgroups. Finally, an increase in wage rates, a proxy for rising opportunity costs for farm household labor, has a negative effect on hog production. All of these are consistent with predictions from the theoretical model. In the next subsection, I show how these factors supplement the effects of labor and grain market development and contribute to rise and fall in hog production.

Although effects of grain market development is not significant when entire sample is used, it is not surprising since the theoretical model predicts different effects in different types of households. The estimation results from separate regressions that use the income-based sub-sample, however, confirm hypothesis 1. Using grain market indicator 1 (or transactions costs to measure grain market development), I find that for poor farm households in the low-income subgroup, a decrease in transactions costs would have a significant positive effect on hog production. For each kilometer closer to a paved road, the household would increase hog production by 3.06 kg, or 4.4 percent (row 2, Table 4). The opposite effects, however, are found for high-income households. One kilometer closer to a paved road reduces hog production by 2.24 kg, or 2.5 percent.

The estimation results using split samples also show that labor market development has a consistent negative effect on hog production, which provides support for Hypothesis 2. A one-percent increase in village labor employment in nonagricultural activities is associated with a decrease of hog production ranging from 0.21 kg to 0.51 kg for farm households in different income groups (row 5, Table 4). Given the fact that, for some villages, the participation in off-farm labor markets by the village labor force

increased by more than 20 percent over the study period, labor market development can have a significant effect on hog production.

The effects of grain market development are robust to the choice of grain market indicators (Table 5). Using grain commercialization rates to measure grain market development (although without fully control for endogeneity), I find that an increase in grain commercialization rate positively affects hog production for households in the low-income tercile but negatively affects for households in the high-income tercile. These results are consistent with my expectation, because for farm households in the low-income tercile, which are more likely to be constrained in grain and feed supply, an improvement in the grain market would improve their access to feed grain and thus encourage hog production. For farm households in the high-income tercile, which are more likely to be grain-surplus and at the same times have more off-farm opportunities, an improvement in grain market would likely lead to an increase in direct grain sales in the market and a reduction in grain fed to hogs.

The possible endogeneity problem in the estimation of the model does not seem to cause a concern (Tables 3.6, 3.7, and 3.8). To address the potential endogeneity problem, as discussed above, I use both an instrumental variable approach and a fixed effects approach. When using the grain commercialization rate to measure grain market development, I use the government grain quota and several variables associated with grain transactions costs as the instruments for grain commercialization rate. I find that grain market development continues to display similar effects on hog production for households in different income terciles. A higher grain commercialization rate leads to expansion of hog production for the low-income households, but its effects on high-

income households are negative. Also, labor market development continues to show a negative effect on hog production for households in different income subgroups.

Alternatively, I use a fixed effects model to control for endogeneity caused by non-time varying fixed effects and find that results are mostly consistent. Because the censoring nature of my dependent variable, I use Honre's fixed effects tobit model (Tables 3.7 and 3.8). Grain market development continues to show a positive effect on hog production for households in the low-income subgroup and a negative effect for the high income subgroup. The effects of labor market development are also negative. Although the t-ratios on the labor market variable are relatively low, it is not altogether unexpected. This might be due to the significant efficiency loss associated with the fixed effects model (Deaton, 1997). It is posited that the presence of measurement error could significantly offset the gains from the reduction of the bias that would come from eliminating the fixed effects. Taking all the regression results together, I believe that I have fairly strong evidence supporting that market development contributes to the observed inverted-U relationship between income and hog production.

4.4. Market Development and Rise and Fall in Hog Production

During the past two decades, backyard hog production has decreased significantly in rich, inland areas, but in the meantime, we observe a significant expansion in poor, inland areas. The following decomposition exercise indicates that labor and grain market development can help explain a significant portion of the observed pattern in hog production from 1986 to 1996 in China. In this analysis, I chose two sets of provinces: Henan and Jiangsu provinces north of the Yangtse river, henceforth North China, and

Guizhou and Guangdong provinces in South China.[27] I compare the simulated changes (predicted using the coefficients in the results times the observed change in the hog production determinants, i.e., the RHS variables in the hog production model in Table 4) with the "actual" changes in hog production reported in published sources. Specifically, I simulate how a representative farm household in one of these provinces would change its hog output from 1986 to 1996 based on the observed changes in various determinants.

During the sample period from 1986 to 1996, the average Jiangsu farm household decreased its hog output by 40 kg (bottom row, Table 9). The expansion of grain and labor markets in Jiangsu, for example, led to a fall in hog production of about 10.51 kg, accounting for about 25 percent of the decline (sum of rows 1 to 4), while rising wage rates and smaller farm household size account for about 17 percent and 4 percent respectively (rows 5 and 6). While the direct effects of labor market development (about 4 percent) might seem small, the better labor markets enable farm households to access off-farm job markets and take advantage of rising off-farm wage rates. Therefore, if we include both direct and indirect effects, labor market development can explain more than 20 percent of decrease in average household hog production from 1986 to 1996.

For Henan province, however, the simulation results show that more than half (52 percent, row 11) of the total increase in hog production in Henan province between 1986 and 1996 (about 31 kilograms per household, row 8) can be explained by the combined effects of changes in markets, risk, the opportunity costs of resources, and other factors (Table 8). Among these factors, grain market development (rows 1 and 3) can account for 32 percent of the increase in hog production, but this positive impact is offset by the

[27] Henan and Guizhou are two poor, inland provinces experiencing a significant increase in household hog production in the past two decades, while Jiangsu and Guangdong are two rich, coastal provinces showing

negative effect from labor market development. Similarly, I find that the development of grain and labor markets can also explain a significant portion of the rise and fall of backyard hog production in Guizhou and Guangdong (Appendix E).

5. Summary of Findings and Future Research

In this paper, I use backyard hog production in China as a case study to explain the linkage between market emergence and patterns of backyard hog production in China. The results indicate that rural market development, especially labor and grain market development, could have significant, but different effects on household hog production for households at the different levels of economic development. While it is true that market development might foster contraction in hog production in rich, coastal areas, market development might also lead to expansion in hog production in poor inland areas.

This study has its limitations. As shown in the decomposition analysis, the regression equation can only explain about half of the observed rise in hog production in poor provinces. This can be due to several reasons. First, the level of grain market development might be underestimated when it is only measured by variables associated with transactions costs. Second, over the past two decades, we also observe significant improvements in livestock output markets. In recent years, livestock products produced in the inland regions are not only sold in the local markets, but also in the distant markets (including markets in the coastal areas). In other words, the livestock output markets are more integrated in recent years than the beginning period of the economic reform in the 1980s. Unfortunately, this information is not available in the RCRE data. Finally, improvements in hog production technologies, including better hog varieties and more

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a decrease in backyard hog production over the study period.

effective and available veterinary services, might also contribute to increases in hog production in the inland region. Again, this information is not available in the RCRE data. Nevertheless, if we take these additional factors into consideration, it is likely that the increased supply from inland region more than compensates for the fall in supply in the coastal region. In fact, the competition from supply from inland areas might have driven some of the commercialized livestock operations in the coastal areas out of business in the late 1990s.

The results from study could benefit the policy makers in the livestock sector in several ways. First, when making livestock policies, decision makers should pay more attention to the backyard livestock sub-sector as well as its relationship with labor and grain market conditions. Second, this study provides a foundation on which we can project how backyard hog production might evolve in the future. Based on the estimates derived in this study, we can assist policy makers to make better use of limited government funds and help prevent investment losses.

Table 1. Labor and Grain Market Development

Income Group	Year	Hog Output Per Household (kg)	Share of Non-Agricultural Labor in Village Labor (%)	Percentage of Grain Sold In the Market (%)	Value of Transportation Assets (100 1986 *yuan*)	Terrain condition: 1-plain; 2-hilly;3-mountainous
Low income	average	70	26	24	1.38	2.05
Medium Income	average	98	32	28	2.32	1.71
High Income	average	91	40	29	5.96	1.53
Low income	86	63	20	14	0.9	2.15
Low income	90	70	22	24	1.2	1.9
Low income	95	71	33	22	1.56	2.08
Low income	98	76	32	30	3.14	2.24
Medium Income	86	93	30	24	1.43	1.51
Medium Income	90	109	26	25	1.61	1.78
Medium Income	95	110	36	21	3.48	1.95
Medium Income	98	96	32	35	1.69	1.77
High Income	86	76	36	28	3.54	1.33
High Income	90	114	37	23	4.27	1.49
High Income	95	73	39	29	5.99	1.57
High Income	98	84	45	34	4.99	1.64

Source: The Household Survey Data Conducted by Research Center of Rural Economy, Ministry of Agriculture, China, 1986-1999

Table 2. Effects of Some Economic Factors on Hog Production Under Different Market Conditions

Period	1	2	3	4	5	6	7	8	9	10	11	12
1. Wage Rate: wage rates increase by 2.5 percent per period												
Wage Rates	2.00	2.05	2.10	2.15	2.20	2.25	2.30	2.35	2.40	2.45	2.50	2.55
Perfect Market	100	90	81	73	66	61	55	51	47	43	40	37
Missing Grain Market Only	35	29	24	22	20	18	16	15	14	13	12	11
Missing Labor Market Only												
Missing Both Labor and Grain Market												
2. Grain Yield: grain yield increases by 5% per period												
Grain Production Shifter												
Perfect Market	100	100	100	100	100	100	100	100	100	100	100	100
Missing Grain Market Only	35	43	52	63	76	90	107	126	147	171	196	223
Missing Labor Market Only	291	264	237	212	189	167	147	129	113	98	85	74
Missing Both Labor and Grain Market	149	162	175	187	199	212	224	236	247	259	271	283
3. Credit: fixed assets used in hog production increases by 50 Yuan per period												
Capital Used in Hog production	100	150	200	250	300	350	400	450	500	550	600	650
Perfect Market	100	150	200	250	300	350	400	450	500	550	600	650
Missing Grain Market Only	35	52	68	84	100	115	130	145	160	174	188	202
Missing Labor Market Only	291	363	419	466	505	540	571	599	624	648	670	690
Missing Both Labor and Grain Market	149	162	171	179	186	192	197	202	206	210	214	217
4. Labor Endowment: household labor endowment decreases by 200 labor-hour per period												
Labor Endowment (hours)	3700	3500	3300	3100	2900	2700	2500	2300	2100	1900	1700	1500
Perfect Market	100	100	100	100	100	100	100	100	100	100	100	100
Missing Grain Market Only	35	35	35	35	35	35	35	35	35	35	35	35
Missing Labor Market Only	311	302	293	284	275	266	257	248	239	229	220	210
Missing Both Labor and Grain Market	223	214	204	194	184	174	163	152	141	130	118	106
5. Hog Price: hog price increases by 10 percent per period												
Hog Prices	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5
Perfect Market	100	146	207	286	384	506	655	835	1050	1303	1600	1945
Missing Grain Market Only	35	50	70	94	122	154	195	248	312	387	476	578
Missing Labor Market Only	291	342	387	426	459	487	512	533	552	569	584	598
Missing Both Labor and Grain Market	149	149	149	149	149	149	175	205	234	263	291	318
6. Grain Price: grain price increases by 2.5 percent per period												
Grain Prices	2.00	2.05	2.10	2.15	2.20	2.25	2.30	2.35	2.40	2.45	2.50	2.55
Perfect Market	100	92	85	78	73	68	63	59	56	52	49	46
Missing Grain Market Only												
Missing Labor Market Only	291	265	240	216	195	175	157	141	126	113	101	91
Missing Both Labor and Grain Market												

Table 3. Estimates From Tobit Model Using Whole Sample Observations, The RCRE Data, 1986-1999

		Random Effects Tobit Model			
	Variable Explanations	Model 1	Model 2	Model 3	Model 4
Grain Market Development Indicator 2	Grain Commercialization Rate	-0.701	-0.675		
		[4.7]***	[4.58]***		
Grain Market Development Indicator 1	Distance to the Major Roads from the Village (km)			0.62	0.421
				[0.65]	[0.44]
	Value of Transportation Facilities, (100 Yuan (1986), lagged one year)			-0.988	-1.018
				[5.19]***	[5.35]***
	City Suburb (1:yes; 0: no)			-31.781	-27.176
				[2.56]**	[2.18]**
	Terrain (1: Plain; 2: Hilly; and 3: Mountainous)			19.144	20.236
				[3.41]***	[3.69]***
Labor Market Development Indicator	Share of Non-agricultural Labor force in the Village, (lagged one year)	-0.023	0.204	0.191	0.267
		[0.1]	[1.26]	[1.02]	[1.61]
Risk					
	Household Wealth Level (100 Yuan (1986), lagged one year)	-0.373	-0.366	-0.232	-0.216
Other Determinants		[7.1]***	[6.93]***	[4.33]***	[4.06]***
	Village Wage Rates	-4.522	-5.618	-4.195	-5.104
		[3.5]***	[4.50]***	[3.21]***	[4.05]***
	Household Size (lagged one year)	10.557	12.425	11.091	13.251
		[5.8]***	[6.78]***	[5.90]***	[7.16]***
	Village Grain Yield	0.173	0.161	0.172	0.17
		[8.8]***	[8.19]***	[8.55]***	[8.48]***
	Village Hog Price (lagged one year)	0.83	0.976	-0.447	-0.453
		[0.3]	[0.32]	[0.15]	[0.15]
	Village Grain Price (lagged one year)	-19.693	-18.054	23.985	29.858
		[1.0]	[0.93]	[1.81]*	[2.28]**
	Education Level	-0.056		-0.092	
		[0.7]		[1.10]	
	Share of Industrial Income in the Total Village Income	0.291		0.129	
		[1.7]*		[0.76]	
	Relative Economic Development Status Within the County: 1: high; 2: medium-high; 3: average; 4: medium low: and 5: low	8.616		5.536	
		[2.7]***		[1.67]*	
Constant		-44.47	-30.711	-115.825	-119.757
		[2.2]**	[1.73]*	[5.59]***	[5.94]***
Number of Observations		6114	6243	6114	6243
Number of Households		936	944	936	944

Table 4. Regression Estimates From Random Effects Tobit Model For Different Income Groups Using Grain Market Indicator 1

		Regression Coefficients				Marginal Effects			
Dependent Variable: Pork Output		Whole Sample	Low Income	Medium Income	High Income	Whole Sample	Low Income	Medium Income	High Income
1. Market Development									
Grain Market Development Indicator	Distance to Major Roads from the Village	0.62	-4.781	0.102	4.195	0.39	-3.06	0.16	2.24
		[0.6]	[3.03]***	[0.07]	[2.12]**				
	Value of Transportation Facilities (100 1986 *yuan*)	-0.988	-0.163	-0.792	-1.642	-0.54	-0.10	-0.49	-0.82
		[5.2]***	[0.50]	[2.08]**	[4.03]***				
	City Suburb (1:yes; 0:no)	-31.781	52.913	1.623	-61.871	-17.94	37.01	1.13	-29.16
		[2.6]**	[2.38]**	[0.08]	[2.58]**				
	Terrain Condition:(1:Plain; 2:Hilly; and 3:Mountainous)	19.144	6.185	23.638	56.975	11.49	2.53	14.86	28.80
		[3.4]***	[1.15]	[3.47]***	[6.09]***				
Labor Market Development Indicator	Share of Non-Agricultural Labor in Village Labor Force (lagged one year)	0.191	-0.77	-0.454	-0.778	0.21	-0.51	-0.41	-0.21
		[1.0]	[2.77]***	[1.55]	[2.17]**				
2. Risk	Household Wealth Level (lagged one year)	-0.232	-0.127	-0.433	-0.247	-0.14	-0.09	-0.27	-0.14
		[4.3]***	[1.05]	[3.43]***	[3.29]***				
3. Other Determinants									
	Wage Rates	-4.195	-2.835	-9.428	-6.95	-2.48	-1.51	-5.60	-3.54
		[3.2]***	[1.42]	[4.16]***	[2.84]***				
	Household Size (lagged one year)	11.091	12.955	18.012	16.677	6.29	7.91	11.07	8.43
		[5.9]***	[5.62]***	[6.00]***	[4.25]***				
	Village Grain Yield	0.172	0.164	0.257	0.224	0.09	0.10	0.16	0.10
		[8.5]***	[6.77]***	[9.48]***	[6.14]***				
	Relative Economic Development Status Within the County: (from1-high to 5-low)	5.536	7.179	0.587	18.186	3.13	5.15	1.26	7.55
		[1.7]*	[1.75]*	[0.11]	[2.59]**				
	Village Grain Price (lagged one year)	23.985	21.47	30.431	-0.051	-5.87	-34.34	-2.66	-64.81
		[1.8]*	[1.66]*	[1.26]	[0.00]				
	Village Hog Price (lagged one year)	-0.447	0.62	0.354	3.63	-0.39	0.41	0.24	2.72
		[0.1]	[0.15]	[0.07]	[0.60]				
	Share of Family Labor with more than junior high education	-0.092	0.18	0.012	-0.788	-0.06	0.10	0.01	-0.38
		[1.1]	[1.77]*	[0.10]	[4.91]**				
	Village data: share of industrial income in total village income	0.129	-0.125	-0.184	1.291	0.06	-0.02	-0.04	0.55
		[0.8]	[0.51]	[0.64]	[3.98]***				
Constant		-115.825	-87.963	-114.848	-198.596				
		[5.6]***	[3.40]***	[3.52]***	[4.87]***				
Observations		6114	1942	2071	2101				
Number of households		936	570	688	628				

Table 5. Regression Estimates From Random Effects Tobit Model For Different Income Groups Using Grain Market Indicator 2

		Regression Coefficient				Marginal Effects			
	Variable	Whole Sample	Low Income	Medium Income	High Income	Whole Sample	Low Income	Medium Income	High Income
1. Market Development									
Grain Market Development Indicator	Grain Commercialization Rate	-0.701	0.265	-0.82	-1.74	-0.39	0.16	-0.51	-0.88
		[4.7]***	[1.55]	[3.64]***	[5.76]***				
Labor Market Development Indicator	Share of Non-agric. Labor in the Village Labor Force (lagged one year)	-0.023	-0.734	-0.588	-1.303	-0.01	-0.45	-0.36	-0.66
		[0.1]	[2.74]**	[1.99]**	[3.58]***				
2. Risk, Credit, and Changing Preference	Household Wealth Level (lagged one year)	-0.373	-0.134	-0.601	-0.376	-0.21	-0.08	-0.37	-0.19
		[7.1]***	[1.22]	[5.21]***	[4.78]***				
3. Other Determinants									
	Wage Rates	-4.522	-2.497	-9.67	-8.272	-2.54	-1.53	-5.96	-4.20
		[3.5]***	[1.26]	[4.30]***	[3.35]***				
	Family Size (lagged one year)	10.557	11.929	17.64	12.554	5.93	7.30	10.87	6.37
		[5.8]***	[5.29]***	[5.91]***	[3.14]***				
	Village Grain Yield	0.173	0.133	0.231	0.206	0.10	0.08	0.14	0.10
		[8.8]***	[5.81]***	[8.64]***	[5.86]***				
	Village Hog Price (lagged one year)	0.83	-0.114	0.186	8.304	0.47	-0.07	0.11	4.21
		[0.3]	[0.03]	[0.04]	[1.37]				
	Village Grain Price (lagged one year)	-19.693	-55.388	-5.705	-97.17	-11.07	-33.89	-3.52	-49.31
		[1.0]	[2.43]**	[0.18]	[2.25]**				
	Education Level	-0.056	0.117	0.025	-0.781	-0.03	0.07	0.02	-0.40
		[0.7]	[1.17]	[0.20]	[4.84]***				
	Share of Village Industrial Income in the Total Village Income)	0.291	-0.053	-0.08	1.326	0.16	-0.03	-0.05	0.67
		[1.7]*	[0.23]	[0.28]	[4.05]***				
	Relative Economic Development Level (from Low-5 to High-1)	8.616	9.349	2.85	23.804	4.84	5.72	1.76	12.08
		[2.7]***	[2.35]**	[0.55]	[3.48]***				
Constant		-44.47	-45.116	-18.098	14.115				
		[2.2]**	[1.83]*	[0.55]	[0.34]				
Observations		6114	1942	2071	2101				
Number of Households		936	570	688	628				

Table 6. Regression Estimates From Tobit Random Effects Instrumental Variable Model Using Grain Market Indicator 2

	Low Income	Medium Income	High Income
Grain Commercialization Rate (with IV)	0.28	1.371	-1.716
	[3.01]***	[1.54]	[1.67]*
Share of Non-agricultural Labor in Village Labor Force (lagged one year)	-0.7	-0.565	-0.896
	[2.55]**	[1.88]*	[1.58]
Household Wealth Level (lagged one year)	-0.072	-0.531	-0.318
	[0.64]	[4.26]***	[3.10]***
Village Wage Rate	-0.626	-9.279	-18.044
	[0.32]	[3.96]***	[4.55]***
Household Size (lagged one year)	12.318	17.193	9.422
	[5.25]***	[5.63]***	[1.59]
Village Unit Grain Yield	0.153	0.242	0.173
	[6.28]***	[9.03]***	[3.05]***
Village Hog Price (lagged one year)	-5.294	-5.268	26.577
	[1.45]	[1.27]	[2.81]***
Village Grain Price (lagged one year)	-50.271	-7.252	-160.982
	[2.16]**	[0.23]	[2.63]**
Education Level	0.167	-0.017	-1.017
	[1.64]*	[0.13]	[4.44]**
Share of Industrial Income in Total Village Income	-0.15	-0.011	1.755
	[0.66]	[0.04]	[3.74]***
Relative Economic Development Level (from Low-5 to High-1)	7.835	5.365	16.328
	[1.95]*	[1.03]	[1.54]
Constant	-59.813	-151.308	64.587
	[2.24]**	[1.89]*	[0.94]
Observations	1935	2059	1035
Number of Households	569	679	423

Table 7. Estimates From Using Honre's Fixed Effects Tobit Model and Grain Market Development Indicator 1

		Low Income	Medium Income	High Income
Dependent Variable: Pork Output	**Variable Descriptions**			
1. Market Development				
Grain Market Development Indicator 2	Grain Commercialization Rate (lagged one year)			
Grain Market Development Indicator 1	Distance to the Major Roads from the Village	-3.31	0.75	0.15
		[2.37]**	[0.51]	[0.05]
	Value of Transportation Facilities (100 1986 *yuan*, lagged one year)	0.44	-1.84	-3.28
		[1.04]	[4.41]***	[2.37]**
	City suburb (1:yes; 0:no)	63.10	55.14	-6.11
		[1.55]	[2.38]**	[0.13]
	Terrain Condition (1:plain; 2: Hilly; and 3:mountainous)	-21.58	54.51	176.50
		[2.04]**	[2.66]**	[1.32]
Labor Market Development Indicator	Share of Non-agricultural	-0.31	-0.12	-0.54
		[1.31]	[0.46]	[1.08]
2. Risk	Household Wealth Level (lagged one year)	0.08	-0.42	-0.16
		[0.26]	[2.01]**	[2.16]**
3. Other Determinants	Wage Rates	5.46	-1.90	-2.38
		[1.73]	[0.45]	[0.53]
	Household Size (lagged one year)	1.64	6.50	-7.40
		[0.55]	[1.20]	[0.67]
	Village Grain Yield	0.06	0.10	-0.37
		[1.07]	[1.60]	[2.94]**
	Village Hog Price (lagged one year)	-3.50	-3.99	16.95
		[0.69]	[0.94]	[1.32]
	Village Grain Price (lagged one year)	-62.98	72.21	-48.63
		[2.04]**	[1.74]*	[0.57]
	Education Level	-0.05	0.06	-0.91
		[0.30]	[0.23]	[2.47]
	Share of Industrial Income in the Total Village Income	0.10	0.77	2.22
		[0.55]	[1.73]*	[2.45]
	Relative Economic Development Status Within the County (from low-1 to high-5)	-5.75	-7.87	-9.30
		[0.83]	[0.80]	[0.63]
Observations		1942	2071	2101

Table 8. Estimates From Using Honre's Fixed Effects Tobit Model and Grain Market Development Indicator 2

Dependent Variable: Pork Output	Variable Descriptions	Low Income	Medium Income	High Income
1. Market Development				
Grain Market Development Indicator 2	Grain Commercialization Rate (lagged one year)	0.80	-0.13	-0.88
		[4.80]***	[0.38]	[1.73]*
Labor Market Development Indicator	Share of Non-agricultural Labor	-0.33	-0.08	-0.36
		[1.42]	[0.29]	[0.72]
2. Risk	Household Wealth Level (lagged one year)	0.27	-0.66	-0.18
		[0.96]	[2.13]**	[2.12]**
3. Other Determinants	Wage Rates	6.44	-1.92	0.41
		[2.08]**	[0.45]	[0.10]
	Household Size (lagged one year)	0.98	6.44	-8.32
		[0.32]	[1.10]	[0.65]
	Village Grain Yield	0.02	0.11	-0.36
		[0.32]	[1.72]*	[2.57]**
	Village Hog Price (lagged one year)	-5.45	-4.41	18.79
		[1.08]	[0.98]	[1.45]
	Village Grain Price (lagged one year)	-33.68	50.65	-38.06
		[1.35]	[1.30]	[0.43]
	Education Level	-0.09	0.05	-0.93
		[0.52]	[0.21]	[2.45]**
	Share of Industrial Income in the Total Village Income	-0.21	0.85	2.49
		[1.17]	[1.85]*	[2.55]**
	Relative Economic Development Status Within the County (from low-1 to high-5)	-3.77	-0.90	-1.88
		[0.56]	[0.09]	[0.13]
Observations		1942	2071	2101

Table 9. Changes in Per Farm Household Hog Production in Hennan and Jiangsu Provinces, China (1986 vs. 1996)

		Henan				Jiangsu			
		marginal effect (column 8 in Table 4)	change in explanatory variable	change in hog production (percent)	change in hog production in percentage	marginal Effect (Column 10 in Table 4)	change in explanatory variable	change in hog production (percent)	change in hog production in percentage
Grain Market Development									
	Distance to Major Roads from the village (km) [a]	-3.06	-2.00	6.12	20%	2.24	-2.00	-4.48	11%
	Transportation Assets (100 1986 Yuan)	-0.1	0.8	-0.08	0%	-0.82	2	-1.64	4%
	City Surburb?	37.01	0.1	3.70	12%	-29.16	0.1	-2.92	7%
Labor Market Development									
	Share of non-agric. Labor force [b]	-0.51	12.00	-6.12	-20%	-0.21	7.00	-1.47	4%
Wage Rate[c]		-1.51	-0.60	0.90	3%	-3.54	1.90	-6.74	17%
Farm Household Size[d]		7.91	-0.66	-5.22	-17%	8.43	-0.20	-1.68	4%
Village Grain Productivity[e]		0.1	116.47	11.65	38%	0.1	66.20	6.62	-17%
Other Economic Factors				5.28	17%			-22.11	55%
Changes explained by above factors				**12.60**	**52%**			**-29.87**	**86%**
Residuals				**18.30**	**48%**			**-10.13**	**14%**
Total Change in Hog Output (1996-1986)				**30.90**	**100%**			**-40.00**	**100%**

[a] The distance to major road decreases by 2km (based on the RCRE data), and transportation assets increase by 80 Yuan in Guizhou and Henan and by 200 Yuan in Jiangsu and Guangdong (based on the summary information on the RCRE) in all provinces over the study period I also assume a change of 0.1 in the dummy variable, whether the village is city suburb or not, to account for the fairly rapid urbanization movement occurred in the study period.

[b] The level of labor market development is measured by the percentage of farm labor working in nonagricultural sector. The data are from China Statistical Yearbook, 1987 and 1997.

[c] Wage rates are based on wage rates in agricultural sectors reported in China Statistical Yearbook, 1987 and 1997. Wage rates for Inland region is adjusted downward to reflected the fact that the real wage rates in the inland provinces decrease during the study period (Xiao-Yuan Dong, Linxiu Zhang, and Amelia Hughart, 2002).

[d] Data for family size are computed as the ratio of provincial population to the number of households from China Statisitical Yearbook, 1987 and 1997.

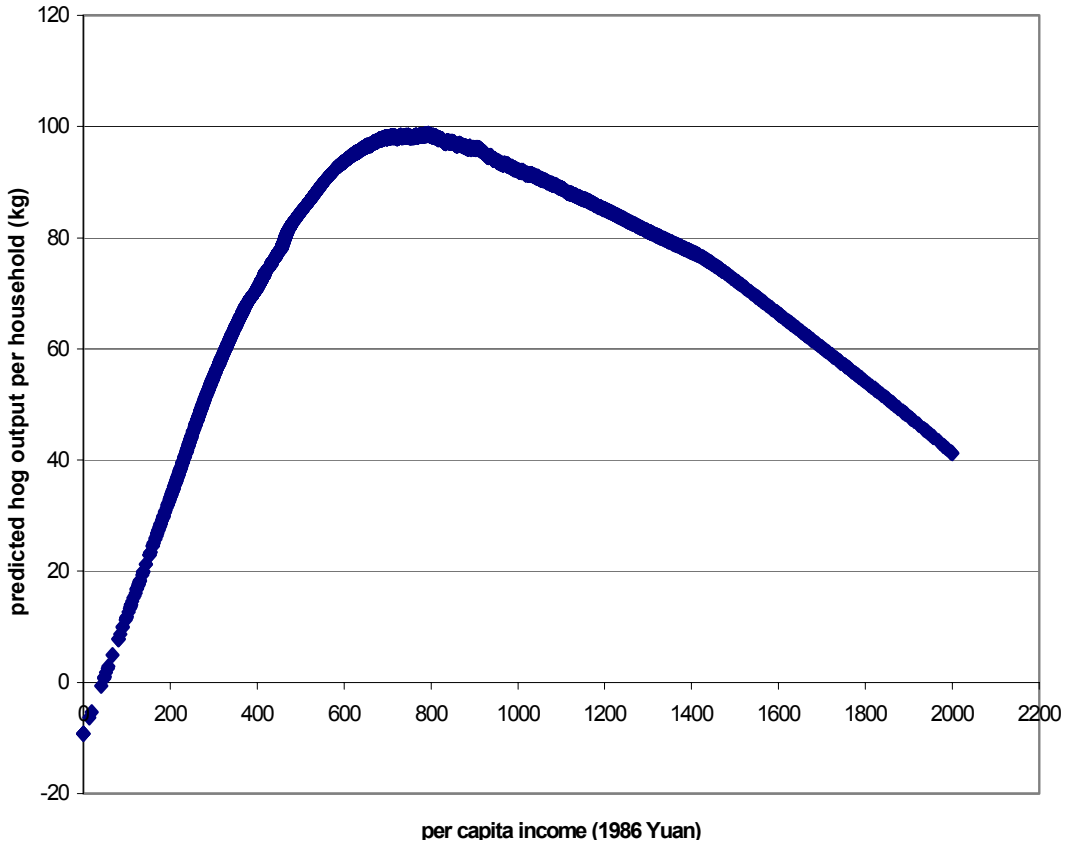
[e] Grain productivity is computed as the ratio of provincial total grain output to the total sown area, China Statisitical Yearbook, 1987 and 1997.

[f] The farm household wealth level are from the RCRE's National Rural Social-Economic Survey Data Collection (or RCRE Survey), where it reports the summary information for different income groups from 1986-1999.

[g] The education level is based on the RCRE's National Rural Social-Economic Survey Data Collection (or the RCRE Survey)

[h] I assume that the relative economic development status in the nation for poor provinces is getting worse (the relative economic development status index increases by 1), and for rich provinces is getter better(the relative economic development status index decreases by 1. This assumption is based on the fact that there are growing economic inequalities across regions in China over the past two decades.

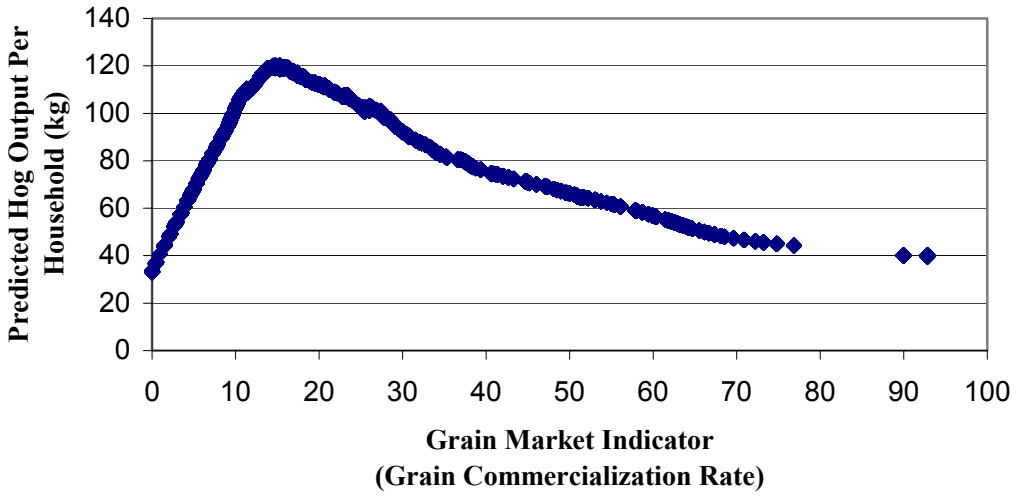
[i] Data for per farm household hog output in 1986 are from China Statistical Yearbook, 1987. And the same data for 1997 are from Agricultural Census conducted in 1996, and are computed as the ratio of the total hog output produced by farm households to the number of agricultural households. The hog output (in head) is then converted into pork output by multiplying a factor of 81.8 kg/head.



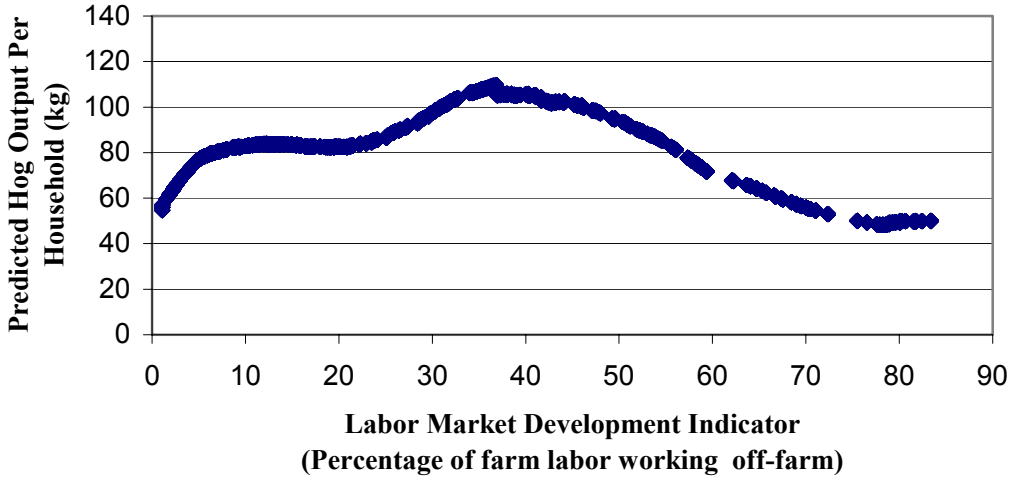
Note: Per capita Income is measure in 1986 Yuan, and the predicted values of hog output from the Lowess estimator (with bandwidth of 0.5) are displayed.

Figure 1: Relationship Between Farm Household Hog Output and Household Per Capita Income, The RCRE data, 1986-1999.

Panel A: Grain Market Development and Household Hog Production



Panel B: Labor Market Development and Household Hog Output

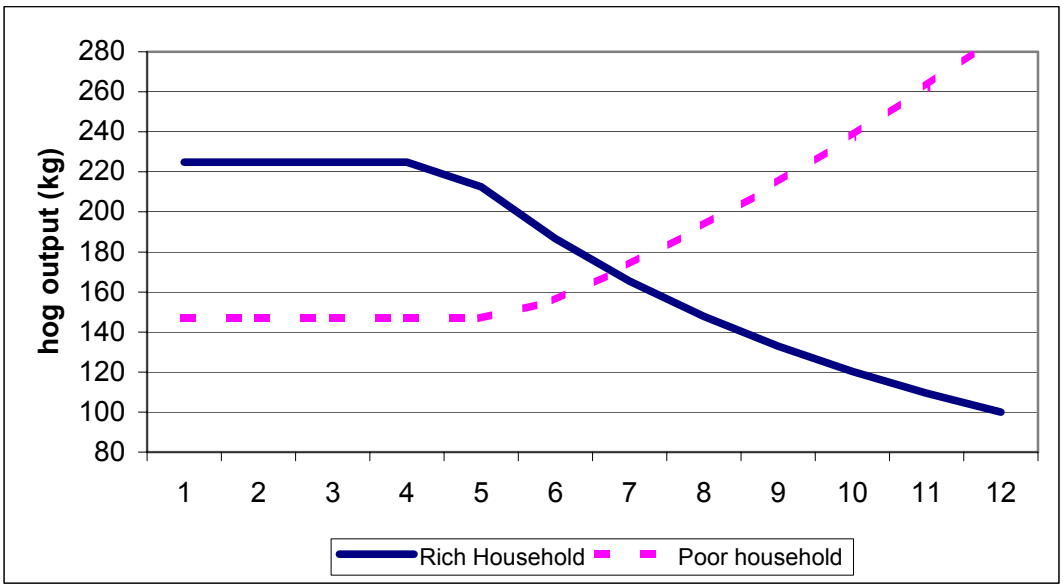


Note: The predicted values of hog output from a lowess estimator (with bandwidth of 0.5) are displayed.

Source: The RCRE Data, 1986-1999

Figure 2: The Relationship Between Grain and Labor Market Development and Household Hog Production

Panel A: Effects of Grain Market Development



Panel B: Effects of Labor Market Development

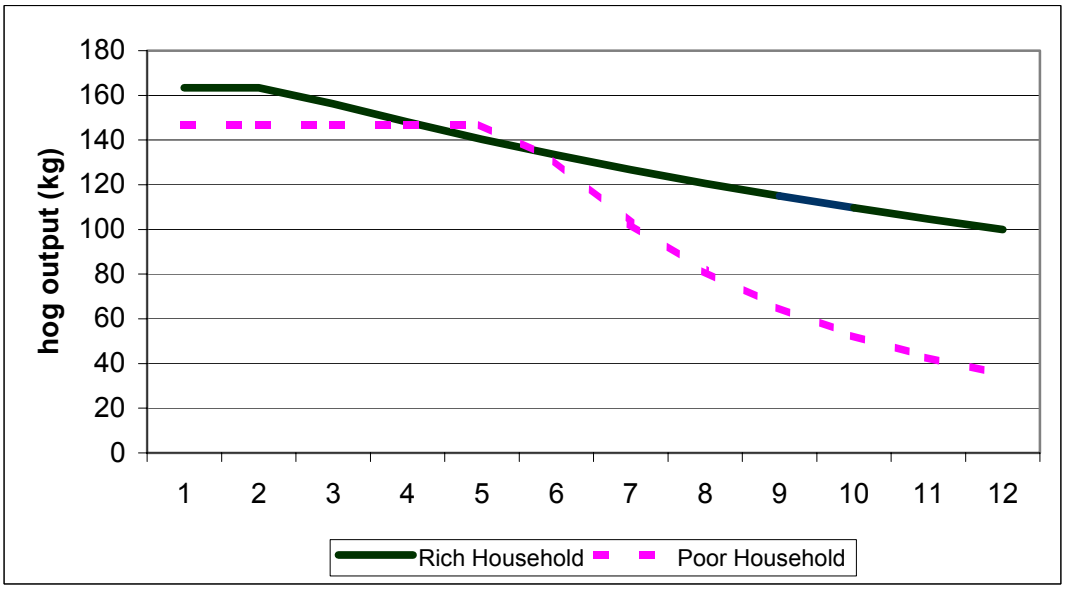
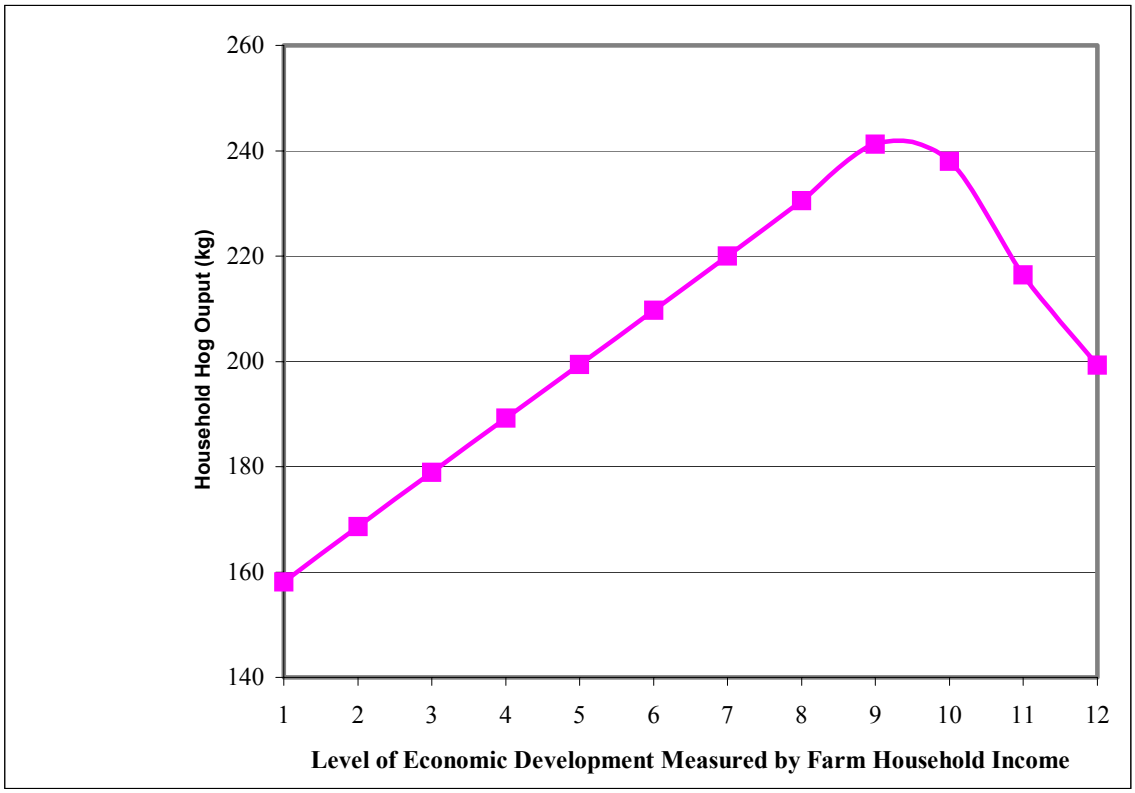


Figure 3: Effects of Market Development on the Farm Household Hog Production



	1	2	3	4	5	6	7	8	9	10	11	12
1. Hog Ouput (kg)	158	169	179	189	199	210	220	231	241	238	216	199
2. Grain Transaction Cost (Yuan/kg)	0.6	0.55	0.5	0.45	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05
3. Labor Transaction Cost(Yuan/Labor_hour)	1.6	1.5	1.4	1.3	1.2	1.1	1	0.9	0.8	0.7	0.6	0.5
4.Grain Productivity Shifter [a]	1.33	1.36	1.39	1.41	1.44	1.47	1.5	1.53	1.56	1.59	1.63	1.66
5.Wage Rate (Yuan/Labor_hour)	2	2.05	2.1	2.15	2.2	2.25	2.3	2.35	2.4	2.45	2.5	2.55
6.Fixed input in hog production (Yuan)	110	120	130	140	150	160	170	180	190	200	210	220
7.Total family labor endowment (labor_hour)	3200	3136	3072	3008	2944	2880	2816	2752	2688	2624	2560	2496

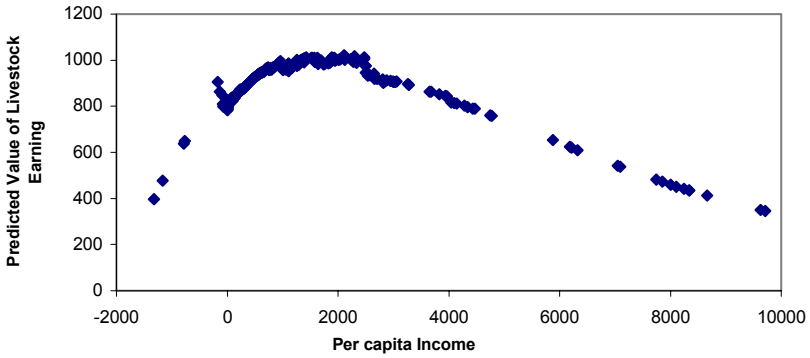
[a] grain production shifter is represented by the coefficient, a, in the hog production technology ($Q_p=aL_pC_gM$)

Source: Based on the simulation model (see the text for details)

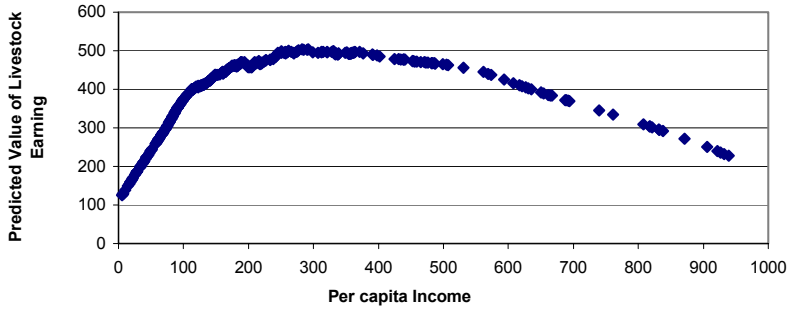
Figure 4. One Illustration of Evolution in Backyard Hog Production as the Economy Develops

Appendix A. Relationship Between Backyard Livestock Production and Household Income

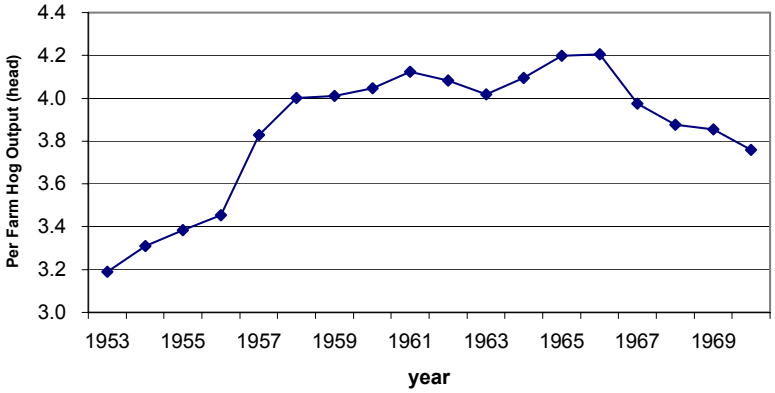
Panel A: Mexico



Panel B: KwaZulu, South Africa



Panel C: Taiwan, 1953-1970



Data Source: The Mexico data contains 309 households surveyed in 8 different villages in Mexico during 1993-1996, while the KwaZulu data contains 463 household observations surveyed in 1998. Data on hog output from small producers in Taiwan are based on Taiwan's Agricultural Yearbook published by the Department of Agriculture and Forestry, Taiwan.

Note: For Mexico and KwaZulu, only predicted livestock earnings are shown in the figure; the predicted livstock earnings are estimated using the Lowess estimator.

Appendix B. Parameters for Household CGE Models

Production Parameters			
	Labor	Fixed Assets	Feed
Staple	0.41	0.59	
Hog	0.45	0.2	0.35

Consumption Parameters		
	Expenditure share	Initial Endowment
Staple	0.4	0
Market	0.15	20
Leisure	0.45	3200

Baseline Market Prices	
Labor	2
Capital	1
grain/feed	2
Hog	5
market good	1

Note:

1) Both production technology and consumption demand functions are based on the standard Cobb-Douglas function.
2) The coefficients of grain and hog production function are approximated using the RCRE data. The coefficients for consumption function are taken from literature, including de Janvry, Fafchamps and Sadoulet (1991).
3) I assume that the farm household has a total of 3,200 labor-hour per year available. The farm household has two adult labor, and each has effective1,200 labor-hours per year. The other family members contribute 800 labor-hours.
4) Prices are largely based on the RCRE data set.

Appendix C. Summary Statistics of Major Variables, The RCRE Data, 1986-1999

	Variable Explanations	The Mean Values of Regressors			
		Whole Sample	Low Income	Medium Income	High Income
Market Development					
	City Suburb?	0.053	0.017	0.049	0.092
	Distances to the Major Roads from the Village (km)	1.862	1.810	1.982	1.794
	Terrain (1: Plain; 2: Hilly; and 3: Mountainous)	1.76	2.06	1.71	1.52
	The Value of Transportation Facilities, 100 Yuan(1986)	3.3	1.4	2.3	6.0
	The Percentage of Village Grain Output sold in the Market	27.78	25.95	28.28	29.04
	The Share of Non-agricultural Laborers in the Village Labor Force	32.15	25.32	31.10	39.79
Wealth and Changing Preference	Wealth level of household in 100 Yuan (1986)	55.78	32.04	47.82	86.65
Other Determinants					
	Village Wage Rates	4.679	3.967	4.530	5.516
	The Number of Prime Age Laborers	2.580	2.614	2.617	2.510
	The Number of Dependents	1.893	2.203	1.939	1.547
	Total Migrant Remittances in the Previous Year, 100 Yuan (1986)	3.40	1.73	2.96	5.44
	Grain Yield: Village Grain Output/ Village Sown Area	381.2	339.0	399.4	404.0
Control Variables					
	Village Hog Price in the Previous Year	2.907	2.880	2.868	2.973
	Village Grain Price in the Previous Year	0.442	0.446	0.429	0.450
	Share of Household Laborers with higher than junior high education	37.72	33.21	35.43	44.36
	Sown Area	8.676	8.141	8.818	9.052
	The share of Migrant Workers in the Village Labor Force	11.86	10.59	12.58	12.36
	Economic Development Status Within the County: 1: high; 2: medium-high; 3: average;4: medium low:; and 5: low	2.36	2.55	2.31	2.22
	Share of Industrial Revenue in the total village revenue	17.2	12.1	16.6	22.8
Average Hog Output		87.7	70.3	96	87.8
Percentage of farm households Raising Hogs		59.2	65.0	58.5	54.0

Appendix D. Sensitivity Analysis of the Inverted-U Relationship Between Hog Production and the Economic Development

	1	2	3	4	5	6	7	8	9	10	11	12
Scenario 1: similar to baseline case, but lower grain transactions costs, and lower, 5% grain yield growth rate												
Grain Transactions costs	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
Labor transactions costs	1.60	1.50	1.40	1.30	1.20	1.10	1.00	0.90	0.80	0.70	0.60	0.50
Grain productivity grow at 5%	1.37	1.44	1.51	1.59	1.67	1.75	1.84	1.93	2.02	2.13	2.23	2.34
Hog Output	163	179	195	211	227	243	260	253	221	191	163	139
Scenario 2: Similar to the baseline case, but lower labor transactions costs, and lower, 5% grain yield growth rate												
Grain Transactions costs	1.6	1.5	1.4	1.3	1.2	1.1	1	0.9	0.8	0.7	0.6	0.5
Labor transactions costs	0.6	0.55	0.5	0.45	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05
Grain yield grow at 5%	1.37	1.44	1.51	1.59	1.67	1.75	1.84	1.93	2.02	2.13	2.23	2.34
Hog output	163	169	172	177	182	188	196	204	214	224	235	220
Scenario 3: Similar to the baseline case, but without any grain and labor transactions costs, and lower, 5% grain yield growth rate												
Grain Transactions costs	0	0	0	0	0	0	0	0	0	0	0	0
Labor transactions costs	0	0	0	0	0	0	0	0	0	0	0	0
Grain yield grows at 5%	1.37	1.44	1.51	1.59	1.67	1.75	1.84	1.93	2.02	2.13	2.23	2.34
Hog output	100	95	90	85	81	77	74	71	68	64	62	59
Scenario 4: same as Scenario 1, but without increases in fixed assets in hog production.												
Grain Transactions costs	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
Labor transactions costs	1.60	1.50	1.40	1.30	1.20	1.10	1.00	0.90	0.80	0.70	0.60	0.50
Grain yield grows at 5%	1.37	1.44	1.51	1.59	1.67	1.75	1.84	1.93	2.02	2.13	2.23	2.34
Hog output	160	172	185	197	209	221	201	166	136	110	88	70
Scenario 5: similar to Scenario 1, but with a very low, 2% growth rate of grain yield												
grain yield grows at 2%	1.33	1.36	1.39	1.41	1.44	1.47	1.5	1.53	1.56	1.59	1.63	1.66
Hog output	158	169	179	189	199	210	220	231	241	238	216	199

Appendix E. Changes in Per Farm Household Hog Production in Guizhou and Guangdong Provinces, China (1986 vs 1996)

		Guizhou				Guangdong			
		marginal effect (column 8 in Table 4)	change in explanatory variable	change in hog production (percent)	change in hog production in percentage	marginal Effect (Column 10 in Table 4)	change in explanatory variable	change in hog production (percent) (	change in hog production in percentage
Grain Market Development									
	Distance to a Major Road from the village (km) [a]	-3.06	-2.00	6.12	15%	2.24	-2.00	-4.48	14%
	Transportation Assets (100 1986 *yuan*)	-0.1	0.8	-0.08	0%	-0.82	2	-1.64	5%
	City Suburb	37.01	0.1	3.70	9%	-29.16	0.1	-2.92	9%
Labor Market Development									
	Share of non-agric. Labor force [b]	-0.51	5.00	-2.55	-6%	-0.21	19.00	-3.99	12%
Wage Rates[c]		-1.51	-0.53	0.81	2%	-3.54	4.20	-14.88	46%
Farm Household Size[d]		7.91	-0.68	-5.38	-13%	8.43	-0.32	-2.72	8%
Village Grain Productivity[e]		0.1	75.53	7.55	18%	0.1	114.91	11.49	-36%
Other Economic Factors									
Changes explained by above factors				**11.93**	**37%**			**-36.69**	**128%**
Residuals				**29.57**	**63%**			**4.39**	**-28%**
Total Change in Hog Output (1996-1986)				**41.50**	**100%**			**-32.30**	**100%**

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