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Efficiency of Smallholder Chicken Farms in Northwestern Vietnam: A Data Envelopment Analysis

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ABSTRACT : *This study aims to examine production efficiency of smallholder chicken farms in North-western provinces of Vietnam. Using input-oriented data envelopment analysis with data from Vietnam household living standard survey, we estimate and analyze overall, technical and scale efficiency of chicken farms with four input and two outputs. We also attempt to identify determinants of farm efficiency by running a Tobit regression on selected smallholder characteristics. We find that average efficiency of chicken farms is relatively low and thus farm efficiency can be improved by adopting best practices and technology. As scale efficiency is 90% on average, chicken farms cannot increase much efficiency through up-scaling. Characteristics of smallholder raisers appear insignificant in explaining farm efficiency, except for total land possession and vocational training of household head.*

KEYWORDS – *Chicken, Data envelopment analysis, Production efficiency, Smallholder farms, Vietnam*

I. INTRODUCTION

Raising chicken is one of the traditional likelihoods of rural households in Vietnam. As income rises, demand for chicken meat and eggs has been increasing steadily, leading to the emergence of semi-intensive and intensive chicken farms. However, smallholder farms are still widespread, especially in rural, mountainous regions. It is questionable whether these farms are efficient and if not, how to enhance their efficiency. Some authors have argued that smallholder farms are not necessarily less efficient and competitive ([1],[2]).

This paper attempts to shed light on the efficiency of smallholder chicken farms in North-western provinces of Vietnam. This is one of the poorest remote, mountainous regions in Vietnam. To this end, an input-oriented Data Envelopment Analysis (DEA) model is used to estimate farm efficiency scores with four inputs and two outputs. The advantages of DEA are that it does not require any assumptions on the mathematical form of production function and that it is capable of uncovering relationships that may be hidden for other methods. In the context of chicken production in Vietnam, any assumption of chicken production function form might not be justifiable. We use a dataset of 335 smallholder raisers extracted from Vietnam Households Living Standard Survey 2016, including 6 provinces in the North-western region. Based on estimated efficiency scores, we employ a Tobit regression model to identify factors that influence farm efficiency.

The remaining of this paper is structured as follow. The next section describes the research methodology and data. Section 3 reports estimation results and discusses findings. The final section is concluding remarks.

II. METHODOLOGY AND DATA

The literature of measuring production efficiency is based around the concept of production frontier as suggested initially by Farell [3]. Accordingly, all decision-making units (DMU) operate either on or under the frontier. As those on the frontier are considered as efficient, efficiency score can be measured as the ratio of a DMU output to maximum output on the frontier. The question is how to know the production frontier. There are two approaches to estimate such production frontier. The first approach assumes ex ante a particular form of the production function and estimates the frontier parametrically. This is the so-called Stochastic Frontier Analysis (SFA) *à la* Aigner *et al* [4] and Meeusen and Van den Broeck [5]. However, the assumption of production function might be subjective and unjustifiable. To avoid such an assumption, the second approach estimates a "best practice" empirical production frontier from data. Charnes *et al* [6] named this approach as "Data Envelopment Analysis" (DEA) and proposed to estimate the production frontier with input orientation and constant return to scale (CRS). Fare *et al* [7] and Banker *et al* [8] modified the CRS model to account for variable return to scale (VRS). Comprehensive introduction to DEA can be found in, for example, Fare et al [9],[10], Seiford and Thrall [11], Cooper et al [12] and Thanassoulis [13].

In this paper, we employ input-oriented Data Envelopment Analysis to investigate the efficiency of smallholder chicken farms in Northern Vietnam. Given the complexity of chicken production in Vietnam where

the majority of chicken raisers are smallholders, it might be impossible to assume any production function form. First, we follow Charnes et al [6] to estimate overall efficiency scores, assuming constant return to scale (CRS).

$$\begin{aligned} &\min_{\theta,\lambda} \theta, \\ st \quad &-q_i + Q\lambda \geq 0 \\ &\theta x_i - X\theta \geq 0 \\ &\lambda \geq 0 \end{aligned}$$

where x_i and q_i are the vectors of inputs and outputs of DMU *i* respectively, i=1,2…N; X and Q are matrices of inputs and outputs of all DMU; λ is a vector of constant and θ is efficiency score of a DMU in the range of [0,1]. θ is unity if the DMU is on the frontier and hence an efficient unit. If it is less than unity, the DMU is inefficient. To compute "pure" technical efficiency scores, we then add the convexity constraints $I1'\lambda = 1$ to the above equation:

$$\begin{aligned} &\min_{\theta,\lambda} \theta, \\ st \quad &-q_i + Q\lambda \geq 0 \\ &\theta x_i - X\theta \geq 0 \\ &I1'\lambda = 1 \\ &\lambda \geq 0 \end{aligned}$$

where I1 is an Ix1 vector of ones. The additional constraints aim to ensure that each DMU is judged against DMUs of a similar size and thus the technical efficiency measures the difference between a DMU and the best of its size. The difference between the overall efficiency and technical efficiency measures the role of farm size, or scale efficiency. In other words, overall efficiency can be decomposed into two components: technical efficiency and scale efficiency such that: Overall efficiency = Technical efficiency * Scale efficiency.

The scale efficiency score indicates whether a DMU is operating at an optimal scale. However, it does not let us know whether a DMU is better off increasing or decreasing its scale. To further test if a DMU is of increasing return to scale (IRS) or decreasing return to scale (DRS), one needs to run an additional DEA and impose the non-increasing return to scale (NIRS) constraint by modifying the convexity condition to $I1'\lambda \leq 1$. If the NIRS efficiency score is equal to VRS efficiency score, the DMU is of decreasing return to scale. Otherwise, the DMU is of increasing return to scale.

To identify determinants of production efficiency, we run a Tobit regression model with household characteristics as regressors. The regression equation takes the form:

$$\text{ES} = X'\beta + u$$

where ES is a vector of overall efficiency scores, X is a vector of potential determinants of farm efficiency, β is a vector of coefficients, and u is a vector of normally-distributed error terms. Our hypothesis is that smallholder demographics and resources might influence the adoption of best practices in production and thus production efficiency. Specifically, we hypothesize that chicken farm efficiency is influenced by household size, gender and age of household head, household dependency ratio, education and training of household head, household assets such as television, mobile phone and motorbikes, and total land owned by household. The list and definition of variables included in the regression are given in Table 1.

The model is applied to a dataset of 335 smallholder chicken farmers in six provinces in the North-western of Vietnam obtained from Vietnam household living standard survey in 2016. This is a remote mountainous region with high rate of poverty and chicken raising is one of the livelihood strategies. We use breed cost, feed cost, medical cost and other cost as production inputs. Chicken meat and eggs in term of value are used as two production outputs in the model. We use value instead of quality since chicken is of several varieties, of which prices might be vastly different. Thus, two chickens with the same weight may have significantly different value and farmers may deliberately choose one variety or another to maximize chicken value rather than chicken weight.

Table 1: Variables used in Tobit regression

Variable	Definition
Household size	Number of persons in household
Gender of household head	Dummy variable which is unity if the household is male-headed and zero if not
Age	Logarithm of the age of household head
Dependency ratio	Ratio of number of household members over 60 or under 18 to total household size
Ethnicity	Dummy variable which is unity if household head is of ethnic minority.
Year of Schooling	Number of years of schooling of household head
Vocational training	Dummy variable which is unity if household head has got vocational training
Total land	The area of land owned by household
Mobile phone	Dummy variable which is unity if the household has mobile phones
Television	Dummy variable which is unity if the household has televisions
Motorbike	Dummy variable which is unity if the household has motorbikes
Electricity	Dummy variable which is unity if household has access to electricity

III. RESULT AND DISCUSSION

Table 2 shows descriptive analysis of the size of chicken farms in North-western provinces of Vietnam. As we can see, farm sizes vary significantly from the smallest size of 4 chickens to the largest size of 350 chickens and the standard deviation is rather high. Largest average farm sizes can be found in Yen Bai and Hoa Binh provinces. With such deviation in farm size, we expect high deviation pattern across farm efficiency scores.

Table 3 reports the descriptive statistics of the overall efficiency scores estimated by our input-oriented data envelopment analysis. The mean of efficiency score is 0.54 implying that on average, smallholder farms operate at efficiency level of 54% percent of the most efficient ones. The least efficient farms run at merely 20% level of the most efficient ones. The mean efficiency scores also vary across provinces, of which lowest efficiency scores are more likely in the most remote mountainous provinces of Lai Chau and Dien Bien.

Table 4 demonstrates results of overall efficiency, technical efficiency and scale efficiency. It is quite surprising that overall efficiency and technical efficiency are not much different and scale efficiency scores are high across the board. This indicates that most small farms are relatively close to optimal scales and changing farm size cannot provide significant boost in efficiency. The differences in efficiency, thus, mainly come from the differences in husbandry technology and practices. The low level of efficiency suggests that farms are likely to significantly enhance their efficiency if they adopt best practices following the most efficient farms in the region. It is, nonetheless, beneficial to farms to increase their size, as most farms (71.59%) are of increasing return to scale (Table 5). 22.16 percent of farms are of decreasing return to scale and only about 6.25 percent of farms are already scale - optimal. However, as farms are close to optimal scale, changing firm size would not induce large efficiency improvement.

Table 2: Smallholder chicken farm size by provinces

Province	Mean	Sd	Min	Max
Lao Cai	50.2	58.7	8	350
Dien Bien	28.8	16.3	4	90
Lai Chau	32	29.9	5	160
Son La	37.2	41.8	5	272
Yen Bai	59.5	46.9	5	232
Hoa Binh	59.7	66.9	8	300
Total	43.6	47.3	4	350

Table 3: Overall efficiency scores of smallholder chicken farms by provinces

Province	Mean	Sd	Min	Max
Lao Cai	0.54	0.20	0.22	1.0
Dien Bien	0.45	0.13	0.28	0.82
Lai Chau	0.48	0.22	0.2	1
Son La	0.6	0.23	0.28	1
Yen Bai	0.66	0.19	0.29	1
Hoa Binh	0.55	0.21	0.22	1
Total	**0.54**	**0.21**	**0.20**	**1.00**

Table 4: Overall, technical and scale efficiency scores of smallholder chicken farms

Province	Overall Efficiency	Technical Efficiency	Scale Efficiency
Lao Cai	0.54	0.61	0.90
Dien Bien	0.45	0.49	0.92
Lai Chau	0.48	0.53	0.91
Son La	0.6	0.66	0.90
Yen Bai	0.66	0.74	0.91
Hoa Binh	0.55	0.64	0.87
Total	**0.54**	**0.60**	**0.90**

Table 5: Return to scale of smallholder chicken farms

Province	Increasing return to scale	Decreasing return to scale	Optimal scale
Lao Cai	66.67	26.19	7.14
Dien Bien	81.82	18.18	0
Lai Chau	72.86	20.0	7.14
Son La	72.58	19.35	8.06
Yen Bai	63.83	27.66	8.51
Hoa Binh	67.69	24.62	7.69
Total	**71.59**	**22.16**	**6.25**

Table 6 presents the result of Tobit regression with smallholder characteristics as regressors to identify if these factors affect chicken farm efficiency. Contrary to our expectation, most variables are statistically insignificant in explaining farm efficiency scores. Interestingly, we find that vocational training of household head is negatively related to farm efficiency. A possible explanation is that household head with vocational training might find alternative livelihood option other than raising chicken and thus have not paid enough attention to improving farm efficiency. The area of land owned by household also appears significant in explaining farm efficiency. Larger land might imply better sources of feed for chicken from the nature and from agricultural by-products. We expect the possession of motorbike, television and mobile phone might help increase the knowledge of farmers and reduce transition costs and thus increase efficiency. However, these variables are not significant in our regression.

Table 6: Results of Tobit regression

Variable	Estimated coefficients
Household size	0.02 (0.01)
Gender of household head	-0.04 (0.05)
Age	0.03 (0.05)
Dependency ratio	-0.01 (0.02)
Ethnicity	-0.0004 (0.002)
Year of Schooling	0.0002 (0.004)

Vocational training	-0.06 (0.03)*
Total land	0.02 (0.01)**
Mobile phone	-0.007 (0.02)
Television	-0.002 (0.04)
Motorbike	0.001 (0.02)
Electricity	0.02 (0.05)
Constant	0.19 (0.2)

***,**: significant at 10 and 5 percent level respectively.**

IV. CONCLUSION

This study investigates the efficiency of smallholder chicken farms in North-western provinces of Vietnam using data from Vietnam household living standard survey 2016. Using input - oriented Data envelopment analysis with four inputs and two outputs, we find that most chicken farms are inefficient, with average efficiency score is merely 0.54. Thus, there is huge room for efficiency improvements as long as the farms follow the technology and practices of the most efficient ones. As most farms operate near optimal scale, there is little space for increasing efficiency by increasing farm size despite the fact that 71 percent of farms are of increasing return to scale. We also find that farm efficiency is not significantly influenced by household demographic characteristics and assets.

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