The Developing Economies
IDE-JETRO

The Developing Economies 49, no. 2 (June 2011): 203–22

MARKET DEVELOPMENT AND THE RISE AND FALL OF BACKYARD HOG PRODUCTION IN CHINA

FANGBIN QIAO,[1] JING CHEN,[2] COLIN CARTER,[3] JIKUN HUANG,[4] AND SCOTT ROZELLE[5]

[1]*China Economics and Management Academy, Central University of Finance and Economics, Beijing, China*; [2]*Business Analysis and Development, Fannie Mae, Washington, D.C., USA*; [3]*Department of Agricultural and Resource Economics, University of California, Davis, California, USA*; [4]*Center for Chinese Agricultural Policy, Institute of Geographical Sciences and Natural Resource Research, Chinese Academy of Sciences, Beijing, China; and* [5]*Freeman Spogli Institute for International Studies, Stanford University, Stanford, California, USA*

First version received November 2009; final version accepted September 2010

With economic growth, the share of backyard hog production has declined in China over the past two decades. However, as backyard hog production fell in the rich, coastal regions, the backyard hog production from less wealthy, inland provinces has increased. In this paper, we illustrate the linkage between market development and patterns of household livestock production in rural China. The results indicate that rural labor and grain market developments have significant effects on household hog production. Using household-level survey data, we find a distinctive inverted-U relationship between backyard livestock production and the stage of market development. Hence, market developments might foster the contraction of hog production in rich coastal areas and at the same time lead to an expansion in hog production in poor inland areas.

Keywords: Market emergence; Backyard hog production; China
JEL classification: O53, Q12, Q13

I. INTRODUCTION

ONE widely observed fact associated with rural household livestock production in many developing countries is an inverted-U shape relationship between household livestock production and the level of economic development. The first part of the relationship is characterized by an expansion of livestock holdings as economies develop—that is, during the time that the level of economic development is low, but growing. At a certain point in time in the

The authors acknowledge the financial support of the European Union project (044255) and the Scientific Research Foundation for the Returned Overseas Chinese Scholars, State Education Ministry of China.

doi: 10.1111/j.1746-1049.2011.00129.x

development process, however, the expansion of backyard livestock production peaks, and then moves back towards zero for most rural households. This is the second part of the inverted-U shape relationship. Evidence of the inverted U-shaped relationship appears in many countries (Adams and He 1995; Rosenzweig and Wolpin 1993; Devendra 1993).

It is important to understand the pattern of backyard livestock production and the economic factors that contribute to observed patterns in backyard production during alternate phases of economic development. The economic literature has suggested that risk (Rosenzweig and Wolpin 1993; Fafchamps, Udry, and Czukas 1998; Kurosaki 1998), off-farm wage rates (Benjamin 1992; Skoufias 1994), and family structure (Benjamin, Brandt, and Rozelle 2000) may affect household production behavior. While economists have noted and documented these factors in different settings during different time periods, the literature still lacks a systematic understanding of the relative magnitudes of each factor's importance. The literature also lacks an understanding of exactly how these factors create the inverted U-shape relationship between income and household livestock supply.

The hog industry in China provides an ideal case study for the purpose of studying the complex relationships among the different factors affecting livestock decision-making processes of rural farmers in developing countries.[1] The hog industry plays a dominant role in China's livestock economy. Despite the rapid expansion of poultry consumption, pork still accounts for about 70% of total meat consumption in urban China. In rural areas, this percentage is even higher. Furthermore, within the hog industry at least 85 to 90% of pork in the 1990s was produced from hogs raised in rural backyards (Pan 2000). Will this be true in the future? In fact, it may be that any systematic change in backyard hog production will have far-reaching effects on China's livestock industry and on the country's overall meat supply and demand balance.

In addition, China's rapid development over the past decades has given rise to an environment in which we may be able to measure the impact of market development (and other factors) on the evolution of backyard hog production. Agricultural inputs, outputs, and labor markets were incomplete in China, especially at the beginning of the economic reforms in the 1980s (Parish, Zhe, and Li 1995; Rozelle, Taylor, and deBrauw 1999). Poor grain and feed markets forced farm households to rely heavily on their own grain production in their livestock operations (Zhang 1999; Park *et al*. 2002). Over the last two decades, however, markets have emerged and developed. In the 1980s, farm households purchased less than 20% of their inputs in the free markets. By the middle of the 1990s, more than

[1] Poultry is mainly produced in large commercial farms in China. There is very little poultry produced by backyard production, and most of that is for farmers' own consumption.

one-half of the factors of farm production were purchased through markets (Chen and Rozelle 1998).

Even though markets have generally improved across China, market development is uneven across regions. Over the past several decades, markets in rich, coastal regions have emerged rapidly while they have evolved more slowly and, indeed, have remained underdeveloped in some poor, inland regions. Institutional barriers have also influenced the development of labor markets, preventing families from moving to locations that promise them higher returns (Nyberg and Rozelle 1998). The heterogeneous nature of China's provinces also provides a natural experimental platform that can be used to enhance our data set and allow us to more effectively study the impact of markets on backyard hog production.

Finally, there is reason to think that China's government has not been successful in its past predictions of the changes in the livestock sector, and therefore this study could provide reliable policy guidance. During the 1980s, concerns that China's 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 hog operations in suburban regions of large cities (Pan 2000). The government subsidized these commercial enterprises, many of which subsequently went bankrupt by the late 1990s. During the same time period, however, with little encouragement from policy makers, hog supplies from backyard operations in China expanded rapidly to the point where competition from backyard operations may well have driven some of the commercialized operations out of business. A more complete understanding of the economics of backyard hog production will help China's policy makers understand which policies may be effective in assisting the expansion of the livestock industry.

In this paper we directly investigate the impact of market development on farm household hog production. We find that the development of grain and labor markets can explain a significant portion of the expansion of hog production in poor, inland areas of China and the contraction in rich, coastal areas (during the past two decades). For poor households in the inland areas it was generally difficult to find off-farm employment (especially at the early stage of economic reform in the 1980s), and thus the opportunity cost of labor was low and so households were willing to feed hogs. In the very poorest areas, however, their hog production was often constrained by the limited feed supply. The emergence of grain and feed markets facilitated household access to less expensive feed grain and allowed them to utilize their low-cost labor in hog production. For relatively richer households in the coastal areas, we find that the effects of labor market development dominated the decision-making process. Better labor markets increased the opportunity cost of labor and encouraged farm households to send more family labor to off-farm labor markets and to use less labor in hog production. In the meantime, improvements in grain markets encouraged commercialized hog production.

The rest of this paper is organized as follows. In Section II, we document the ways in which market developments 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. We also discuss the data set used in this paper. In Section III, we econometrically estimate the effects of labor and grain market developments on household hog production. The results indicate that market development can explain the dynamics in China's backyard hog sector. Section IV summarizes our findings and draws policy implications.

II. INCOME, MARKET DEVELOPMENT, AND BACKYARD HOG PRODUCTION

Traditional backyard production systems are characterized by breeding stock of low genetic quality, a prolonged fattening period reflecting minimally nutritious feed or forage, virtually nonexistent sanitary management, and small scale of production (usually 1–2 head per household). Traditional backyard production is practiced throughout rural China and accounts for a large percentage of total pork production. This mostly involves family labor and does not use specialized facilities. It helps generate complementary income for these families. The hogs are slaughtered on site or in local abattoirs for home use or for sale in nearby market centers.

The literature indicates that the relationship between backyard livestock production and the level of economic development might 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 reaches a certain level in the later stages of economic development, livestock production falls for many farm households.[3] Using household-level survey data of Mexico, South Africa, and Taiwan, Chen (2003) found a distinctive inverted-U relationship between backyard hog production and the stage of economic development.

To examine the relationship between backyard hog production and income in China, we use a data set collected by the survey department of the Research Center for Rural Economy, a research unit affiliated with China's Ministry of Agriculture

[2] For instance, richer farm households in Pakistan raised more livestock than poorer households (Adams 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 (Devendra 1993).

[3] For example, the number of hog producers in Korea in 1998 was only 3% of the 1970 level (Korea, Republic of, Ministry of Agriculture and Forestry).

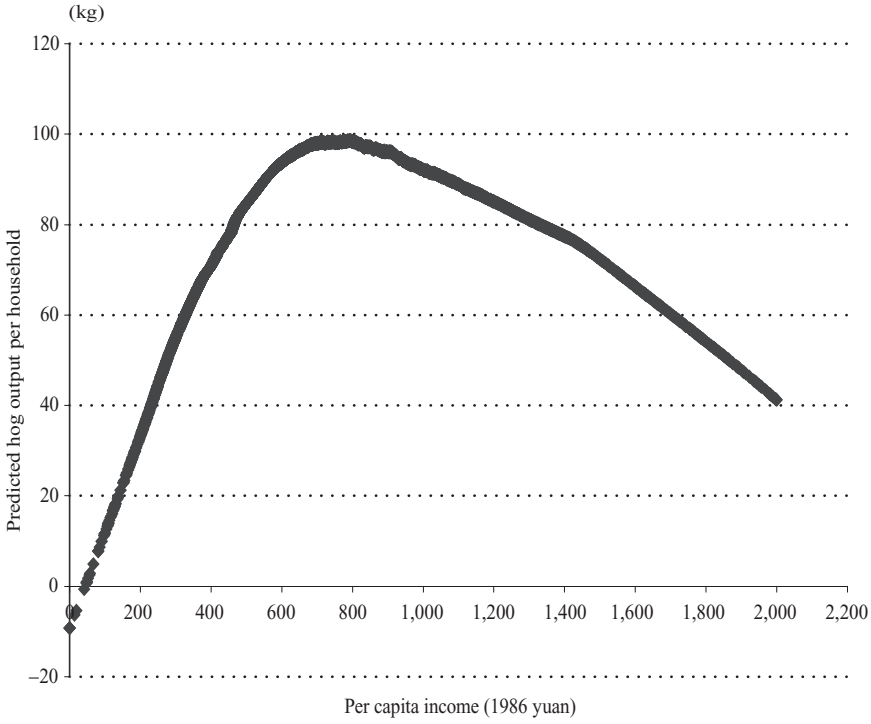
(hereinafter referred to as the RCRE). The RCRE data set includes both household-level and village-level information. In the RCRE survey, each sample household is required to record all daily activities in the form of a "diary." The information is aggregated and available on an annual basis, covering 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 village-level data set. The village 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, our sample includes 670 households in 29 villages from nine different provinces (Hebei, Shanxi, Liaoning, Helongjiang, Jiangsu, Anhui, Shandong, Sichuan, and Yunan) from 1986 to 1999. These nine provinces span widely different geographic and climate regions in China. Farm households in each village were drawn randomly from the overall sample in each village. For most villages, we have 20 household observations for each year. For villages in Liaoning, Heilongjiang, and Shandong, we increased our samples to 30 households. The large sample size in these villages is due to the fact that there were more frequent adjustments in surveyed households over the study period. The increase in the sample size attempts to overcome this problem. More detailed discussion is seen in Chen (2003).

Nonparametric analysis, based on a locally weighted scatterplot smoothing (LOWESS) estimator, demonstrates that, as in other nations, there is an inverted-U relationship between income and livestock production in China (Figure 1). Low-income households produce the fewest hogs per household. When per capita income improves, households tend to increase hog production until income reaches about 850 yuan (or US$104) in 1986 prices, a level somewhat above the median for this time period. A further increase in per capita income, however, is associated with a decrease in household hog production.

Although the inverted-U relationship focuses on the relationship between hog output and income per capita, we should emphasize that we are not suggesting that income changes, per se, drive changes in herd sizes. Instead, we argue that there are many factors that change during the course of development that may generate this pattern of household livestock production. For example, several important constraints might keep poor farm households from expanding production. Poorer farm households are more likely to face higher transactions costs in the purchase of inputs and sales of outputs as well as in accessing capital markets. To the extent that inferior transportation facilities are associated with less perfect markets and to the extent that they keep households from expanding livestock production, the low levels of production in poor areas may be caused in part by poor markets.

Fig. 1. Relationship between Farm Household Hog Output and Household Per Capita Income, RCRE Data, 1986–98



Note: Per capita income is measured in 1986 yuan, and the predicted values of hog output from the LOWESS estimator (with bandwidth of 0.5) are displayed.

Moreover, if markets improve as economies develop, and if emerging markets allow farmers to expand their herd size, then markets may also be associated with the expansion phase of the livestock–income relationship. If further expansion of markets encourages specialization and raises opportunity costs, it is possible that market development can also pressure most wealthier farmers (all but a few who specialize in hog production) to contract their backyard livestock activities. In short, while the exact nature of the relationship between income levels, market emergence and livestock production is unclear, the descriptive data suggests that there is some relationship.

Other factors are also correlated with rising incomes and the rise and fall of backyard hog production. For example, as incomes rise in an economy, household wealth also rises, allowing farmers to self-finance livestock production. At the

same time, as wealth grows further, it could take away the motivation of farmers to raise and hold livestock as a risk-reducing activity.

In addition, systematic changes in the grain-producing capacity of households, the number of family members, and the wage rate—three variables that reflect the value of household resources—could also encourage expansion of household livestock production at low levels of income (e.g., as productivity in grain production increases, in the absence of feed markets, the household has cheaper feed, ceteris paribus); while at higher income levels, falling family size and rising wages raise the opportunity cost of labor and lead to a reduction in backyard hog raising.

The RCRE data illustrate that market development, especially in the case of grain and labor markets, is one of the most important features that characterizes rural economic development over the past two decades in China. Like Sadoulet, de Janvry, and Benjamin (1996) and Giles (2006), we use the percentage of the village labor force working in nonagricultural sectors as an indicator of labor market development. Similarly, the percentage of grain marketed off the farm (or the grain commercialization rate) is used as an indicator of grain market development. To demonstrate that farm households face different markets at different stages of economic development, we divide the sample into three income subgroups: low-, middle-, and high-income subgroups. Our assumption is that households in the low-income subgroup represent those at early stages of economic development, while the high-income subgroup characterizes those at relatively advanced stages of development. Examining the data in this way, we find that labor and grain markets were better developed in regions with higher-income subgroups (Table 1).

TABLE 1

Labor and Grain Market Development

Income Group	Year	Hog Output per Household (kg)	Distance to Major Road from the Village (km)	Share of Nonagricultural Labor in Village Labor (%)	Percentage of Grain Sold in the Market (%)
	(1)	(2)	(3)	(4)	(5)
Low income	1986	63	3.07	20	14
	1990	70	1.74	22	24
	1995	71	1.36	33	22
	1998	76	1.07	32	30
High income	1986	76	3.05	36	28
	1990	114	1.72	37	23
	1995	73	1.35	39	29
	1998	84	1.05	45	34

Source: The household survey data conducted by the Research Center for Rural Economy, Ministry of Agriculture, China.

The share of nonagricultural labor accounted for 36% of the village labor force for high-income subgroups, while it was only 20% for the low-income subgroups in 1986. The grain commercialization rates also were higher for the high-income subgroups. In richer areas, households might have access to better grain markets because they face lower transportation and transaction costs.

In addition, we find that labor and grain markets improved significantly over the survey period for both low-income and high-income subgroups (Table 1). The village-level data shows that the share of nonagricultural labor increased by about 10% from 1986 to 1998, for both income subgroups in the labor markets (column 4). Similar improvements were also found in the grain markets (column 5). For example, in the low-income subgroup, the commercialization rate has more than doubled from 14% in 1986 to 30% in 1998 (rows 1 to 4).

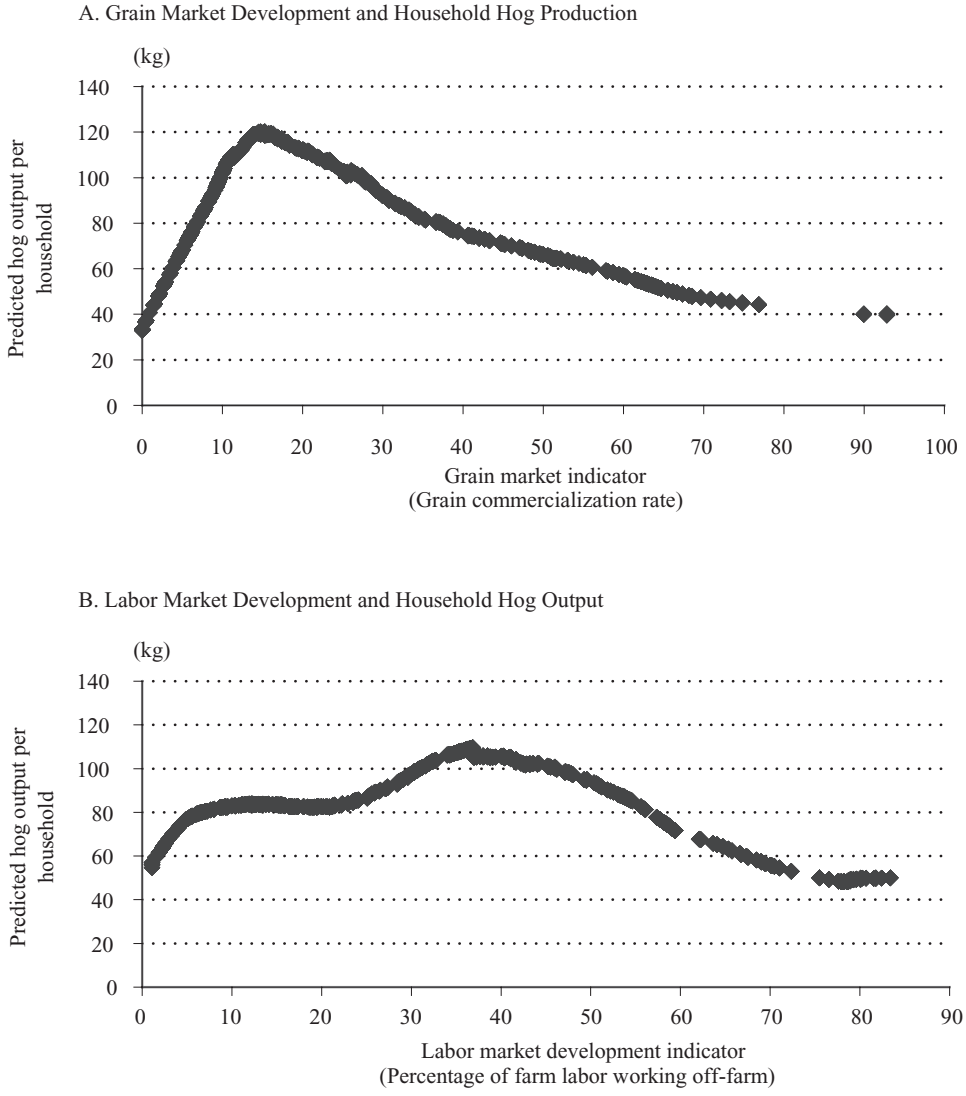
Using a LOWESS estimator, we trace out the inverted U-shaped relationship between hog production and grain (or labor) market development (Figure 2). Household hog production continues to increase until the grain commercialization rate reaches a level of about 20% (or when the share of nonagricultural labor in the village labor force increases to 35%). Further improvements in grain or labor markets, however, were associated with decreases in hog production per household.

The changing relationship between grain and labor market development and hog production as the economy develops might be a result of complex interactions among many economic factors. More than 62% of the households in the low-income subgroup were in grain deficit. In contrast, only 31% of high-income households were in grain deficit.[4] Thus, it is possible that grain market improvements might help households overcome grain and feed supply constraints and allow hog production to expand. For poor households, the initial positive relationship between hog production and labor market development could be due to the fact that, as labor markets emerge, income from off-farm jobs allow poor farm households to overcome credit constraints.

At the more advanced stages of economic development, additional market improvements may have a negative impact on backyard hog production. 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 a fall in hog output. While a few households may take advantage of better

[4] It is very likely that the percentage of households in the low-income tercile that are in grain deficit might be even higher than the above percentage, because some of the poor households cannot purchase grain due to credit constraints. By contrast, the actual percentage of farm households in the high-income tercile that are in grain deficit might be lower, because their decision to purchase grain from the market might not be necessarily related to grain adequacy.

Fig. 2. The Relationship between Grain and Labor Market Development and Household Hog Production



Source: RCRE Data, 1986–98.
Note: The predicted values of hog output from a LOWESS estimator (with bandwidth of 0.5) are displayed.

grain markets to purchase grain and feed to specialize in hog production and become commercial hog producers, most households will give up hog production.

III. EMPIRICAL MODEL

In this section, we construct an econometric model to test the linkage between market development and backyard hog production. As discussed above, we want to test whether the market development, from market emergence to maturation, is associated with the rise and fall of backyard hog production.

A. *Basic Model and Variable Construction*

The basic econometric model is:

$$Hog_{ijt} = \beta_1' M_{jt} + \beta_2' R_{ijt} + \beta_3' Z_{ijt} + u_{ijt} + \varepsilon_{ijt}. \quad (1)$$

In equation (1) 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 (1), 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. The coefficient of share of the nonagricultural labor in the village labor force, β_1, is used to test the effects of labor market development on hog production. A negative and significant β_1 means that, as labor markets develop, hog production falls.

We utilize two approaches to test the impact of the grain market. First, we use a variable, the distance to a major road, to measure the transaction cost. This variable henceforth is referred to as *grain market indicator 1*. Alternatively, we use the percentage of the village grain output sold in the market as the grain market development index. This variable henceforth is referred to as *grain market indicator 2*. We test whether β_1 is positive for low-income households and negative for high-income households.

There are advantages and disadvantages associated with both grain market indicators. Many empirical studies use some or all of the variables in grain market indicator 1 to create a proxy for transaction costs and market development (Key, Sadoulet, and de Janvry 2000; Goetz 1992). These indicators have the virtue of being exogenous and directly associated with grain market transaction costs. However, these variables may not capture all aspects of local market performance or may fail to pick up all of the costs associated with grain transactions. In other words, these variables might underestimate grain market development.

The literature provides evidence suggesting that agricultural commercialization rates are linked to the level of market development (Ahmed 1994; Von Braun and

Kennedy 1994). The strength of using grain commercialization rates is that, unlike grain market indicator 1, they may be able to capture a broader set of transaction costs and other factors that make up market development. The weakness of using the grain commercialization rate variable is that it could 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, we try to control for any possible endogeneity. Because no one indicator is without limitations, we use both indicators to test the effects of grain market development on hog production.

We include several other variables in the estimation model. Household wealth level is used to capture farm household risk preferences, R_{ijt}. Other economic factors included in Z_{ijt} that might affect hog production consist of nonfarm 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.[5] 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 term, ε_{ij}, is uncorrelated with shocks to hog production.

B. *Estimation Strategies*

Tobit model. The dependent variable, hog output per household, is truncated at zero. Therefore, a Tobit model is suitable for the empirical estimation and can be specified as:

$$\begin{aligned} y_{ijt} &= x_{ijt}\beta + \varepsilon_{ijt} \quad \text{if } x_{ijt}\beta + \varepsilon_{ijt} > 0; \\ &= 0 \qquad\qquad\quad \text{if } x_{ijt}\beta + \varepsilon_{ijt} \le 0; \\ &\text{where } y_{ijt} = Hog_{ijt} \text{ and } x_{ijt} = \left[M_{ijt}, R_{ijt}, OD_{ijt}, u_{ijt}\right], \end{aligned} \tag{2}$$

ε_{ijt} is an independently distributed error term and assumed to be normal with zero mean and constant variance σ^2. 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.

Unobserved effects. To estimate how grain and labor market development, both across villages and over time, affect hog production, we choose to rely mainly on a Tobit random effects model.[6] The consistency of the random effects model,

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

[6] Because a fixed effects 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

however, requires that unobservable household and village characteristics (i.e., u_{ijt} that could also affect hog production) be uncorrelated with other explanatory variables in the equation. This requirement might not hold in our case. For example, as mentioned above, the grain commercialization rate as an indicator of grain market development might be endogenous.

To try and control for any covariance between the residual in equation (1) and grain market development, we use instrumental variables. We assume that grain quotas and transactions costs affect the endogenous variable (grain market development) but do 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 grain quotas to villages without consideration of their livestock production, and the size of the quota could affect the development of the local grain market, we have a valid instrument. The same logic is used for transactions costs.

We also tried several other approaches to correct for unobserved fixed effects to minimize possible endogeneity. First, we use Honore's fixed-effect Tobit model (Honore 1992). 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 bias that would result from eliminating the fixed effects. Second, in our empirical models, most of the explanatory variables are lagged for one period to minimize the contemporary correlation between u_{ijt} and explanatory variables.[7] Finally, we use many explanatory variables obtained from village-level surveys rather than household-level surveys. For example, grain yields, wage rates, and grain and hog prices are all based on data from village-level surveys. This has the benefit of controlling the covariance between the error term and the explanatory variables. Since the data for the left- and right-hand-side variables come from different survey instruments, there is less reason to believe that there are correlated errors from the data collection process. In addition, using explanatory variables constructed from village-level data eliminates the presence of unobserved household effects.

Finally, we test the impact of market development on backyard hog production by dividing the entire sample into three income subgroups. 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, we

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

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

divide the entire sample into three income subgroups (i.e., low-, middle-, and high-income subgroups). Using the data subsets, we conduct separate regression analyses, and we use the lower income subgroup to test whether or not backyard livestock production rises as grain markets emerges. We then use the higher income subgroup to test whether or not grain market development and labor market development leads to falling hog production.

C. *Estimation Results*

Almost all the models perform well and produce robust results that are largely consistent with our expectations. Many coefficients are of the expected sign and statistically significant. We find that family size, grain yields and wage rates all have 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 we use the entire sample, use different indicators to measure grain market development, or divide the entire sample into three income subgroups. For example, family size has a significant and positive effect on hog production. 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 household labor, has a negative effect on hog production. All of these empirical results are consistent with predictions from the theoretical model.

The effects of grain market development are not significant when the entire sample is used, which is not surprising since the theoretical model predicts different effects across different types of households. The estimation results from separate regressions that use income-based sub-samples, however, confirm our expectation. Using grain market indicator 1, we find that for poor farm households, a decrease in transactions costs has a significant and positive effect on hog production. For each kilometer closer to a paved road, the household increases hog production by 3.06 kg, or 4.4% (first row, Table 2). The opposite effect, however, is found for high-income households; being one kilometer closer to a paved road reduces hog production by 2.24 kg, or 2.5%.

The effects of grain market development are robust in relation to the choice of grain market indicators (Tables 2 and 3). Using grain commercialization rates to measure grain market development (although without fully controlling for endogeneity), we find that an increase in the grain commercialization rate positively affects hog production for households in the low-income tercile but negatively affects production for households in the high-income tercile. These results are consistent with our expectations, because farm households in the low-income tercile are more likely to be constrained in grain and feed supply. An improvement in markets for these households thus encourages hog production. For farm households in the high-income tercile, which are more likely to be grain-surplus and at

TABLE 2

Regression Estimates from Random Effects Tobit Model for Different Income Groups Using Grain Market Indicator 1

Variable	Quantity of Hog Output (kg)		Marginal Effects	
	Low Income	High Income	Low Income	High Income
1. Market Development				
Grain market development indicator (distance to major roads from the village)	–4.78 (3.03)***	4.19 (2.12)**	–3.06	2.24
Labor market development indicator (share of nonagricultural labor [lagged one year])	–0.77 (2.77)***	–0.78 (2.17)**	–0.51	–0.21
2. Risk				
Household wealth level (lagged one year)	–0.13 (1.05)	–0.25 (3.29)***	–0.09	–0.14
3. Other determinants				
Value of transportation facilities (100 1986 yuan)	–0.16 (0.50)	–1.64 (4.03)***	–0.10	–0.82
City suburb (1: yes; 0: no)	52.91 (2.38)**	–61.87 (2.58)**	37.01	–29.16
Terrain condition (1: plain; 2: hilly; and 3: mountainous)	6.19 (1.15)	56.98 (6.09)***	2.53	28.80
Wage rates	–2.84 (1.42)	–6.95 (2.84)***	–1.51	–3.54
Household size (lagged one year)	12.96 (5.62)***	16.68 (4.25)***	7.91	8.43
Village grain yield	0.16 (6.77)***	0.22 (6.14)***	0.10	0.10
Relative economic development status within the county: (from 1-high to 5-low)	7.18 (1.75)*	18.19 (2.59)**	5.15	7.55
Village grain price (lagged one year)	21.47 (1.66)*	–0.05 (0.00)	–34.34	–64.81
Village hog price (lagged one year)	0.62 (0.15)	3.63 (0.60)	0.41	2.72
Share of family labor with more than junior high education	0.18 (1.77)*	–0.79 (4.91)**	0.10	–0.38
Village data: share of industrial income in total village income	–0.13 (0.51)	1.29 (3.98)***	–0.02	0.55
Constant	–87.96 (3.40)***	–198.60 (4.87)***		
Observations	1,942	2,101		
Number of households	570	628		

Note: Numbers in parentheses are absolute *t*-values.
***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

TABLE 3

Regression Estimates from Random Effects Tobit Model for Different Income Groups Using Grain Market Indicator 2

Variable	Quantity of Hog Output (kg)		Marginal Effects	
	Low Income	High Income	Low Income	High Income
1. Market development				
Grain market development indicator (grain commercialization rate)	0.265 (1.55)	−1.74 (5.76)***	0.16	−0.88
Labor market development indicator (share of nonagricultural labor [lagged one year])	−0.734 (2.74)**	−1.303 (3.58)***	−0.45	−0.66
2. Risk				
Household wealth level (lagged one year)	−0.134 (1.22)	−0.376 (4.78)***	−0.08	−0.19
3. Other determinants				
Wage rates	−2.497 (1.26)	−8.272 (3.35)***	−1.53	−4.20
Family size (lagged one year)	11.929 (5.29)***	12.554 (3.14)***	7.30	6.37
Village grain yield	0.133 (5.81)***	0.206 (5.86)***	0.08	0.10
Village hog price (lagged one year)	−0.114 (0.03)	8.304 (1.37)	−0.07	4.21
Village grain price (lagged one year)	−55.388 (2.43)**	−97.17 (2.25)**	−33.89	−49.31
Education level	0.117 (1.17)	−0.781 (4.84)***	0.07	−0.40
Share of village industrial income	−0.053 (0.23)	1.326 (4.05)***	−0.03	0.67
Relative economic development level (from low-5 to high-1)	9.349 (2.35)**	23.804 (3.48)***	5.72	12.08
Constant	−45.116 (1.83)*	14.115 (0.34)		
Observations	1,942	2,101		
Number of households	570	628		

Note: Numbers in parentheses are absolute *t*-values.
***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

the same time have more off-farm opportunities, an improvement in grain markets would likely lead to an increase in direct grain sales and a reduction in grain fed to hogs.

The results using the income-based sub-samples also show that labor market development has a consistent negative effect on hog production. 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 (second row, Table 2). Given that for some villages, the participation in off-farm labor markets increased by more than 20% over the study period, the labor market had had a significant effect on hog production.

The possible endogeneity problem does not seem to materially affect the results. To address the potential endogeneity problem, as discussed above, we use both an instrumental variable approach and a fixed effects approach. When using the grain commercialization rate to measure grain market development, we use the government grain quota and several of the variables associated with grain transactions costs as instruments for the grain commercialization rate. Alternatively, we use a fixed effects model to control for endogeneity caused by non–time-varying fixed effects and find that the results are mostly robust. Because of the censoring nature of the dependent variable, we use Honore's fixed-effects Tobit model. Results of using both an instrumental variable approach and a fixed effects approach are consistent with what we expected. All the results are available on request. Taking all the regression results together, however, we believe that there is strong evidence supporting our main hypotheses: grain and labor market development contributes to the observed inverted-U relationship between rural household income and hog production.

D. *Market Development and Rise and Fall in Hog Production*

The following decomposition exercise indicates that labor and grain market developments can explain a significant portion of the observed patterns in hog production from 1986 to 1996 in China. In this analysis, we chose two sets of provinces: Henan and Jiangsu provinces north of the Yangtse river (or North China), and Guizhou and Guangdong in South China.[8] We compare the simulated changes (predicted using the estimated coefficients times the observed change in the hog production determinants, i.e., the right-hand-side variables in the hog production model in Table 2) with the "actual" changes in hog production reported in published sources. Specifically, we 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 the explanatory variables.

During the sample period from 1986 to 1996, our simulations show that the average Jiangsu farm households lowered its hog output by 40 kg per year (bottom row, Table 4). The expansion of grain and labor markets in Jiangsu led to an estimated fall in hog production of about 10.51 kg, accounting for about 25% of

[8] Henan and Guizhou are two poor, inland provinces that have experienced a significant increase in household hog production in the past two decades. Jiangsu and Guangdong are two rich coastal provinces that experienced a decrease in backyard hog production over the study period.

TABLE 4

Changes in Per Farm Household Hog Production in Henan and Jiangsu Provinces, 1986–96

	Henan				Jiangsu			
	Marginal Effect (Column 4 in Table 2)	Change in Explanatory Variable	Change in Hog Production (kg)	Share of Contribution to the Change in Hog Production (%)	Marginal Effect (Column 5 in Table 2)	Change in Explanatory Variable	Change in Hog Production (kg)	Share of Contribution to the Change in Hog Production (%)
Grain market development								
Distance to major roads from the village (km)	−3.06	−2.00	6.12	20	2.24	−2.00	−4.48	11
Transportation assets (100 1986 yuan)	−0.10	0.80	−0.08	0	−0.82	2.00	−1.64	4
City suburb	37.01	0.10	3.70	12	−29.16	0.10	−2.92	7
Labor market development								
Share of nonagricultural labor force	−0.51	12.00	−6.12	−20	−0.21	7.00	−1.47	4
Wage rate	−1.51	−0.60	0.90	3	−3.54	1.90	−6.74	17
Farm household size	7.91	−0.66	−5.22	−17	8.43	−0.20	−1.68	4
Village grain productivity	0.10	116.47	11.65	38	0.10	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 (1986–96)			30.90	100			−40.00	100

the decline (sum of rows 1 to 4), while rising wage rates and smaller farm households accounted for about 17% and 4%, respectively (rows 5 and 6). While the direct effects of labor market development (about 4%) might seem small, 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 developments explained more than 20% of the decrease in average household hog production from 1986 to 1996.

For Henan province, however, the simulation results show that more than half (52%, row 9) of the total increase in hog production between 1986 and 1996 (about 31 kg per household, row 11) can be explained by the combined effects of changes in markets, risk, the opportunity costs of resources and other factors (Table 4). Among these factors, grain market development (rows 1 and 3) accounted for 32% of the increase in hog production. But this positive impact was offset by the negative effect from labor market developments. Similarly, we find that the development of grain and labor markets explained a significant portion of the rise and fall of backyard hog production in Guizhou and Guangdong (the results are available on request).[9]

IV. SUMMARY OF FINDINGS AND CONCLUSIONS

In this paper, we tried to illustrate the linkage between market development and household backyard hog production in China. The results indicate that rural labor and grain market developments have significant effects on household hog production. Market developments might foster a contraction of hog production in rich coastal areas and at the same time lead to an expansion in hog production in poor inland areas.

While our results are specific to China, one of the more fundamental issues raised by our study is the extent to which our explanation is applicable to livestock cycles in other developing countries. To a surprising degree, the contours of the rise and fall of backyard livestock production across income levels are similar: rising until reaching the median income point before falling sharply. The results of our study should provide a set of hypothesis to test for the determinants of the rise and fall of backyard livestock production in other countries.

[9] As shown in the decomposition analysis, our regression equation can only explain about half of the observed rise in hog production in the poor provinces. This could be due to several reasons. First, the level of grain market development might be underestimated. Second, over the past two decades, there have been significant improvements in livestock output markets. In recent years, livestock produced in the inland regions are being sold in both the local and distant markets (including markets in the coastal areas). Unfortunately, this information is not available in the RCRE data. Finally, improvements in hog production technologies, including better hog varieties and more 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.

A comprehensive understanding of backyard livestock production behavior is important for policy formation in developing countries. When setting livestock policies, decision makers should pay attention to market development, one of the primary determinants of the rise and fall of backyard livestock production.

REFERENCES

Adams, Richard, and Jane He. 1995. "Source of Income Inequality and Poverty in Rural Pakistan." Research Report no. 102. Washington, D.C.: International Food Policy Research Institute.

Ahmed, Raisuddin. 1994. "Investment in Rural Infrastructure: Critical for Commercialization in Bangladesh." In *Agricultural Commercialization, Economic Development, and Nutrition*, ed. Joachim von Braun and Eileen Kennedy. Baltimore, Md.: Johns Hopkins University Press.

Benjamin, Dwayne. 1992. "Household Composition, Labor Markets, and Labor Demand: Testing for Separation in Agricultural Household Models." *Econometrica* 60, no. 2: 287–322.

Benjamin, Dwayne; Loren Brandt; and Scott Rozelle. 2000. "Aging, Wellbeing, and Social Security in Rural Northern China." *Population and Development Review* 26, Suppl.: 89–116.

Chen, Hongyi, and Scott Rozelle. 1998. "Leaders, Managers, and the Organization of Township and Village Enterprises in China." *Journal of Development Economics* 60, no. 2: 529–57.

Chen, Jing. 2003. "Economic Development and the Evolution of Backyard Livestock Production: A Case Study of Hog Production in China." Ph.D. diss., University of California, Davis.

Deaton, Angus. 1997. *The Analysis of Household Surveys: A Microeconometric Approach to Development Policy*. Baltimore, Md.: Johns Hopkins University Press.

Devendra, C. 1993. *Sustainable Animal Production from Small Farm Systems in South-East Asia.* FAO Animal Production and Health Paper, no. 106. Rome: Food and Agriculture Organization of the United Nations.

Fafchamps, Marcel; Christopher Udry; and Katherine Czukas. 1998. "Drought and Saving in West Africa: Are Livestock a Buffer Stock? " *Journal of Development Economics* 55, no. 2: 273–305.

Giles, John. 2006. "Is Life More Risky in the Open? Household Risk-Coping and the Opening of China's Labor Markets." *Journal of Development Economics* 81, no. 1: 25–60.

Goetz, Stephan J. 1992. "A Selectivity Model of Household Food Marketing Behavior in Sub-Saharan Africa." *American Journal of Agricultural Economics* 74, no. 2: 444–52.

Honore, Bo E. 1992. "Trimmed Lad and Least Squares Estimation of Truncated and Censored Regression Models with Fixed Effects." *Econometrica* 60, no. 3: 533–65.

Key, Nigel; Elisabeth Sadoulet; and Alain de Janvry. 2000. "Transaction Costs and Agricultural Household Supply Response." *American Journal of Agricultural Economics* 82, no. 2: 245–59.

Korea, Republic of, Ministry of Agriculture and Forestry. 2000. *Agricultural and Forestry Statistical Yearbook*. Seoul: Ministry of Agriculture and Forestry, Republic of Korea.

Kurosaki, Takashi. 1998. *Risk and Household Behavior in Pakistan's Agriculture.* Occasional Papers Series, no. 34. Tokyo: Institute of Developing Economics.

Nyberg, Albert, and Scott Rozelle. 1998. *Accelerating China's Rural Transformation*. Washington, D.C.: World Bank.

Pan, Yaoguo. 2000. "Zhongguo xumuye de xin tedian he fazhan zhongdian" [New features in China's livestock industry and the focuses of future development]. In *21 shiji Zhongguo xumuye jingji fazhan zhanlue yanjiu lunwenji* [Strategic development of China's livestock industry in the 21st century], comp. Chinese Forestry, Livestock, and Fishery Economics Association. Beijing: Chinese Forestry, Livestock, and Fishery Economics Association.

Parish, William L.; Xiaoye Zhe; and Fang Li. 1995. "Nonfarm Work and Marketization of the Chinese Countryside." *China Quarterly* 143, 697–730.

Park, Albert; Hehui Jin; Scott Rozelle; and Jikun Huang. 2002. "Market Emergence and Transition: Arbitrage, Transition Costs, and Autarky in China's Grain Market." *American Journal of Agricultural Economics* 84, no. 1: 67–82.

Rosenzweig, Mark R., and Kenneth Wolpin. 1993. "Credit Market Constraints, Consumption Smoothing, and the Accumulation of Durable Production Assets in Low-Income Countries: Investments in Bullocks in India." *Journal of Political Economy* 101, no. 2: 223–44.

Rozelle, Scott; J. Edward Taylor; and Alan deBrauw. 1999. "Migration, Remittances, and Agricultural Productivity in China." *American Economic Review* 89, no. 2: 287–91.

Sadoulet, Elisabeth; Alain de Janvry; and Catherine Benjamin. 1996. "Household Behavior with Imperfect Labor Markets." Working Paper no. 786. Berkeley, Calif.: Department of Agricultural and Resource Economics, University of California, Berkeley.

Skoufias, Emmanuel. 1994. "Using Shadow Wages to Estimate Labor Supply of Agriculture Households." *American Journal of Agricultural Economics*, no. 76: 215–27.

Von Braun, Joachim, and Eileen Kennedy, eds. 1994. *Agricultural Commercialization, Economic Development, and Nutrition*. Baltimore, Md.: Johns Hopkins University Press.

Zhang, Xiaohui. 1999. "Zhongguo nonghu shengzhu shengchan zhuangkuang ji chenben xiaoyi fenxi" [The current situation and benefit/cost analysis of rural household hog production in China]. In *Zhongguo nongcun yanjiu baogao, 1990–1998* [Research report of China's rural economy, 1990–1998], comp. Research Center of Rural Economy, Ministry of Agriculture, China. Beijing: China's Finance and Economics Publishing House.