Hog Production in China: Technological Bias and Factor Demand*

Hengyun Ma and Allan Rae

China Agriculture Working Paper 2/04

Centre for Applied Economics and Policy Studies,
Massey University, Palmerston North
New Zealand

* Financial support from FRST grant IERX0301is gratefully acknowledged.

Hog Production in China: Technological Bias and Factor Demand

Abstract

China's agricultural output has expanded rapidly since the economic reforms of the late 1970s, reflecting both productivity growth and mobilization of inputs. Over the same period, increased consumption of livestock products has been a feature of China's food consumption. Widely different projections of China's demand for feedgrains to feed its expanding livestock sector have motivated this research. Productivity growth is an important component of such projections, but past estimates have been controversial, few focus on livestock, and we are aware of none that examine technological bias in China's livestock production. For example, does the nature of technical progress lead to increased or reduced use of feedgrains relative to other inputs? A feature of China's livestock sector is rapid structural change towards larger and more commercial and intensive production systems. As specialization has developed over the last two decades, the share of backyard livestock production has declined and the shares of specialized households and commercial enterprises have increased. We measure technological change and biases for each of these structures so that this information can be eventually combined with that on structural change when making feedgrain demand projections. Our commodity focus in this paper is on hog production, which is the major consumer of feedgrains in China. We use a translog cost function and adjusted livestock data to estimate technological change and biases. Technical change has not been neutral, and the bias towards feedgrain-saving was found to be statistically significant. We also find that the demand for feedgrains is elastic with respect to its own price and that strong substitution relationships exist with respect to some other inputs. Thus input price changes are important, along with technological biases, in changing the feedgrain input shares to hog production.

Hog Production in China: Technological Bias and Factor Demand

Introduction

China's economic growth is driving rapid change in food consumption patterns, including increased consumption of livestock products, which in turn is fuelling China's derived demand for feedgrains. A current concern is whether China's grain output expansion will be able to match its growth in demand from livestock producers (Huang et al., 1999; Rutherford, 1999; Rae and Hertel, 2000; Simpson and Li, 2001; Ianchovichina and Martin, 2003; Huang and Rozelle, 2003; Nin et al., 2004). Nowadays, the question seems very clear - the concern has shifted from a very general "who will feed China" to a very specific "who will feed China's animals" (Brown, 1995; Fuller et al. 2002; Simpson, 1997). Since pigmeat is still the major meat consumed in China, and hog production accounts for over 55% of total feed consumption by China's livestock (feedgrain equivalent, authors' calculations) hogs will be the focus of this paper.

Answering the above questions will require a better understanding of technological change and factor input relationships for China's livestock sector. Considerable variation exists between published estimates of technological change in China's agriculture, and very few estimates exist for livestock let alone for different types of animal. Nin et al. (2004) estimated 3.0 percent annual growth in hog output per head over 1991-97, Nin et al. (2003) reported growth in total factor productivity (TFP) of 1.8 percent per year over 1965-94 for the aggregate livestock sector (but around 6.5 percent over 1980-94), and Ludena (2004) estimated TFP annual growth for non-ruminants of 4.33 percent over 1990-2001. None of these studies tests for possible biases in technical progress, yet knowledge of whether such change is feed-saving, feed-using, or neutral seems critical for projecting China's feedgrain demands. Nor do these studies differentiate between different production structures, but this seems important for two reasons. First, feed-gain conversion coefficients vary from approximately 2.0 in the backyard hog sector to around 2.5 for specialized household and commercial hog production units.[1] Second, structural change the reduced the share of backyard hog production in total hog output from more than 90 percent in the early 1980s to only 71 percent in 2001.

[1] Averages for 1999-2001 from State Development Planning Commission, "The Compiled Materials of Costs and Returns of Agricultural products of China."

It is clear that differing assumptions about technical change in China's livestock production have contributed to the substantial variation in past projections of China's grain trade (Fan and Agcaiili-Sombilla 1997; Zhou 2004). Given the importance of China's livestock economy and inaccuracies of past feed grain projections, there is an urgent need to study China's feed grain demand so that more accurate projections of China's future grain trade can be made, and policy-makers can formulate improved sectoral policies. We believe our paper makes a contribution by presenting an improved understanding of technological change and factor demand in China's hog sector.

The paper is organized as follows. The next section will introduce our empirical approach to measuring technological change and factor bias, conducting various hypothesis tests, and deriving factor demand parameters. We then describe our data sources including a detailed discussion of how we constructed our hog production and factor demand data. In section four, we document the estimated econometric results and major findings. The conclusions and implications will be presented in the final section.

Methodology

The translog cost function is a convenient specification of duality theory that has been favoured in empirical studies and as the second order approximation, its application allows ones to avoid the need to specify a particular production function (Stratopoulos et al., 2000). Nor is it necessary to assume constant or equal elasticities of substitution (Woodland, 1975). We use a truncated third-order Taylor expansion in this study instead of the usual second-order format for two reasons (Stevenson, 1980). First, it allows all coefficients estimated from cross-sectional data to change from time period t to $t+j$. Second, the truncated third-order form allows us to specify certain tests not addressed under the second-order formulation, such as price-induced technological factor bias. The third-order Taylor series expansion in time and the logged input price and output can normally be expressed as:

$$(1)\quad \ln C_t^* = \beta_0 + \sum_{i=1}^{N}\beta_i \ln P_{it} + \beta_y \ln Y_t + \beta_T T + \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N}\beta_{ij} \ln P_{it} \ln P_{jt}$$

$$+ \sum_{i=1}^{N}\beta_{iy} \ln P_{it} \ln Y_t + \sum_{i=1}^{N}\beta_{iT} T \ln P_{it} + \frac{1}{2}\beta_{yy}(\ln Y_t)^2$$

$$+ \beta_{yT} T \ln Y_t + \frac{1}{2}\beta_{yyT} T (\ln Y)^2 + \frac{1}{2}\beta_{TT} T^2$$

$$+ \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N}\beta_{ijT} T \ln P_{it} \ln P_{jt} + \sum_{i=1}^{N}\beta_{iyT} T \ln Y_t \ln P_{it}$$

where ln indicates the natural logarithm; C^* is the equilibrium total cost; P_{jt} (P_{it}) denotes the price of input j (i) at time T; Y_t is the level of output in period t and T denotes a time trend reflecting biased technical change. With the proper set of restrictions on its parameters, equation (1) can therefore be used to approximate any of the unknown cost and production functions. The symmetry restrictions

$$(2)\quad \beta_{ij} = \beta_{ji} \text{ and } \beta_{ijT} = \beta_{jiT} \text{ for all } i \neq j$$

imply equality of the cross-derivatives. Linear homogeneity in prices (when all factor prices double, the total cost has to double) implies:

$$(3)\quad \sum_{i=1}^{N}\beta_i = 1,\ \sum_{j=1}^{N}\beta_{ij} = \sum_{i=1}^{N}\beta_{iy} = \sum_{i=1}^{N}\beta_{iT} = 0$$

and $\sum_{i=1}^{N}\beta_{ijT} = \sum_{j=1}^{N}\beta_{ijT} = \sum_{i=1}^{N}\beta_{iyT} = 0$, $i = 1,\cdots,N$.

By Shephard's lemma, a firm's system of cost minimizing demand functions (the conditional factor demands) can be obtained by differentiating the total cost function with respect to input prices to obtain the following system of factor input share equations:

$$(4)\quad S_{it}^* = \beta_{iT} + \sum_{j=1}^{N}\beta_{ij} \ln P_{jt} + \sum_{j=1}^{N}\beta_{ijT} T \ln P_{jt} + \beta_{iy} \ln Y_t + \beta_{iyT} T \ln Y + \beta_{iT} T$$

Measures of Technological Bias

Stevenson (1980) proposed several measures for technological bias. Given factor-input prices and other state of nature constraints, technological change would permit the firm to produce the same level of output at a lower level of expenditure. Thus, on the cost side of the production dual, the rate of technological progress (*TC*) can be measured as:

(5) $$TC = \left.\frac{\partial \ln C_t^*}{\partial T}\right|_{Y,P,Z}$$

$$= \beta_T + \sum_{i=1}^{N} \beta_{iT} \ln P_{it} + \beta_{yT} \ln Y_t + \frac{1}{2}\beta_{yyT}(\ln Y)^2 + \beta_{TT}T$$

$$+ \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} \beta_{ijT} \ln P_{it} \ln P_{jt} + \sum_{i=1}^{N} \beta_{iyT} \ln Y_t \ln P_{it}$$

where Z is a vector of "state of nature" variables.

Technological change may be biased both with regard to the factor inputs and with regard to the scale characteristics of the production process. With regard to technical change and factor input bias, Hicks' definition of neutrality implied no change in factor proportions or factor cost shares as technology progressed. Given the existence of technological change, the following factor-share derivative with respect to time can be used to measure factor input bias (FB_i):

(6) $$FB_i = \left.\frac{\partial S_{it}^*}{\partial T}\right|_{Y,P,Z} = \sum_{j=1}^{N} \beta_{ijT} \ln P_{jt} + \beta_{iyT} \ln Y_t + \beta_{iT}$$

Technological change is factor i-using if $FB_i > 0$, factor i-saving if $FB_i < 0$ and neutral if $FB_i = 0$.

Technological change may also be biased with respect to the return-to-scale characteristics of the production process and such a factor bias would alter the range over which returns to scale of a given degree could be realized, possibly altering the output level at which minimum average costs could be attained. The scale measure (S_c) can be expressed as:

(7) $$S_c\big|_{P,Z} = \frac{\partial \ln C_t^*}{\partial \ln Y_t} = \beta_y + \sum_{i=1}^{N} \beta_{iy} \ln P_{it} + \beta_{yy} \ln Y_t + \beta_{yT}T + \beta_{yyT}T \ln Y_t + \sum_{i=1}^{N} \beta_{iyT} T \ln P_{it}$$

where $S_c < 1$ implies the existence of economies of scale; $S_c = 1$ means constant return to scale, and $S_c > 1$ indicates diseconomies of scale. The measure of technological scale bias (TS_c) is expressed as:

(8) $$TS_c = \left.\frac{\partial S_c}{\partial T}\right|_{Y,P,Z} = \beta_{yT} + \beta_{yyT} \ln Y_t + \sum_{i=1}^{N} \beta_{iyT} \ln P_{it}$$

Assuming the sign of TS_c is the same over the output range, $TS_c < 0$ implies that minimum efficient firm size is increased; $TS_c = 0$ indicates no change in minimum efficient firm size; and $TS_c > 0$ signals minimum efficient firm size can be attained at a lower level of output.

The extent to which factor-share bias is induced by factor-price shifts is given by:

(9) $PIB_i = \frac{\partial^2 S_{it}^*}{\partial T \partial P_j} = \beta_{ijT}$

where β_{ijT} is expected to be positive for $i \neq j$ and negative for $i = j$.

Hypothesis Tests

Placing restrictions on the parameters of equations (1) and (4) permits econometric testing of several economic hypotheses (Allen and Urga, 1999; Atkinson and Halvorsen, 1998) as follows:

Constant return to scale (CRS):

(10) $\beta_y = 1$, $\beta_{iy} = 0$, $i = 1, 2, \cdots, N$; $\beta_{yy} = \beta_{yT} = 0$, $\beta_{yyT} = \beta_{iyT} = 0$.

No overall technological change in China's livestock production:

(11) $\beta_T = \beta_{iT} = \beta_{yT} = \beta_{TT} = 0$, $\beta_{ijT} = \beta_{iyT} = \beta_{yyT} = 0$, $i = 1, 2, \cdots, N$.

No factor-input bias:

(12) $\beta_{iT} = 0$, $\beta_{ijT} = \beta_{iyT} = 0$, $i, j = 1, 2, \cdots, N$.

No price-induced factor input bias:

(13) $\beta_{ijT} = 0$, $i, j = 1, 2, \cdots, N$.

No scale bias:

(14) $\beta_{yT} = \beta_{yyT} = \beta_{iyT} = 0$, $i = 1, 2, \cdots, N$.

No scale-induced factor-share scale bias:

(15) $\beta_{yyT} = \beta_{iyT} = 0$, $i = 1, 2, \cdots, N$.

Homothetic production technology not subject to technical progress growth bias:

(16) $\beta_{iy} = 0$, $\beta_{iyT} = 0$, $i = 1, 2, \cdots, N$. $\beta_{yT} = 0$.

Allen Partial Elasticities of Substitution (AES)

Important economic information can be obtained in the form of elasticities of substitution and factor demand elasticities. There are two commonly used summary measurements of price responsiveness - the Allen-Uzawa partial elasticities of substitution (σ_{ij}) and the price elasticities of demand (η_{ij}). Following Uzawa (1962) and Binswanger (1974a), these (long run) elasticities for the translog cost function are measured as:

$$(17)\ \sigma_{ij} = 1 + (\beta_{ij} + \beta_{ijT} T) / S_i S_j \quad \text{for all } i,\ j;\ i \neq j$$

$$\sigma_{ii} = (\beta_{ii} + \beta_{iiT} T + S_i^2 - S_i) / S_i^2 \quad \text{for all } i$$

$$\eta_{ij} = \sigma_{ij} S_j \quad \text{for all } i,\ j;\ i \neq j$$

$$\eta_{ii} = \sigma_{ii} S_i \quad \text{for all } i$$

where S_i is the share of *i*th factor, σ_{ij} are the elasticities of substitution between factors *i* and *j*, η_{ii} are the own-price elasticities of demand for factors and η_{ij} are the cross-partial elasticities of demand for factors. A positive *AES* between factors *i* and *j* indicates that they are substitutes, while a negative *AES* implies that the factors *i* and *j* are complementary.

Data and Variable Construction

Cross-section and time-series data sets will be pooled in this study. Because of the number of datasets to be used, we will clarify the data sources and discuss how these datasets were constructed.

Hog Production Cost

Hog production cost data were obtained from "The Compiled Materials of Costs and Returns of Agricultural Products of China." These costs and returns were originally collected from surveys of individual farms, but were then aggregated to the provincial and national levels prior to publication by the State Development Planning Commission. The cost surveys provide not only detailed factor expenditure but also factor consumption for feed (in grain equivalents), labour and animal purchases.

The cost survey provides cost information on a 'per unit animal' basis so that we can derive total costs by multiplying cost per animal by total numbers of the relevant hog category. Labour includes the farmer and family labour and hired labour. Animal purchases are the costs of young animals for hog production. All other inputs to production were aggregated into an 'other' input category, which includes non-livestock capital and fodder.[2] No quantity data were available for these inputs. Therefore, we have to set fodder and equipment capital into one input group.

[2] Note that this input cost comprised 11 percent capital and 55 percent fodder for backyard hog farms, 22 percent capital and 35 percent fodder for specialized household hog farms, and 31 percent capital and 12 percent fodder for commercial hog farms on average in 1996-2001.

The hog production systems in China are complex, and include traditional backyards units, specialized households and commercial hog operations. The cost survey provides detailed cost data for these three types of production structure. When used in conjunction with the production structure estimates (see below), they allow model estimation by production structure, which is potentially valuable given the substantial variation in production technologies (such as feeding practices) across the three structures combined with rapid structural change in the hog sector.

Factor Prices

Factor prices for feed grain equivalent, labour and animal purchases were directly derived from the cost survey data as total expenditure divided by quantity. However, for the 'other' input category the cost survey provided only values and not volumes. Therefore we used a general price index of agricultural production inputs.

Livestock Output

Traditionally, hog production data has been obtained directly from official statistical yearbooks. However, many concerns have arisen over the quality of China's official livestock statistics and therefore some data adjustments may be prudent (ERS, 1998; Fuller et al. 2000). Taking the advantage of the First National Agricultural Census of China (NACO), Ma et al. (2004) made comprehensive adjustments to supply and demand data for China's major livestock commodities and we use that source's adjusted livestock production data sets. A brief description of the adjustment procedures is given below but the reader is referred to Ma et al. (2004).

Hog Production Structure

China's livestock sector is experiencing a rapid evolution in production practices that involve traditional backyard, specialized households and commercial enterprises. There also appears to be considerable differences in production methods over the three farm types. For example, traditional backyards make full use of readily available low cost feedstuffs, while specialized households and commercial enterprises feed their animals more grain and protein meal, implying that the shift from traditional backyard to specialized household and commercial enterprises in livestock production will increase feed grains consumption (Fuller, Tuan and Wailes, 2002). Surry (1990) has pointed out the importance of such disaggregation by type of production since most econometrically-estimated demand relations for feed inputs have been estimated at a very aggregate level so failing to take into account the wide diversity of production practices.

We constructed share sheets by hog production structure in order to disaggregate total factor inputs by farm type. While estimation of output shares for each year is impossible due to data unavailability, there exist a great variety of data sources that allowed us to construct share sheets by hog production structure for various time periods. Such data sources included the NACO (detailed data for 1996), Animal Husbandry Statistics:1949-1988 (which give a picture of livestock structure in the 1980s), Agricultural Statistical Yearbooks, Animal Husbandry Yearbooks and a wide variety of other materials (e.g., annual reports, authority speeches and specific livestock surveys and websites) which allow estimation of production share for various years. When all these data were combined with 1996 values from the census, many missing values still existed. On the assumption that declining backyard production and increasing shares of specialized and commercial operations were gradual processes over the data period, linear interpolations were made to estimate all missing values.

Empirical Results

Estimating Procedure and Hypothesis Tests

The full dual system of the total cost function and cost share equations was estimated using Zellner's seemingly unrelated regression technique. One share equation had to be dropped since only N-1 share equations are linearly independent due to the homogeneity restriction. As symmetry and homogeneity in input price have to be satisfied theoretically, we always impose these two restrictions into our estimation.

First, the cost and factor-share functions incorporating only the restrictions of symmetry (equation 2) and homogeneity (equation 3) were estimated. Results are given in Table 1. Several restricted versions of the model were next estimated to test the various joint hypotheses concerning the nature of technical change and production scale (equations 10 - 16). Estimates of the restricted models are not presented here, but all null hypotheses were rejected at the 5 percent level for the national aggregate hog cost function and the backyard cost function. The null hypotheses of no scale bias, no scale-induced factor bias and homothetic technology could not be rejected in the case of specialized household farms, nor could the latter with respect to commercial farms.

Technological Change and Scale Bias

Given our final choice of models, we can measure the extent of technological progress and any associated factor or scale biases (Table 2). By fixing factor prices and output at their average 1991-2001 levels, we can calculate technological change year by year for national aggregated hog production and the three types of hog farms using equation (5). On average over this period, the effect of technological change has been to reduce production costs by 3.2 percent per year in the aggregate. Technological change was a little faster in backyard production (3.3 percent) and therefore somewhat slower on specialized (2.1 percent) and commercial operations (2.3 percent). In each case technological advancement was more rapid than during the previous decade.

Factor biases were estimated with equation (6) by allowing factor prices and output to change over time. At the national aggregate level, the effect of technological change over 1991-2001 was to reduce the feed cost share from its average value of 44.9 percent in 1991 to 32.0 percent (i.e. the feed share was reduced due to technological bias on average by 1.3 per year), and to increase the cost shares of labour from 13.0 percent to 14.4 percent (but this bias was not statistically significant), of animal purchases from 24.1 percent to 28.4 percent, and 'other' inputs from 18.1 percent to 25.2 percent. Thus technical change has been significantly feed-saving over this period, and a similar result was obtained with respect to the feed input for each of the three production types. Figure 1 shows how the trends in technological biases shifted sharply between the 1980 and the 1990s. The feed-saving and 'other' input-using biases were stronger on the commercial farms, where technological biases over the 1990s resulted in an average 2.1 percent reduction in the feed cost share. During the 1980s, technological change was feed-using only on the specialized household structure.

Explanation of the 'other' input bias is not straightforward since the 'other' input includes fodder, capital and other miscellaneous inputs (see footnote 2). However, after identifying the major reason for the sharp reduction of 'other' category in total cost, we may conclude that in the 1980s 'other' saving bias is due to a sharp reduction of fodder share in total cost, which implies that it is fodder-saving technological bias in the 1980s. For example, the total cost share of 'other' category reduced by 16 percent in the 1980s (from 37 percent in 1980 to 21 percent in 1990) on backyard farms, and the total cost share of fodder reduced by 11 percent (from 23 percent in 1980 to 12 percent in 1990) on backyard farms. Therefore, it can be calculated that fodder accounts for two thirds of the total cost share reduction of 'other' input category. Likewise, of the 28 percent reduction of 'other' input share in total cost on specialized household farms, more than 80 percent was due to reduction in the share of the fodder input in the 1980s. In other words, technologies adopted during the 1980s may have emphasized increased use of feed grains, but during the 1990s technological biases may have been towards increased use of capital as well as use of fodder as a feedstuff. In contrast, 'other' input-using technical bias in the 1990s most likely implies fodder-using technical bias. For example, of the 25 percent total cost share increase in the 1990s, nearly 80 percent is due to the share increase of the fodder input on back yard farms. While the total cost share of the 'other' input on specialized household and commercial farms apparently reduced in the 1990s (the former reduced by 7 percent and the latter reduced by 4 percent), their total cost shares of the capital input either significantly increased or were maintained (e.g., capital share in total cost increased by 57 percent on commercial farms), which likely indicates 'other' input-using technical bias in the 1990s to have been capital-using technical bias.

Technological change is significantly biased towards labour-using technology on backyard production units. This finding is consistent with the reality of livestock production in China. For example, it can be a good compromise for backyard hog farms to adopt feed-saving and labour-using technologies, and to save feed grain, backyard hog farms feed hogs more fodder that most likely also requires more labour.

Turning to the animal input, its cost share has generally been increased through technological change, but there are differences among hog farms. For instance, though commercial hog farms tended to animal-saving technology (insignificantly), only backyard hog farms appear to adopt animal-using technology. Although we are not sure, it is possibly due in part to the fact that backyard hog farms have to buy piglets from markets, but commercial hog farms have adopted their own breeding systems and can be self-sufficient in piglet supply.

Scale elasticities are estimated from equation (7). Averaged over 1991-2001, these elasticities were 1.013 for both backyard operations and at the national aggregate level, and 1.074 for specialized households. The elasticities for individual years showed a declining trend over the entire data period for backyard operations and in the aggregate, indicating that technological change was biased towards increasing the minimum efficient firm size. The opposite bias was found for specialized households, where technological change had the effect of reducing the efficient firm size over time. The scale elasticities were less than one each year for the commercial farms, indicating economies of scale. However, technological change did not appear to exert a scale bias on these farms.

Factor Demand and Substitution

All own-price elasticities of factor demand have the expected sign (table 3). In general, feed and 'other' input demands are elastic, but labour and animal demands are inelastic. Similar patterns are found across the three production structures. The cross-price elasticities of Table 4 are positive for all but one factor pair (feed and labour on specialized farms) indicating that factor substitution is the norm. The highest cross-elasticities are those that measure a strong substitution effect between feed and 'other' inputs. For example, a one percent increase in feed prices gives rise to an increase in the demand for 'other' inputs of three and six percent depending on farm type. The demand for feed is also elastic with respect to the 'other' input price. We believe this captures substitution between feedgrain and fodder, given the inclusion of the latter in the definition of the 'other' input.

The Allen partial substitution elasticities (Table 5) show considerable variation across input pairs. All are positive at the national level, indicating substitution relationships. The strongest substitution effects are found for the feed - 'other' and labour – 'other' pairs of inputs. Given that the 'other' input category necessarily aggregated feed in the form of fodder, and non-livestock capital, it is possible that these estimates are picking up substitution between feed grain and fodder inputs on the one hand, and between labour and capital on the other.

All but one of the substitution elasticities are also positive across the three farm types. The exception is the apparent complementary relationship between feed and labour on specialized hog farms, suggesting that increased feed use could help absorb surplus rural labour. There are also some differences in the trend and magnitudes of the labour and 'other' input substitution elasticities across farm types. For the backyard hog farms, the elasticity averaged less than one over the 1990s but showed a rising trend. For the specialized and commercial hog farms, this substitution relationship was stronger on average over the 1990s but decreased sharply over the last two decades in the case of commercial farms but displayed a rising trend on specialized farms.

Conclusion and Implication

Our empirical results suggest that technological change had been more rapid in the 1990s than the previous decade, in both the aggregate and on each farm type. During both decades, the rate of change was greatest on backyard farms. We found evidence of scale economies only on commercial farms, but no evidence that these farms are using technologies that encourage larger-scale operations. But we found evidences of significant scale diseconomies on specialized household farms.

The nature of innovation indicates the technological advancement over the 1990s has generally been feedgrain-saving and using of all other inputs. At constant input prices, this would imply that cost-minimizing hog farms producing a given level of output would be induced by technological change to substitute labour, animal and ‘other’ inputs for feed grain. These results may go some way to explain why China has recently been exporting, rather than importing corn. The annual changes in cost shares resulting from these biases appear to have been significant, in particular for the changes in cost shares of feedgrain and ‘other’ inputs. There are some exceptions to this pattern of biases with respect to commercial farms (where animal and labour-saving biases are found) but the estimated biases in these cases are not significant.

The demand for feed and ‘other’ inputs appears very elastic with respect to own-price, but labour and animal input demands are inelastic. Thus changes in the relative prices of grain, fodder and farm capital could significantly affect their demands (given the dominance of the latter two in the ‘other’ input category). While rising feedgrain prices may produce a policy challenge through benefiting crop farmers at the expense of hog farmers, the ease with which feedgrain can be substituted with fodder will have an ameliorating effect. The highest partial substitution elasticies were between the feed-‘other’ input pair. As regards the feeding regime, this might imply that either feedgrain intensive or fodder extensive practices could be chosen especially for backyard hog farms since a substantial proportion of the ‘other’ input comprised fodder (an average of 55 for 1996-2001). Labour-‘other’ substitution was also relatively strong. This could measure labour-capital substitution on commercial farms in particular, where the ‘other’ input included a large proportion of capital expenditure (31 percent on average over 1996-2001. Further disaggregation of the ‘other’ input into fodder and capital may help strengthen this conclusion. This would appear to require new farm survey work.

Our research found some evidence of complementarity between feed and labour, but only for specialized household hog farms. While the relevant partial substitution elasticity was significantly different from zero (Table 5) the cross-price elasticities (Table 4) were not. Thus while our statistical evidence is not compellingly strong, the finding does suggest another area for further study. If confirmed, it could suggest that encouragement of feed use could also provide more opportunities for labour employment on hog farms.

Due to the reality that backyard hogs were fed with a lot of fodder and given backyard hog farmers are price takers, this suggests there is strong substitution between fodder and something else. Unfortunately, due to the unavailability of either quantity or price data, we could not disaggregate the fodder input in the model. Therefore, more work on fodder needs to be done so as to identify the substitution relation between fodder and other inputs.

It should be noted that the model used in this study is still a traditional translog cost approach. Therefore the relative influences of particular investments or policy actions on technological change were not identified in this paper. In addition, using a time trend to measure technical change is an implicit acknowledgment that at least the dependent variable is nonstationary. Thus, dynamic specifications of this translog cost function may be more appropriate for empirical estimation.

References:

1. Allen, C. and G. Urga. “Interrelated Factor Demands from Dynamic Cost Functions: An Application to the Non-Energy Business Sector of UK Economy.” *Economica*. 66(May 1999):403-413.
2. Atkinson, S. E. and R. Halvorsen. “Parametric Tests for Static and Dynamic Equilibrium.” *Journal of Econometrics*. 85(January 1998):33-55.
3. Binswanger, H. “The Measurement of Technical Change Biases with Many factors of Production.” *The American Economic Review.* 64(December 1974b):964-976.
4. Brown, L.R. “Who Will Feed China? Wake-Up Call For A Small Planet.” The World Watch Environmental Alert Series. First Edition, Published by World Watch Institute, 1995.
5. ERS [Economic Research Service]. “Statistical Revision Significantly Alter China’s Livestock PS&D.” Livestock and Poultry: World Market and Trade, Foreign Agricultural Service, U.S. Department of Agriculture. Circular Series FL&P 2-98 Oct. 1998.
6. Fan, S. and M. Agcaoili-Sombilla. “Why Projection on China's Future Food Supply and Demand Differ.” *Australian Journal of Agricultural and Resource Economics*. 41(June 1997):169-90.
7. Fuller, F., D. Hayes, and D. Smith. “Reconciling Chinese Meat Production and Consumption Data.” *Economic Development and Cultural Change* 49(2000):23-43.
8. Fuller, F., F. Tuan and E. Wailes. “Rising Demand for Meat: Who Will Feed China’s Hogs.” China’s Food and Agriculture: Issues for the 21st Century / AIB 775. Economic Research Service/USDA. 2002.
9. Fuller, F., F. Tuan and E. Wailes. “Rising Demand for Meat: Who Will Feed China’s Hogs.” China’s Food and Agriculture: Issues for the 21st Century / AIB 775. Economic Research Service/USDA. 2002.
10. Huang, J., S. Rozelle, and M. W. Rosegrant. "China’s Food Economy to the 21st Century: Supply, Demand and Trade.” *Economic Development and Cultural Change*. 47(July 1999):737-766.
11. Ianchovichina, E. and W. Martin. Economic impacts of China’s accession to the World Trade Organisation. Policy Research Working Paper 3053, World Bank, Washington D.C. 2003. Huang, J. and S. Rozelle. "Trade Reform, WTO and China’s Food Economy in the 21st Century." *Pacific Economic Review*. 8(June 2003):143-156.
12. Ludena, C. “Impact of productivity growth in crops and livestock on world food trade patterns”. Presented to 7th Annual Conference on Global Economic Analysis, Washington D.C., USA, 17-19 June 2004.
13. Ma, H., J. Huang and S. Rozelle. “Reassessing China’s Livestock Statistics: Analyzing the Discrepancies and Creating New Data Series.” *Economic Development and Cultural Change.* 52 (January 2004):445-473.
14. Ministry of Agriculture. *Livestock Statistics of China, 1949-1988.* Beijing: China Economy Press, 1990.
15. Ministry of Agriculture. *Statistical Yearbooks of Agriculture of China.* Beijing: China’s Statistical Press, 1981-2002 (annual).
16. Ministry of Agriculture. *Statistical Yearbooks of Animal Husbandry of China.* Beijing: China’s Statistical Press, 1999-2002 (annual).
17. NACO [National Agricultural Census Office]. *The First National Agricultural Census Data Collection of China*. Beijing: China Statistics Press, 1999.

18. Nin, A., C. Arndt, T.W. Hertel and P.V. Preckel. “Bridging the gap between partial and total productivcity measures using directional distance functions”. American Journal of Agricultural Economics 85(4): 928-42, 2003.
19. Nin, A., T.W.Hertel, K. Foster and A.N. Rae. “Productivity growth, catching-up and uncertainty in China’s meat trade”. *Agricultural Economics* 31(1): 1-16, 2004.
20. Rae A. N., and T. Hertel. “Future Development in Global Livestock and Grains Markets: The Impact of Livestock Productivity Convergence in Asian-Pacific.” *The Australian Journal of Agricultural and Resource Economics*. 44(September 2000):393-422.
21. Rutherford, A.S. Meat and milk self-sufficiency in Asia: Forecasts, trends and implications. *Agricultural Economics* 21(August 1999):21-39.
22. Simpson, J. R. “China’s Ability to Feed its Livestock in the Next Century.” *Asia Pacific Journal of Economics and Business*. 1(December 1997):69-84.
23. Simpson, J. R. and O. Li. “Long-Term Projections of China’s Supply and Demand of Animal Feedstuffs.” International Agricultural Trade Research Consortium, 18-19 January 2001, Auckland, New Zealand.
24. State Development Planning Commission. *National Agricultural Production Cost and Return Collection.* Beijing, 1980-2002 (annual).
25. Stevenson, R. “Measuring Technological Bias.” *American Economic Review.* 70(March 1980):162-173.
26. Stratopoulos, T., E. Charos and K. Chaston. “A Translog Estimation of the Average Cost Function of the Steel Industry with Financial Accounting Data.” *International Advances in Economic Research*. 6(May 2000):271-286.
27. Surry, Y. “Econometric Modeling of the European Community Compound Feed Sectors: An Application to France.” *Journal of Agricultural Economics*. 41(1990):404-421.
28. Uzawa, H. “Production Functions With Constant Elasticities of Substitution.” *Review of Economic Studies*. 29(October 1962):291-299.
29. Woodland, A. D. “Substitution of Structure, Equipment and Labor in Canadian Production.” *International Economic Review*. 16(February 1975):171-187.
30. Zhou, Zhangyue. “Feed versus Food: The Future Challenge and Balance for Farming.” *Australian Agribusiness Review*. 12(June 2004).

Table 1. Estimates of Hog Translog Cost Functions, 1980-2001

Variable	National Aggregate	Backyard	Specialised Households	Commercial Operations
LnP1	0.4405 [a]	0.4653 [a]	0.5290 [a]	0.5593 [a]
LnP2	0.2016 [a]	0.2161 [a]	0.1596 [b]	0.1722 [a]
LnP3	-0.0026	-0.0098	0.0259	-0.0658
LnP1LnP1	0.0845 [a]	0.1117 [a]	0.1320 [a]	0.2035 [a]
LnP1LnP2	-0.0168 [c]	-0.0142	0.0087	-0.0204
LnP1LnP3	-0.0675 [a]	-0.0676 [a]	-0.0612 [b]	-0.0570 [b]
LnP2LnP2	0.0626 [a]	0.0502 [a]	0.0244	0.0364 [b]
LnP2LnP3	-0.0068	-0.0115	-0.0239	-0.0383 [b]
LnP2LnP4	-0.0390 [a]	-0.0245 [b]	-0.0091	0.0223 [c]
LnP3LnP3	0.0518 [a]	0.0567 [a]	0.0832 [b]	0.1501 [a]
LnP3LnP4	0.0225 [c]	0.0224 [c]	0.0020 [b]	-0.0548 [c]
LnP4LnP4	0.0167	0.0320 [c]	0.0866	0.1586 [a]
LnY	0.8331 [a]	0.7987 [a]	0.9556 [a]	0.9892 [a]
LnYLnY	0.0223 [a]	0.0272 [a]	0.0055	-0.0057
LnYLnP1	0.0123 [a]	0.0093 [c]	-0.0037	0.0000
LnYLnP2	-0.0164 [a]	-0.0146 [a]	-0.0080	-0.0080 [c]
LnYLnP3	0.0099 [b]	0.0109 [b]	0.0143 [c]	0.0167 [b]
T	-0.0542 [a]	-0.0628 [a]	0.0238 [c]	-0.0455 [a]
TT	-0.0013 [a]	-0.0012 [a]	-0.0016 [b]	-0.0005
TLnP1	0.0141 [a]	0.0096 [a]	0.0116 [c]	0.0032
TLnP2	-0.0093 [a]	-0.0114 [a]	-0.0068 [c]	-0.0096 [a]
TLnP3	0.0081 [b]	0.0097 [a]	0.0066	0.0197 [a]
TLnY	0.0094 [b]	0.0121 [a]	-0.0087 [c]	0.0066 [c]
TLnYLnY	-0.0013 [b]	-0.0016 [a]	0.0016 [c]	-0.0004
TLnP1LnP1	-0.0296 [a]	-0.0293 [a]	-0.0407 [a]	-0.0470 [a]
TLnP1LnP2	-0.0025 [b]	-0.0033 [a]	-0.0036 [c]	0.0001
TLnP1LnP3	0.0022 [c]	0.0030 [a]	0.0006	0.0015
TLnP2LnP2	-0.0001	0.0020 [b]	0.0003	-0.0006
TLnP2LnP3	-0.0006	-0.0001	0.0011	0.0016 [c]
TLnP2LnP4	0.0032 [a]	0.0015 [c]	0.0022 [c]	-0.0012
TLnP3LnP3	0.0007	-0.0004	-0.0007	-0.0063 [a]
TLnP3LnP4	-0.0023 [c]	-0.0026 [b]	-0.0010	0.0032 [c]
TLnP4LnP4	-0.0307 [a]	-0.0285 [a]	-0.0449 [a]	-0.0474 [a]
TLnP1LnY	-0.0013 [a]	-0.0010 [a]	-0.0001	0.0003
TLnP2LnY	0.0013 [a]	0.0011 [a]	0.0006 [c]	0.0007 [b]
TLnP3LnY	-0.0005 [c]	-0.0006 [b]	-0.0008 [c]	-0.0018 [a]
Logged L	2940	2788	1369	1184

[a], [b] and [c]: $|t| > 2.576$, $|t| > 1.96$ and $|t| > 1.28$, respectively.
Unrestricted models, except for symmetry and homogeneity.

Table 2. Technological Change, Factor Input Bias, Scale Economies and Scale Bias

Hog Farm Types	1980-1990 (S.E)	1991-2001 (S.E)
Technical Change (*TC*):		
National Aggregate	-0.0185 (.0049)***	-0.0322 (.0045)***
Backyard Households	-0.0195 (.0050)***	-0.0325 (.0047)***
Specialized Households	-0.0042 (.0074)	-0.0214 (.0061)***
Commercial Operations	-0.0172 (.0082)**	-0.0226 (.0065)***
Factor-Input Bias (*FB_i*): Feed		
National Aggregate	0.0025 (.0014)	-0.0129 (.0025)***
Backyard Households	0.0016 (.0015)	-0.0128 (.0024)***
Specialized Households	0.0090 (.0021)***	-0.0180 (.0037)***
Commercial Operations	0.0028 (.0020)	-0.0209 (.0042)***
Factor-Input Bias (*FB_i*): Other		
National Aggregate	-0.0083 (.0013)***	0.0071 (.0024)***
Backyard Households	-0.0068 (.0015)***	0.0065 (.0024)***
Specialized Households	-0.0110 (.0019)***	0.0171 (.0035)***
Commercial Operations	0.0017 (.0019)	0.0256 (.0041)***
Factor-Input Bias (*FB_i*): Labor		
National Aggregate	0.0019 (.0012)	0.0014 (.0013)
Backyard Households	0.0033 (.0012)***	0.0026 (.0013)**
Specialized Households	0.0006 (.0015)	-0.0005 (.0019)
Commercial Operations	-0.0027 (.0012)**	-0.0020 (.0015)
Factor-Input Bias (*FB_i*): Animal		
National Aggregate	0.0039 (.0012)***	0.0043 (.0013)***
Backyard Households	0.0036 (.0012)**	0.0038 (.0013)***
Specialized Households	0.0014 (.0016)	0.0014 (.0022)
Commercial Operations	-0.0017 (.0019)	-0.0027 (.0024)
Scale Economies (*Sc*) [b]:		
National Aggregate	1.0305 (.0206)	1.0133 (.0202)
Backyard Households	1.0403 (.0213)	1.0132 (.0201)
Specialized Households	1.0191 (.0034)***	1.0740 (.0254)***
Commercial Operations	0.9813 (.0329)	0.9860 (.0279)
Scale Bias (*TSc*) [c]:		
National Aggregate	-0.0019 (.0020)	-0.0022 (.0023)
Backyard Households	-0.0082 (.0021)***	-0.0031 (.0024)
Specialized Households	0.0021 (.0030)	0.0029 (.0040)
Commercial Operations	0.0015 (.0027)	0.0014 (.0039)

Note: Technical change was based on means of factor prices and output, while scale economies were based on means of factor prices over the relevant period. Factor bias and scale bias were calculated using actual prices and output levels since there is no time variable in their equations.

[a] Standard errors are in parenthesis.

[b] the null hypothesis of scale economies is ***Sc*** equal to one.

[c] the null hypothesis of scale bias is ***TSc*** equal to zero.

*** and ** stand for 1 percent and 5 percent significant levels, respectively.

Table 3. Own-Price Elasticities of Demand for Inputs for Hog Production (1991-2001)

Production	Feed	Labour	Animal	Other
National Aggregate	-1.4166	-0.4666	-0.4947	-3.8859
	(.1627)	(.0618)	(.0447)	(.4688)
Backyard	-1.4093	-0.3754	-0.5482	-3.4208
	(.1749)	(.0575)	(.0450)	(.4524)
Specialized Households	-1.4462	-0.5616	-0.4658	-5.8484
	(.1507)	(.1607)	(.0552)	(.6565)
Commercial Operation	-1.3904	-0.4777	-0.5487	-6.4890
	(.1563)	(.1691)	(.0696)	(.8440)

Note: In parentheses are standard errors, which are estimated by:

$$S.E(\eta_{ii}) = [\text{var}(\beta_{ii}) + T^2 \ \text{var}(\beta_{iiT}) + 2T \ \text{cov}(\beta_{ii}, \beta_{iiT})]^{0.5} \ / \ S_i$$

Table 4. Cross-Partial Elasticities of Demand for Inputs in Hog Production (1991-2001)

Factor	Feed	Labor	Animal	Other
Aggregate:				
Feed	-1.4166 (.1627)	0.0397 (.0213)	0.1577 (.0208)	1.2191 (.1604)
Labour	0.1077 (.0576)	-0.4666 (.0618)	0.1300 (.0455)	0.2288 (.0638)
Animal	0.3088 (.0408)	0.0939 (.0329)	-0.4947 (.0447)	0.0920 (.0435)
Other	3.5078 (.4614)	0.2429 (.0678)	0.1352 (.0640)	-3.8859 (.4688)
Backyard:				
Feed	-1.4093 (.1749)	0.0287 (.0216)	0.1773 (.0209)	1.2033 (.1716)
Labour	0.0656 (.0493)	-0.3754 (.0575)	0.1507 (.0403)	0.1590 (.0614)
Animal	0.3405 (.0402)	0.1266 (.0339)	-0.5482 (.0450)	0.0811 (.0468)
Other	3.1301 (.4464)	0.1810 (.0699)	0.1098 (.0633)	-3.4208 (.4524)
Specialized:				
Feed	-1.4462 (.1507)	-0.0112 (.0232)	0.1647 (.0245)	1.2926 (.1513)
Labour	-0.0750 (.1553)	-0.5616 (.1607)	0.1860 (.1211)	0.4506 (.1800)
Animal	0.3341 (.0497)	0.0564 (.0367)	-0.4658 (.0552)	0.0753 (.0506)
Other	5.4109 (.6332)	0.2821 (.1127)	0.1554 (.1045)	-5.8484 (.6565)
Commercial:				
Feed	-1.3904 (.1563)	0.0265 (.0177)	0.2055 (.0264)	1.1584 (.1541)
Labour	0.2596 (.1733)	-0.4777 (.1691)	0.0470 (.1588)	0.1711 (.2166)
Animal	0.4456 (.0572)	0.0104 (.0352)	-0.5487 (.0696)	0.0927 (.0577)
Other	6.1683 (.8206)	0.0931 (.1178)	0.2276 (.1418)	-6.4890 (.8440)

Note: Each element in the table is the elasticity of demand for the input in the row after a price change of the input in the column. These elasticities are not symmetric. In parentheses are standard errors, which are estimated by:

$$S.E(\eta_{ij}) = [\mathrm{var}(\beta_{ij}) + T^2 \ \mathrm{var}(\beta_{ijT}) + 2T \ \mathrm{cov}(\beta_{ij}, \beta_{ijT})]^{0.5} \ / \ S_i$$

Table 5. Elasticities of Substitution Between Pairs of Inputs for Hog Production, 1991-2001

Production	Feed-Labour	Feed-Animal	Feed-Other	Labour-Animal	Labour-Other.	Animal-Other
National Aggregate	0.2399 (.0213)	0.6878 (.0208)	7.8130 (.1604)	0.5670 (.0455)	1.4665 (.0638)	0.5894 (.0435)
Backyard	0.1537 (.0216)	0.7977 (.0209)	7.3323 (.1716)	0.6781 (.0403)	0.9691 (.0614)	0.4940 (.0468)
Specialized Households	-0.1411 (.0232)	0.6286 (.0245)	10.1808 (.1513)	0.7098 (.1211)	3.5487 (.1800)	0.5929 (.0506)
Commercial Operation	0.4545 (.0177)	0.7803 (.0264)	10.8011 (.1541)	0.1785 (.1588)	1.5953 (.2166)	0.8645 (.0577)

Note: The elasticities of substitution are symmetric. Since the own elasticities of substitution have little economic meaning, we did not need to present them in this table (Binswanger, 1974b). In parentheses are standard errors, which are estimated by:

$$S.E(\sigma_{ij}) = [\text{var}(\beta_{ij}) + T^2 \ \text{var}(\beta_{ijT}) + 2T \ \text{cov}(\beta_{ij}, \beta_{ijT})]^{0.5} \ / \ S_i S_j$$

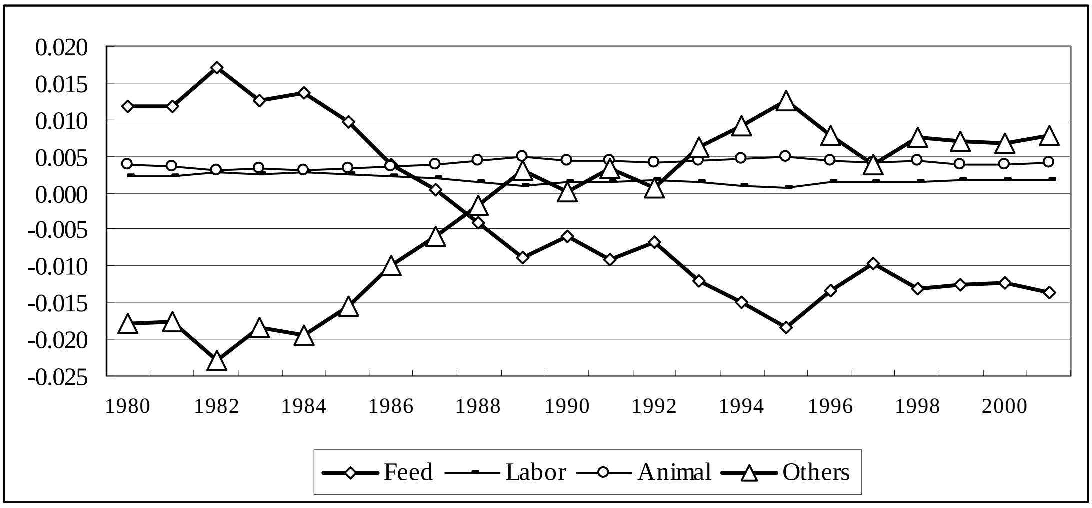

Figure 1. Hog Production Input Biases at National Aggregate Level over time