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Emerald Article: Productivity, efficiency and structural problems in Chinese dairy farms

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Productivity, efficiency and structural problems in Chinese dairy farms

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Abstract

Purpose – The purpose of this paper is to identify the structural problem in the Chinese dairy sector. There exists a large number of low-efficiency, small-scale farms, and productivity inequality between small and large farms keeps increasing, which is a possible driving force behind the Melamine scandal in 2008.

Design/methodology/approach – Using the stochastic frontier production function, this paper estimates and compares the changes in technology and technical efficiency between backyard, small-scale, medium-scale and large-scale dairy farms in China over the period between 2004 and 2008.

Findings – There are compensating effects between technology and technical efficiency. However, low yield for backyard farms is mainly caused by traditional low-yield varieties, even though the technical efficiency is very high, which cannot compensate for the low technology.

Research limitations/implications – The author put the assumption of constant return to scale mainly due to the data availability. Such an assumption implies that there are no scale-effects between the different scales in productivity, and the productivity difference is explained by technology and technical efficiency.

Practical implications – In order to solve the structural problems, Chinese governments should help small-scale farmers to adopt new high-yield varieties, to subsidize small-scale farmers, and to train farmers to master the complicated skills for raising high-yield varieties.

Originality/value – The paper gives another possible explanation for the Melamine scandal of milk powder in 2008. If the structural problem cannot be solved, similar food safety scandals could happen once again.

Keywords China, Agriculture, Farms, Productive capacity, Chinese dairy farmers, Productivity, Technical efficiency, Structural problems

Paper type Research paper

Introduction

In the past decade, driven by fast income growth and drastic changes in dietary patterns, Chinese dairy industry has experienced a rapid growth. Milk products increased from about 8.3 million tons in 2000, to 37.8 million tons in 2008, over fourfold of that in ten years ago, and now is the third largest dairy producer in the world, just after India and the USA. During the same period, the number of cows only rises from 4.9 to 12.2 million, or about 2.5 times. The rapid growth of dairy production mainly results from both expansion of the number of cows and technological progress.

JEL classification – Q12

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Specifically, Chinese dairy farmers have adopted more and more high-yield varieties, such as Hosltein cows, which however are mainly adopted by medium – or large-scale dairy farmers with more capital, entrepreneurship and skills to handle more complicated production procedures for the high-yield varieties.

Even though Wang *et al.* (2010) had a comprehensive review for the development and trend of Chinese dairy industry, the structural problem of Chinese dairy farms has not been well studied. Table I reports the milk productivity and quality for different scale farms. It indicates that milk productivity for small scale farms (less than 50 cows) are significantly lower than large-scale farms, and the milk quality, such as fat and protein contents, is also lower.

Still, the statistics by the Chinese Dairy Association show that about 67.5 percent cows in China are raised by small scale dairy farms, namely less than 20 cows in a farm, in 2008, as is indicated by Table II. Surprisingly, on the one hand, even though the number of backyard dairy farms, namely less than four cows per farm, shares 80.9 percent of total Chinese dairy farms, they only contribute 39.7 percent of total national output. On the other hand, the number of large farms (more than 100 cows per farm) shares only 0.3 percent of total dairy farms, but they produced 16.4 percent of total milk output in China.

Consequently, productivity inequality between small and large farmers keeps increasing, which becomes a structural problem in Chinese dairy production: incentivizing small farmers to ignore milk quality and safety to achieve higher profit

	Yield (kg/day)		Fat proportion (%)		Protein proportion (%)	
Scale	2007	2008	2007	2008	2007	2008
<50	20.02	19.14	3.47	3.51	3.08	3.08
50-100	22.13	20.47	3.64	3.51	3.23	3.21
100-200	21.28	20.72	3.72	3.68	3.20	3.41
200-500	22.42	21.47	3.76	3.69	3.20	3.33
500-1,000	24.80	24.39	3.93	3.75	3.20	3.28
$\geq 1{,}000$	24.12	23.71	3.78	3.71	3.15	3.29

Note: 2007-2008
Source: Chinese Dairy Association

Table I. Milk output and quality for different scale dairy farms

Scale	No. of famers	Share (%)	No. of cows	Share
1-4	2,159,701	80.93	5,942,220	39.73
5-19	444,895	16.67	4,160,598	27.82
20-99	56,254	2.11	2,409,223	16.11
100-199	4,421	0.17	634,835	4.24
200-499	2,336	0.09	696,967	4.66
500-999	768	0.03	526,927	3.52
1,000	339	0.01	586,749	3.92
Total	2,668,714	100.00	14,957,519	100.00

Note: 2008
Source: Chinese Dairy Yearbook (2009)

Table II. Scale distribution of Chinese dairy farmers due to information asymmetry in quality. A large number of small scale farmers increases the difficulty of food safety regulation by Chinese governments as the regulation costs are relatively very huge. It is speculated that the structural problem in current dairy industry in China might be an important driving force behind the food scandal of mixing melamine in baby milk powder in 2008.

Even though the investigation of Chinese governments shows that some milk producers mixed melamine in raw milk on purpose in order to deceitfully increase the fat content in the measurement. Above denouncing these criminals, we should analyze the economic rationale behind the phenomenon. In order to catch up with the profit of high-productivity and large-scale dairy farms, it is comprehensible that small scale farms mix melamine in milk to deceive protein measurement under an environment of high regulation costs and low punishment. If the structural problem cannot be solved, similar food safety scandals could happen once again in the future.

Recently, some studies have point out that recent dramatic growth of Chinese dairy industry is mainly driven by the rapid growth of the number of cows (Yang *et al.*, 2004). However, technological progress can technical changes also play important roles. Using Nonparametric Malmquist index, Cao (2005) calculated the technological changes and technical efficiency changes for state-owned farms in nine provinces and privately-owned farms over 1998-2003, and found that total factor productivity (TFP) for state-owned farms decreased by 2.6 percent in which 36.12 percent is caused by increase in technical inefficiency and 65.38 percent caused by technological retrogress, and the TFP for privately-owned farms is positive, in which the contributions of technical efficiency increase and technological progress are almost even. Similarly, Zhang *et al.* (2006) use Malmquist index and the data of 29 provinces over the period of 1998-2005, and find that annual growth of TFP in Chinese dairy industry is about 0.6 percent in which technical inefficiency annually increases 0.1 percent and the technological progress is about 0.8 percent annually.

Using distance function and the data of 24 provinces over the period of 1992-2003, Ma *et al.* (2007) find that the TFP annual growth rates are 0.25 and 2.33 percent, respectively, for state-and-collectively-owned farms and privately-owned farms, and technological progress is the main reason.

Using the stochastic frontier production function, Fuller *et al.* (2006) also find that TFP of Chinese dairy industry is also positive during the period of 1991-2001, and the technological progress is the main driving force behind it.

Most studies show that the TFP of Chinese dairy industry is positive before 2005, and it mainly results from technological progress rather technical efficiency increase. However, they did not compare the differences of technological progress and technical efficiency changes between different scale groups and ignored the heterogeneities among farms.

This paper uses the aggregate data at province and city level over the period between 2004 and 2008 to compare technological progress and technical efficiency changes between different scale groups of dairy farm in China, and to identify the structural problems in Chinese dairy industry, and tries to provide some policy suggestions to remedy it.

Econometric model

Even though production efficiency comprises technical efficiency, allocative efficiency and scale efficiency in the current literature (Kumbhakar and Lovell, 2003), we will mainly look into the technical efficiency due to the data constraints. Given the panel structure of the data, the model used in this study is the Panel Stochastic Frontier Model with time-varying technical efficiency proposed by Battese and Coelli (1992). According to the statistics of Chinese Dairy Association, the scale of dairy farmers is categorized into four groups: backyard farmers ($\leq$10 cows), small scale farmers ($>$10 cows, but $\leq$50 cows), medium scale farmers ($>$ 50 cows, but $\leq$ 500 cows) and large-scale farmers ($>$500 cows). The production technologies for different groups might be different, so that we should analyze each group separately.

The production function is specified as a Cobb-Douglas form:

$$\ln\ Q_{ijt} = A_i(t) + \alpha_i \ln K_{ijt} + \beta_i \ln L_{ijt} + \theta_i \ln C_{ijt} + v_{ijt} - u_{ijt} \quad (1)$$

where Q_{ijt} denotes the output of raw milk for dairy farmer group i in region (province or city) j at time t. K_{ijt}, L_{ijt} and C_{ijt} denote intermediate inputs, such as feed, labor input and number of cows, respectively. Then α, β and γ are related input elasticities. $A_i(t)$ captures the technical change.

v_{ijt} is a random term with a normal distribution $v_{ijt} \sim N\left(0, \sigma_{v_i}^2\right)$ and u_{ijt} is a non-negative term capturing the technical efficiency. Following Battese and Coelli (1992), we assume technical efficiency changes over time for each farmer i, and:

$$u_{ijt} = \exp\{-\eta_i(t - T_i)\}u_{ij} \quad (2)$$

where T_i is the last observed period for farmer i; η_j is a term denoting the decay rate of technical efficiency; and u_{ij} follows a truncated normal distribution with variance $\sigma_{v_i}^2$. Then the technical efficiency can be expressed as $E_{ijt} = \exp(-u_{ijt})$. We also define $\gamma_i = \sigma_{u_i}^2/(\sigma_{v_i}^2 + \sigma_{u_i}^2)$, which is the proportion of the error explained by inefficiency.

Technology $A_i(t)$ changes over time, and it is a function of time. We assume:

$$A_i(t) = A_{0i} + r_i t \quad (3)$$

where A_{0i} is a constant for group i, and r_i models the technological progress rate.

Furthermore, we assume dairy farmers are of constant return to scale[1], such that $\theta_i = 1 - \alpha_i - \beta_i$. Rewriting equation (1), gives that:

$$\ln\ q_{ijt} = A_{0i} + r_i t + \alpha_i \ln k_{ijt} + \beta_i \ln l_{ijt} + v_{ijt} - u_{ijt} \quad (4)$$

In equation (4), q_{ijt}, k_{ijt}, and l_{ijt} are, respectively, annual per cow milk output, per cow intermediate input and per cow labor input. In the rest session, we will use the data from Chinese Dairy Association to empirically estimate the changes in technology and technical efficiency for different scales of dairy farmers.

Data

The data used in this study are collected from the Cost and Profit Survey of Milk Production, included in the *Chinese Dairy Yearbooks* (2005-2009) published by Chinese Dairy Association. This survey reports the cost structure of farmers with different scales for different provinces and cities. Totally, we have 550 observations over the period from 2004 through 2008.

The main variables include annual per cow raw milk production (Kg), annual per cow intermediate inputs (yuan), annual per cow labor inputs including both household labor inputs and employment (labor*days). Table III reports the descriptive statistics for the different farm groups. The sample sizes for backyard farmer, small scale, medium scale and large-scale farms, respectively, are 111, 131, 156 and 152.

Similar with Table I, we find that per cow output for the backyard farms is the lowest, but the labor input is the highest. It indicates that the labor productivity for backyard farms is very low in China. As the farm size increases, the intermediate input increases, which implies that there is substitute effect between labor and intermediate inputs.

Estimation results

Table IV reports the estimation results of equation (4) for different scale groups. In order to examine the existence of structural difference between different groups, we pool them together and use a likelihood ratio test to test their difference, and find that the test does reject the null hypothesis of no structural difference at 1 percent significant level. Hence, we should estimate the models separately.

First, for the backyard, the estimated input elasticities for intermediate inputs and labor, respectively, are 0.12 and −0.12, and both are statistically significant at 5 percent level. It indicates that an increase of 1 percent in intermediate inputs, per cow milk output will increase by 12 percent, while an increase of 1 percent labor input, milk

	Backyard (<10)		Small scale (10-50)		Medium scale (50-500)		Large scale (>500)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Output (q)	5,025.47	584.60	5,591.17	4,944.14	5,655.73	924.73	6,354.05	1,055.62
Intermediate (k)	7,596.75	2,018.48	7,701.05	1,734.21	9,793.61	2,979.64	12,022.11	3,367.27
Labor (l)	61.91	15.15	44.62	11.81	40.54	13.67	35.78	13.53
Samples	111		131		156		152	

Note: Per year per cow
Source: Chinese Dairy Yearbook (2005-2009)

Table III.
Descriptive statistics for outputs and inputs

	Backyard (<10)		Small scale (10-50)		Medium scale (50-500)		Large scale (>500)	
	Coef.	*t*-ratios	Coef.	*t*-ratios	Coef.	*t*-ratios	Coef.	*t*-ratios
lnk	0.12	2.03**	0.45	3.48***	0.41	13.16***	0.42	8.36***
lnl	−0.12	−2.48**	0.01	0.13	−0.03	−1.33	0.10	4.02***
t	0.00	−0.25	0.08	2.47**	−0.03	−4.83***	0.04	2.14**
Intercept	8.16	16.51***	4.72	4.09***	5.24	16.87***	4.90	10.07***
η	−0.06	−1.37	−0.20	−3.04***	0.00	0.11	−0.12	−2.68***
γ	0.80		0.47		0.95		0.71	
u2	0.02		0.03		0.06		0.01	
v2	0.00		0.04		0.00		0.01	
Log likelihood	114.69		13.96		174.32		143.79	
Sample size	111		131		156		152	

Note: Significant at: * 10, **5, and ***1 percent levels

Table IV.
Estimation results

output however will decrease by 12 percent. It implies that labor is over input for backyard farms. Most backyard farmers are not well-educated, and do not have much training or experience in dairy production, which may results inefficient labor input. In addition, we can calculate the elasticity for cow inputs which is equal to 1.00, which implies that marginal output for cow is very high for backyard farms. The coefficient for the time trend is 0.003 and the coefficient for technical efficiency decaying rate is −0.06, but both are statistically insignificant. Both changes in technology and technical efficiency for backyard farms are not significant.

Second, the estimated input elasticities for intermediate inputs and labor, respectively, are 0.45 and 0.01 for the small scale farms, and only the coefficient for intermediate inputs is statistically significant. It indicates that an increase of 1 percent in intermediate inputs, per cow milk output will increase by 45 percent, while further increase in labor input cannot increase output any more. It means that labor inputs are saturate for small scale farms, and the possible explanation is similar to backyard farms. Then, we can calculate the elasticity for cow inputs which is about 0.44. The coefficient for the time trend is 0.08 and the coefficient for technical efficiency decaying rate is −0.20, but both are statistically significant. It suggests that the technology is progressing but the technical efficiency is decaying over time for small scale farms, and both rates are highest among the four groups. The possible reason could be that small scale farms are introducing high-yield variety cows, but the efficiency decreases due to difficulty of management.

Third, the estimated input elasticities for intermediate inputs and labor, respectively, are 0.41 and −0.03 for the medium scale farms, and only the coefficient for intermediate inputs is statistically significant. Similar to the results of small scale farms, an increase of 1 percent in intermediate inputs, per cow milk output will increase by 41 percent, but further increase in labor input does not have significant impact on output any more. It also implies that labor inputs are saturate. Then, we calculate the elasticity for cow inputs and it is about 0.62. The coefficient for the time trend is −0.03 and statistically significant at 1 percent. However, the coefficient for technical efficiency decaying rate is 0.004, but not statistically significant. It suggests that the technology is retrogressing for the medium scale farms, but the technical efficiency does not change. Of course, the TFP is also negative.

Then, all estimated coefficients for the large-scale farms are statistically significant. Specifically, the estimated input elasticities for intermediate inputs and labor, respectively, are 0.42 and 0.10, and both are statistically significant at 1 percent. Similar to the results of small and medium scale farms, an increase of 1 percent in intermediate inputs, per cow milk output will increase by 42 percent. But differently, a 1 percent increase in labor input can also increase output by 10 percent, and it indicates that all other equal, an increase in labor input can still increase the output for large-scale dairy farms. Then, we calculate the elasticity for cow inputs and it is about 0.48. The coefficient for the time trend is 0.04 and statistically significant at 5 percent. However, the coefficient for technical efficiency decaying rate is −0.12, and statistically significant at 1 percent. It suggests that the technology is progressing for the large-scale farms, but the technical efficiency is decaying over the observed period.

Finally, Table V reports the technical efficiencies for different groups. The most efficient group is the medium scale group, and the value is 0.87. The above econometric exercise shows that the medium scale farms experienced a significant technological retrogression, but the technical efficiency did not change much. It plausible that those farms adopt the maturate technologies, and the technical efficiency keeps in a high level, and a high technical efficiency can compensate the retrogression of technologies.

The second most efficient group is the backyard group, and the number is 0.85. Similarly, the above econometric exercise shows that both technology and technical efficiency have no significant changes. It is possible that those farms adopt low-level technology, but keep in a high level technical efficiency to compensate it.

The third highest and the lowest technical efficiency, respectively, are the small and large-scale farms, and the figures, respectively, are 0.61 and 0.51. The above econometric exercise shows that both small and large-scale farms have similar structure in changes in technology and technical efficiency: increase in technology, but decrease in technical efficiency. It makes senses that adopting new technologies often causes low technical efficiencies, as new technologies need more human capital to operate.

Conclusions and policy implications

In China, most dairy farms remain very small. For instance, the number of backyard dairy farms, namely less than four cows per farm, is about 80.9 percent of total Chinese dairy farms, but their output only shares about 39.7 percent; while the number of large farms (more than 100 cows per farm) is only 0.3 percent of total dairy farms, but produced about 16.4 percent milk in China. Compared with large-scale farms, the productivity of small farms is very low which causes a structural problem for Chinese dairy industry, as it can incentivize small farms to ignore milk quality and safety in order to achieve higher profit.

The study finds that the output elasticity of intermediate put and labor input are very low for backyard dairy farms, and particularly the labor is over input and the marginal output even is negative. Furthermore, the labor inputs for small and medium scale farms are also saturate.

Different scale groups have different performance in technological progress and technical efficiencies. Usually, there are compensation effects between technological progress and technical efficiency changes. Particularly, we find that:

- both technologies and technical efficiency do not have significant changes during the observed period for backyard farms;
- the medium scale farms experienced a significant technological retrogression, but the technical efficiency did not change much; and
- both small and large-scale farms have an increase in technology, but a decrease in technical efficiency.

Therefore, backyard and medium scale farms have higher technical efficiency than those of small and large-scale farms. The analysis shows that the low yield for backyard farms is mainly caused by low-yield variety, even though their efficiency is very high, which cannot compensate the low technology.

Table V. Technical efficiency in China

	Backyard (<10)	Small scale (10-50)	Medium scale (50-500)	Large scale (>500)
Efficiency	0.85	0.61	0.87	0.59
SD	0.08	0.11	0.09	0.07

In order to solve the structural problems, Chinese governments should help small scale farms to adopt new high-yield variety, and train farms to master the skills for raising them as well. In addition, as most dairy farms in China are backyard or small scale farms, those farms should be organized to increase the scale, such as forming dairy farm cooperative, or strengthening the connection between farms and dairy process firms, in order to increase their productivity and milk quality, and to secure the milk safety.

Note

1. We put the assumption of constant return to scale mainly due to the data availability, as we do not have farm level data. Such an assumption implies that there are no scale-effects between the different scales in productivity, and the productivity difference is explained by technology and technical efficiency.

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