TECHNICAL EFFICIENCY OF ANNUAL CROP FARMS IN NORTHERN VIETNAM

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ABSTRACT

Vietnamese agriculture is dominated by small-scale farm households. The diversified cropping system is common in northern Vietnamese agriculture. Farms have been transformed since independence, from self-sufficient systems that produced mainly rice, to diversified farming systems, which now produce and market a large variety of products. The approach of this paper offers some other important innovations over previous Vietnamese studies. Data Envelopment Analysis is used to estimate technical efficiency and its components. Technical efficiency estimates are measured on diversified crops rather than individual crops. This is important because, a major challenge in examining production of farm households is crop diversification. The investigation of technical efficiency should inform diversification policy for Vietnamese agriculture, especially from the base of rice production, and better understand the behaviour of farmers using land for annual crops. The results of this paper indicate the importance of crop diversification. Farms favouring market-oriented products, such as annual industrial crops, have greater efficiency than farms focusing on staple crops such as rice and maize. The results also suggest that there is technical and scale inefficiency among farm households in the North. Thus there is room to increase efficiency.

JEL classifications O13, C61, Q12

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I.   Introduction

Vietnamese agriculture is dominated by small-scale farm households. According to the Vietnamese General Statistics Office, the Vietnamese population grew from 84.1 million in 2006 to 87.8 million in 2011 (VGSO, 2007; 2012). As the population increases, farm households must produce even more food to feed the growing population. Constraints to achieving food security in Vietnam include the small size and fragmentation of land holdings, especially in Northern Vietnam. Given fixed or falling supplies of agricultural land and labour, economic growth depends on improved efficiencies. It is important to measure the level of technical efficiency as part of a strategy to increase agricultural production.

Since the beginning of its 'Doi moi' market reform process in 1981, Vietnam has achieved remarkable success in increasing agricultural output, especially rice (Kompas, 2004 and Kompas et al., 2012). The importance of rice production in the Vietnamese economy demonstrates the importance of the efficiency of rice production and understanding the determinants of efficient production. Although rice production dominates the farming system in farm households, however, several other annual crops are grown in conjunction with rice to meet subsistence and cash needs in Vietnam.

The diversified cropping system is common in northern Vietnamese agriculture. Farms have been transformed since independence, from self-sufficient systems that produced mainly rice, to diversified farming systems, which now produce and market a large variety of products. Pederson and Annou (1999) claimed that crop diversification away from rice was associated with small farms in irrigated areas like the North. Minot et al. (2006) also revealed:

"Farm households in the poor area have been moving toward rice self-sufficiency on the basis of higher yields, while allocating any new land to higher-value crops, thus they have not been sacrificing rice production to diversify into higher-value crops" (Minot et al., 2006, p. 41).

Henin (2002) found farmers in the northern uplands adopting modern rice varieties and fertilisers (though they continue to use local varieties as well) and expanded production of cash crops.

The aim of this paper is to identify the technical efficiency of rice-based diversified crops in the northern part of Vietnam. Farrell's (1957) paper has led to many applications of efficiency measures to evaluate the performance of decision-making units like farm households. Many such studies have shown substantial inefficiency and identified the potential to improve the productivity of agricultural production in developing countries. However, Vietnamese agriculture has not received much attention in the research literature, particularly on the technical efficiency of diversified crops. Therefore, a study of a technical efficiency in Vietnamese agriculture would seem logical as a means of uncovering the reasons that hinder productivity growth of annual cropping. The identification of technical efficiency on household farms is a significant step to helping agricultural growth through productive agricultural strategy and, therefore, the measurement of technical efficiency of farms may be used to assist farmers to improve their income.

The approach of this paper offers some other important innovations over previous Vietnamese studies. Technical efficiency estimates are measured for diversified crops rather than individual crops. This is important because, a major challenge in examining production of farm households is crop diversification. The investigation of technical efficiency on rice-based diversified crops should inform the Government's diversification policy for Vietnamese agriculture, especially for

diversification from the base of rice production and better understand the behaviour of farmers using land for annual crops.

Farm households in the northern part of Vietnam are made up of small and fragmented landholdings. Landholdings in Northern Vietnam are highly fragmented as a result of a land allocation policy that equitably distributes land, accounting for varying land quality (Pham et al., 2007). In revising the Vietnamese Land Law in 1998 (Circular No. 346/1998/TT-TCDC,1998), the Vietnamese government supported farm and plot consolidation by outlining procedures and designing responsibilities for land transactions to encourage efficient land use. This paper focuses on farm households in the North to examine technical efficiency of farms in a land-scarce region to assist the land policy makers.

This paper investigates the technical efficiency of annual cropping in Northern Vietnam using data from the Vietnam Household Living Standards Survey of 2008 (VHLSS 2008). Data Envelopment Analysis is used to estimate technical efficiency and its components. Section 2 provides a theoretical framework of technical efficiency. Data and descriptive statistics are presented in Section 3. Methods of efficiency estimation are detailed in Section 4. Section 5 presents the results. The implications of the results for policy and for further research are discussed in section 6.

II.   Theoretical framework

The terms productivity and efficiency are often used interchangeably but they are not precisely the same things. Productivity, including partial factor productivity and total factor productivity, is an absolute concept and is measured by the ratio of outputs to inputs. Efficiency is a relative concept and is measured by comparing the actual ratio of outputs to inputs with the optimal ratio of outputs to inputs. The recent history of efficiency measurement begins with Farrell (1957)

who defined a measure of firm efficiency. The efficiency of a firm is defined as the actual productivity of a firm relative to maximal potential productivity. This measures the firm's success in producing as much as output as possible from a given set of inputs.

Farrell (1957) proposed that the economic efficiency of a firm or a farm consists of two components. Technical efficiency measures the ability of a farm to obtain maximal output from a given set of inputs (output-oriented measures); or use the minimum feasible amount of inputs to produce a given level of output (input-oriented measures). Allocative efficiency measures the ability of a farm to use inputs in optimal proportions given their respective prices and the production technology. Allocative inefficiency arises when inputs of production are used in proportions that do not minimise the costs of producing a given level of output. Economic efficiency is the product of technical efficiency and allocative efficiency. A firm that is both technically and allocatively efficient is said to be an economically efficient firm.

The efficiency of a firm, or the maximal potential productivity, is defined by the production frontier. Measurement of efficiency involves measurement of the distance from observed data point to that frontier (Coelli et al., 2005). The original frontier function model introduced by Farrell (1957) uses the efficient farm isoquant to measure economic efficiency (EE), and to decompose this measure into technical efficiency (TE) and allocative efficiency (AE). In the Farell framework, economic efficiency is a measure of overall performance and is equal to

$$EE = TE \times AE.$$

The technical and allocative efficiency are graphically demonstrated in Figure 1 below. This Figure is used to illustrate the concept of input-oriented measures. It is assumed that a set of farms use two inputs (x_1 and x_2) to produce output (y), under the assumption of constant returns to scale.

Figure 1: Technical and Allocative Efficiencies
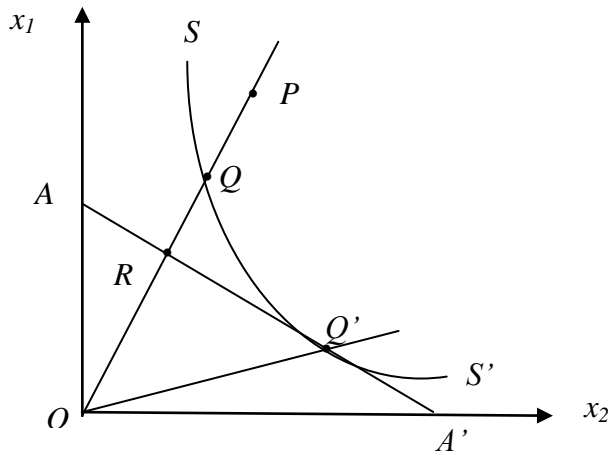
Point P is a technically inefficient farm.

Q = a technically efficient farm (any point on SS')

Q'= an allocatively efficient farm (Slope = ratio of price of x_1 and x_2)

AA'= the isocost line (Where SS' is tangential to isocost line)

SS' = the isoquant of efficiency

The unit isoquant of technically efficient input combinations is represented by SS' and permits the measurement of technical efficiency. Where the farm uses quantities of inputs defined by, for example, point P technical inefficiency can be represented by the distance QP, which is the amount by which all inputs could be proportionally reduced without a reduction of the output level. Technical efficiency is expressed in percentage terms by the ratio QP/OP, which represents the percentage by which all inputs need to be reduced to achieve technically efficient production. Technical efficiency is commonly measured by the ratio OQ/OP which is equal one minus QP/OP.

Technical Efficiency: TE = OQ/OP = 1- QP/OP

AA' is the input price ratio, represented by the slope of the isocost line. The allocative efficiency (AE) of the farm operating at P is defined to be the ratio OR/OQ since the distance RQ represents the reduction in production cost that would arise if production were to occur using the allocative (and technically) efficiency input proportion at point Q', instead of the allocatively inefficient input proportion at point P.

Allocative Efficiency: AE = OR/OQ

The total economic efficiency is defined to be the ratio OR/OP where the distance RP can also be interpreted in terms of cost reduction. We can show that the product of technical and allocative efficiency measures provides the measure of overall economic efficiency.

Economic Efficiency: EE = OQ/OP = (OQ/OP) x (OR/OQ) = TE x AE
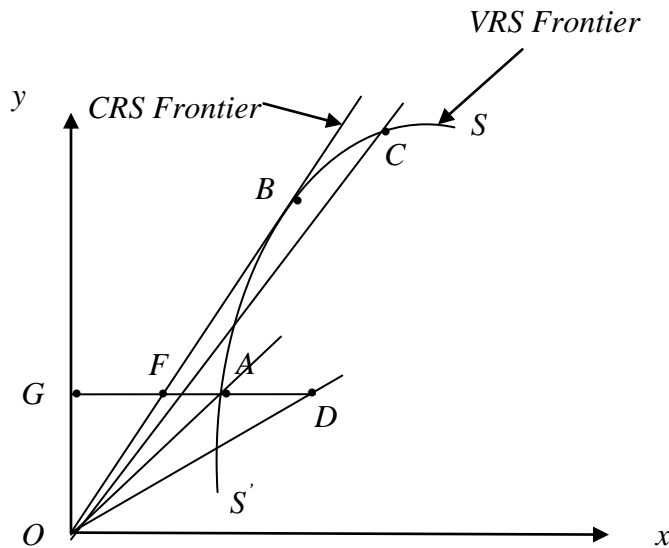
Technical efficiency (Total technical efficiency) consists of pure technical efficiency and scale efficiency where there are variable economies of scale. It is possible that a firm is both pure technically and allocatively efficient but the scale of operation of the firm may not be optimal (Coelli et al., 2005). If a firm is too small in its scale of operation, it is subject to increasing returns to scale. A firm may be too large and it may be operate within decreasing returns to scale. In both of these cases, the firm is using a variable returns to scale (VRS) technology and efficiency of the firm might be improved by changing their scale of operations. If the underlying production technology is a constant returns to scale (CRS) technology then the firm is automatically scale efficient.

A one-input (x), one-output (y) VRS production technology is depicted in Figure 2. The firms operating at points A, B, C are all VRS technically efficient (or pure technically efficient), because they are operating on the VRS production frontier (SS'). However, because the

productivity of each of these firms is equal to the ratio of their observed output and input quantities (y/x), we can see that even though these three firms are all technically efficient (pure technically efficient), they are not equally productive. This apparent inconsistency is due to the effects of scale.

Point B is operating at the most productive scale (where SS$^{'}$ is tangential to a ray from the origin, this ray is called the CRS frontier). Point A is operating in the increasing returns to scale portion of the production frontier. It could become more productive by increasing its scale of operation towards point B. Point C is operating in the deceasing returns to scale portion of the production frontier. It could become more productive by decreasing its scale of operation towards point B.

Figure 2: Constant, Increasing and Decreasing Returns to Scale

A scale efficiency measure can be used to indicate the amount by which productivity can be increased by moving to the point of the most productive, point B. Here, point D is depicted as a technically inefficient firm. The productivity of firm D (as reflected in the slope of the ray from the origin) could be improved by moving from point D to point A on the VRS production

frontier SS$^{'}$ (same output for fewer inputs). Productivity could be further improved by moving from the point A to the point B which represents scale efficiency.

The ratio of the slope of the ray OD to the slope of the ray OA is equal to the ratio GA/GD. The ratio of the slope of the ray OA to the slope of the ray OF (which also equals the slope of the ray OB) is equal to the ratio GF/GA. Thus we can clearly use distance measures to calculate the productivity differences.

The pure technical efficiency of firm at D is measured relative to the distance from point D to the VRS technology (VRS production frontier) at A, is equal to the ratio

TE_{VRS}= GA/GD (pure TE)

The scale efficiency (SE) of firm at D is measured relative to the distance from the VRS technically efficient point, A, to the CRS technology (CRS frontier) and is equal to the ratio

SE = GF/GA

The distance from the observed point D to the CRS technology is called CRS technical efficiency score (TE_{CRS} or total technical efficiency)

TE_{CRS} = GF/GD (Total TE)

It can then be used to calculate the SE of firm at D as

SE = TE_{CRS}/ TE_{VRS} = (GF/GD) / (GA/GD) = GF/GA

Efficiency has been usually referred as important economic concept to measure the economic performance of a production unit. As seen in the above definition, production efficiency is concerned with the relative performance of the process used in transforming inputs into outputs. Battese (1992); Bravo-Ureta and Pinheiro (1993) and Bravo-Ureta et al. (2007) reviewed the

concepts, models and measurement of technical efficiency and production frontier technology stimulated by Farrell (1957). They identified the importance of an economic concept of farm efficiency and the use of frontier production models to compare the efficiency of farms. In this light, this paper applies a frontier production approach (best practice frontier) to explore the technical efficiency of farm households. Due to limited data, the paper focuses on estimating technical efficiency rather than allocative and economic efficiency.

Data Envelopment Analysis (DEA) is an accepted tool in economic analysis used in many empirical studies of efficiency (Hartwich and Kyi, 1999). It seems that from 1990s to the present, studies with a DEA approach have become more prevalent. In particular, DEA is used broadly to measure technical efficiency, as well as allocative efficiency and scale efficiency.

III.   Data and Descriptive Statistics

The major data source used in this paper is the Vietnam Household Living Standard Survey 2006-2008 (VHLSS 2008). VHLSS is a multi-purpose national survey investigating living standards in Vietnam. The survey was conducted by the General Statistics Office of Vietnam (VGSO) with technical support from the World Bank. The Vietnam Household Living Standard Survey series from 2002 to 2010 was based on a master sample for sample selection. The master sample was a random sample of households from the 1999 Population Census enumeration areas. The target population of the VHLSS comprised of the civilian, non-institutionalised population of Vietnam (VHLSS, 2008b).

This study uses farm-level, cross-sectional data for the year 2008, for annual crops selected from two regions in Northern Vietnam. The selected data consist of farm households collected by VHLSS 2008 in four provinces: Phu Tho, Yen Bai, Hung Yen and Thai Binh. These provinces were chosen for three reasons. First, they represent different ecological regions in the northern

part of Vietnam. Phu Tho and Yen Bai provinces are located in the North-East, Hung Yen and Thai Binh in the Red River Delta region. Also, Phu Tho and Yen Bai are located in the centre of the mountainous provinces in the North. They were chosen for the sample because the ability of farmers to speak Vietnamese is high in Phu Tho and Yen Bai. The proportion of farm heads who could speak Vietnamese in Phu Thu and Yen Bai is 100 and 99.4 per cent, respectively, compared to other provinces where the proportion is lower. In Lai Chau, for example, 70 per cent of farm heads speak Vietnamese. The proportion of farm heads who can read and write in Phu Tho is 98 per cent compared to 61 and 69 per cent in Lai Chau and Dien Bien, respectively. These proportions also are extremely high in the delta areas. Second, outputs of farms in the sample are similar. Farms in these four provinces mainly grow rice, starchy crops, vegetables and industrial annual crops in land for annual crops. Finally, farms in the sample were chosen randomly. The sample was collected by VGSO from 161 areas and 179 communes.

In the study area, there were 106, 77, 99 and 165 farms listed on the VHLSS 2008, located in Phu Tho, Yen Bai, Hung Yen and Thai Binh, respectively. In total, there are 447 farms in the sample. Detailed crop input-output data for individual farms were selected for annual crops. From the 447 farms, there were 10 farms which did not use family labour for agricultural activities that are excluded from the sample. This means that in these farms, the value of inputs "family labour" was equal to zero, perhaps as a result of a measurement error. Moreover, there were 14 observations considered as outliers. These were excluded because compared with other observations in the sample, their ratio of total value of outputs and total value of inputs were extremely different from others. This paper used Data Envelopment Analysis (DEA) to estimate technical efficiency. DEA can be sensitive to extreme points, especially when data may be

contaminated by measurement error therefore outliers are excluded. Finally, 423 farms were used to estimate technical efficiency.

Table 1: Summary statistics for the sample farms

Inputs/Output	Units	Minimum	Maximum	Mean	Std. Deviation
Land area cropped	square metres	1,010	24,280	5,098	3,331
Seed	1000 VND	24	2,424	384	295
Fertiliser	1000 VND	191	11,040	1,825	1,329
Pesticide	1000 VND	0	2,611	407	349
Equipment	1000 VND	0	4,544	684	514
Other cost	1000 VND	0	3,384	384	431
Family labour	hours for farming	117	6,499	1,438	1,029
Output (the total value of crops)	1000VND	2,292	40,797	11,253	6,813

Source: Based on VHLSS (2008).

Farms in the sample differ in size, intensity of input use and output. Table 1 shows the descriptive statistics of the inputs and output. The sampled farms are quite small, with an average size of only half of a hectare. The average cultivated land area used was 5,098 square metres, with a minimum area of 1,010 square metres and maximum area of 24,280 square metres.

The sampled farms planted rice, starchy crops (including maize, sweet potatoes, cassava), many kinds of vegetables and annual industrial crops (such as peanuts, soybeans, sesame seeds). These four groups of crops are classified in this paper as "rice", "starchy crops", "vegetable" and "annual industrial crops".

Table 2: Crops sold in markets

	Rice	Starchy crops	Vegetables	Annual industrial crops
Number of farms producing crops	413	226	290	113
Number of farms consuming all output	161	109	149	30
Number of farms selling all output	0	17	3	18
Percentage of crop sold				
Mean	23	37	29	61
Min	0	0	0	0
Max	97	100	100	100

Source: Based on VHLSS (2008).

Traditionally, rice is the main crop produced in Vietnam and is planted in every province. In the sample, rice is the most popular crop among annual crops. As Table 2 shows, there are 413 of the 423 farms producing rice compared with 226 farms growing groups of starchy crops, 290 vegetables and 113 annual industrial crops, out of the 423. Of the 413 farms producing rice, 161 farms cultivate rice only for consumption, while none of farms sell all their rice production. Table 2 shows that farms sell on average of 23 per cent their output of rice and 37 per cent output of starchy crops, 29 per cent vegetable, and 61 per cent output of annual industrial crops. Clearly, farm consumption is very important in these farms but a part of output is marketed.

IV.   Methods

Technical efficiency relates to the degree to which a farmer produces the maximum feasible output from a given bundle of inputs, or uses the minimum feasible amount of inputs to produce a given level of output. These two definitions of technical efficiency are known as output-oriented and input-oriented efficiency measures, respectively. Coelli, et al. (2002) suggested selecting between an input-oriented DEA model or output-oriented DEA model according to

which quantities (inputs or outputs) the manager of a farm has more control over. As, farmers have more control over inputs than output, input-orientated DEA models are used in this paper.

The efficiency of a farm relative to other farms is calculated by forming an index of the ratio of a weighted sum of outputs to a weighted sum of inputs. With the DEA approach, multiple inputs and multiple outputs are reduced to a single virtual input and virtual output and finally to a single summary relative efficiency score. DEA proposes that each farm should be allowed to adopt a set of weights which shows it in the most favourable light in comparison to the other farms. This means that the values of weights for outputs and inputs (*u's* and *v's*) are not established from empirical data but are estimated from the model with the help of programming techniques (Hartwich and Kyi, 1999).

We have data on K inputs and M outputs of N farms. The ratio of output to input then measures the efficiency of a particular farm in the sample. For example, the efficiency of farm *i* would be computed according to:

$$E_i = u_1 y_{11} + u_2 y_{21} + ... + u_m y_{mi} \,/\, v_1 x_{11} + v_2 x_{21} + ... + v_j x_{ji} = \frac{\sum_1^M u_{mi} y_{mi}}{\sum_1^K v_{ji} x_{ji}} \qquad (1)$$

where E_i is the technical efficiency of farm *i*

   u_m is the weight given to output *m*

   y_{mi} is the amount of output m from farm *i*

   v_j is the weight given to input *j*

   x_{ji} is the amount of input j on farm *i*

Under the restriction that each farm's efficiency is judged against its individual criteria (individual weighting system), the efficiency of a farm can be obtained as a solution to the

following problem: maximise the efficiency of farm i, under the restriction that the efficiency of all farms must be less than or equal to one (farm must be on or below the production possibility frontier). The algebraic model is the fractional model as follows:

$$\text{Max}_{u,y} \ E_i = \frac{\sum_1^M u_{mi} y_{mi}}{\sum_1^K v_{ji} x_{ji}} \qquad (2)$$

subject to: $\dfrac{\sum_1^M u_{mi} y_{mi}}{\sum_1^K v_{ji} x_{ji}} \leq 1$ for each farm

$$u_m, \ v_j \geq 0$$

The solution of the above model in relation to farm i, gives the value of efficiency of a farm i, and the weights, u and v, leading to efficiency E_i. However, one problem with this particular ratio formulation is that it has an infinite number of solutions. To solve the model, it is first necessary to convert it to linear form so that the methods of linear programming can be applied. A transformation for fractional programming allows the introduction of a constraint $\sum vx_i = 1$, meaning that the sum of all inputs is 1. The model is as follows

$$\text{Max}_{u,v} \ E_i = \sum_1^M (u_{mi} y_{mi})$$

Subject to: $\sum_1^M (u_{mi} y_{mi}) - \sum_1^K (v_{ji} x_{ji}) \leq 0$, for each unit $\qquad (3)$

$$\sum_1^K (v_{ji} x_{ji}) = 1$$

$$u_m, \ v_j \geq 0$$

The linear programming problem must be solved N times, once for each unit in the sample. A value of technical efficiency (E) is then obtained for each farm.

Using the duality in linear programming, an equivalent envelopment form of this problem can be derived

Min $_{\theta,\lambda}$ θ,

Subject to: $-y_i + Y\lambda \geq 0$ (4)

$\theta x_i - X\lambda \geq 0$

$\lambda \geq 0$

where θ is a scalar and λ is a vector of N constraints. X is an input matrix for N farms and Y is an output matrix for N farms.

This envelopment form involves fewer constraints than the multiplier form (j+m < n+1), and thus is generally the referred form to solve. The value of θ obtained is the efficiency score for the i-th farm. It satisfies $\theta \leq 1$, with the value of 1 indicating a point on the frontier and hence a technically efficient farm.

The input oriented DEA model under the assumption of constant returns to scale (CRS) and the DEA model under the assumption of variable returns to scale (VRS) are used to estimate total technical and pure technical efficiency, respectively, of the sample farms. We have data on K inputs and M outputs of N farms. x_i is an input vector for ith farm and y_i is an output vector for the ith farm, X is an input matrix for N farms and Y is an output matrix for N farms.

The input oriented constant return to scale DEA model for calculation of total technical, efficiency is estimated as:

Min $_{\theta,\lambda}$ θ,

Subject to $-y_i + Y\lambda \geq 0$ (5)

$\theta x_i - X\lambda \geq 0$

$\lambda \geq 0$

where θ is the total technical efficiency score of *ith* farm and λ represents Nx1 constants.

Y is the output matrix for N farms

X is the input matrix for N farms

For the *i* th farm, input and output data are represented by the column vectors x_i and y_i, respectively.

The DEA model with assumption of constant returns to scale is only appropriate when all farms are operating at optimal scale. However, this is not possible in agriculture due to many constraints. The use of the constant returns to scale model when all farms are not operating at optimal scale results in measures of technical efficiencies that are confounded by scale efficiencies. To avoid this problem, the variable returns to scale model is used by adding convexity constraints to constant returns to scale DEA model. It allows the calculation of technical efficiency free from the effects of scale efficiencies. The input oriented variable return to scale DEA model for calculation of pure technical efficiency is estimated as:

Min $_{\theta,\lambda}$ θ,

Subject to $\qquad$ -y_i +Y$\lambda \geq 0$ $\qquad\qquad\qquad$ (6)

$\qquad\qquad\qquad$ $\theta x_i - X\lambda \geq 0$

$\qquad\qquad\qquad$ N1/ $\lambda = 1$

$\qquad\qquad\qquad$ $\lambda \geq 0$

Where:

θ represents the pure technical efficiency of *ith* farm

N1/ λ = 1 represents a convexity constraint which ensures that an inefficient firm is only benchmarked against firms of a similar size.

DEA is a deterministic method used to estimate technical efficiency. It means that it does not explicitly incorporate a random error term and the overall deviation from the frontier is interpreted as inefficiency. The use of DEA provides an opportunity to decompose the total technical efficiency into pure technical and scale efficiency. Pure technical efficiency relates to management practices while scale efficiency relates to the residuals. Thus the results of pure technical and scale efficiency enable better understanding of the nature of technical efficiency of farms belonging to different farm size groups.

In calculating of scale efficiency, the method suggested by Coelli et al. (2005) is applied. Scale efficiency can be obtained residually by dividing the total technical efficiency (TE_{CRS}) by pure technical efficiency (TE_{VRS})

$$SE = \quad TE_{CRS}/ TE_{VRS}$$

SE=1 indicates scale efficiency or constant return to scale (CRS) and SE <1 indicates scale inefficiency. Scale inefficiency arises due to the presence of either increasing returns to scale or decreasing return to scale. DEA also provides means to assess whether a particular firm is operating in an area of increasing returns to scale or of decreasing returns to scale. This may be determined by running another DEA model under non increasing returns to scale.

The input-oriented VRS DEA model under non-increasing returns to scale (NIRS) is estimated as: $\quad\quad\quad$ Min $_{\theta, \lambda}$ θ,

Subject to $\quad\quad\quad$ $-y_i + Y\lambda \geq 0$ $\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad$ (7)

$\quad\quad\quad\quad\quad\quad$ $x_i - X\lambda \geq 0$

$$N1/\lambda \leq 1$$

$$\lambda \geq 0$$

The nature of the scale inefficiency for a particular farm, due to increasing returns to scale or due to decreasing returns to scale, can be determined by seeing whether the non increasing returns to scale technical efficiency score is equal to the variable return to scale technical efficiency score. If they are unequal, then increasing returns to scale exist but if they are equal, decreasing returns to scale exists for the farm.

Bootstrapping is used to correct for the bias in DEA estimators and establish confidence intervals. Ignoring the statistical noise in the estimation can lead to biased DEA estimates and misleading results because all the deviations from the frontier are considered to be inefficient. Simar and Wilson (1998, 2000) argued that bootstrapping is the most currently feasible method to establish the statistical properties for DEA estimators. This paper uses the approach of Simar and Wilson (1998, 2000), a smoothed bootstrap procedure, to test the bias in DEA estimators and establish their confidence intervals. Recent advances in DEA literature include using bootstrap methods to establish the confidence intervals of technical efficiency. The bootstrap method in Simar and Wilson (2000) has been applied empirically in several studies of farm efficiency (Brümmer, 2001; Latruffe et al., 2005 and Vu, 2008).

DEA models and the bootstrap approach were estimated in this paper using the package FEAR developed by Wilson (2009). Using FEAR, the input-based technical efficiencies with constant returns to scale, variable returns to scale and the bias and the confidence interval of the input-based technical efficiency with variable returns to scale were estimated.

V. Technical efficiency estimation results

The results derived from DEA models are presented in Table 3. It is evident from the results that total technical efficiency indices (TE_{CRS}) range from 0.33 to 1.0, with a mean of 0.80. The mean pure technical efficiency (TE_{VRS}) of the sample farms is 0.83, with a low of 0.43 and a high of 1.00. The results imply that if the average sample farm operated at full efficiency level it could reduce, on average, its input use by 20.5 per cent $\left(\dfrac{1}{0.83}-1\right)$ and still produce the same level of outputs.

Table 3: Data Envelopment Analysis estimates

	TE_{CRS}	TE_{VRS}	SE	Bias-corrected TE	Lower bound	Higher bound
Mean	0.80	0.83	0.95	0.76	0.70	0.83
Std. Dev	0.15	0.14	0.06	0.12	0.10	0.14
Min	0.33	0.43	0.63	0.39	0.35	0.42
Max	1.00	1.00	1.00	0.95	0.92	0.99

Note: Lower and Upper bound apply to the Bias corrected TE

Using DEA to estimate technical efficiency may have biases in efficiency scores because in the model, the true production frontier is unknown and the points on the observed production function may be inefficient in the presence of the true production frontier. Using bootstrap method in Wilson (2009a, b), bias-corrected TE scores were estimated. As Table 3 shows, the mean of bias-corrected TE is 0.76 which is lower than the initial TE score. This means that the amount of input saving is 31.6 per cent $\left(=\dfrac{1}{0.76}-1\right)$ after correcting for the bias. In the same way, a farm can reduce their inputs on average from 20.5 per cent to 42.9 per cent with a 95 per

cent confidence interval. It implies that the potential amount of inputs that can be saved is considerable.

The decomposition of the total technical inefficiency measure produced estimates of 17 per cent pure technical inefficiency and 5 per cent scale inefficiency (Table 3). By eliminating scale inefficiency the farms can increase their average technical efficiency level only moderately from 80 to 83 per cent.

Table 4: Summary of returns to scale results (n=423)

			Output (1000 VN Dong)		
Characteristics	Number of farms	Percentage	Mean	Min	Max
CRS	159	38	13,424	2,292	40,797
IRS	204	48	7,534	2,429	18,629
DRS	60	14	18,149	3,202	38,828

The results of this study indicate that the mean scale efficiency of the sample farms is 0.95, with the minimum of 0.63 and a maximum of 1.0. The results reported in Table 4 are the percentages of farms which have increasing returns to scale (IRS), decreasing returns to scale (DRS) and constant returns to scale. The results indicate that in the sample, 38 per cent of farms are scale efficient while the remaining 62 per cent are scale inefficient. Among scale inefficiency farms, 204 farms (representing 77.27 per cent) have increasing returns to scale and 60 farms (representing 22.73 per cent) have decreasing returns to scale. These results reveal that increasing returns to scale outweighs decreasing returns to scale, suggesting a large number of farms should increase their scale to gain scale efficiency.

Table 5: Comparison with other studies

Study	Country	DRS	CRS	IRS	TE pure	SE
This study	Vietnam	14	48	38	0.83	0.95
Vu (2008)	Vietnam	18	23	59	0.78	0.89
Krasachat (2004)	Thai Land	19	32	49	0.74	0.96
Wadud and White (2000)	Bangladesh	63	16	21	0.86 and 0.91	0.91
Coelli et al. (2002)	Bangladesh	58.06	10.90	31.04	0.66	0.93
		38.18	8.26	53.56	0.69	0.94
Brádik (2006)	Indonesia	66	12	22	0.60 and 0.77	0.90
		62	16	22		
Javed (2009)	Pakistan					
Small size		0	17	83	0.87	0.79
medium		10	17	73	0.79	0.94
large		42	24	34	0.81	0.94
Dhhungana (2004)	Nepal	42	11	47	0.82	0.93

The mean of scale efficiency among sampled farms is 0.95. Assessing the scale efficiency results, it can be concluded that scale inefficiency is not the major source of total farm inefficiency. This result is consistent with the literature on scale efficiency of the rice-based farms indicating scale efficiency is larger than pure technical efficiency (as can be seen in Table 5).

The pure technical efficiency of the sample is 0.83. This estimated mean level of technical efficiency is higher than other estimates in the literature on technical efficiency for producing only rice in Vietnam. For example, Vu (2008) estimated the technical efficiency of rice production in all regions of Vietnam to be 0.78 while Huynh and Yabe (2011) estimated it to be 0.81. This suggests higher technical efficiency in diversified crops.

VI. Conclusion

The result of this paper indicate the importance of crop diversification in farming systems that produce diversified crops to cover subsistence and cash needs. In the sampled farms, farms favoring market-oriented products such as annual industrial crops, have greater efficiency than farms focusing on staple crops such as rice and maize. These results show the relevance of identifying the underlying determinants for effective policy design. For example, a policy that is targeted at increasing land use intensity may be consistent with the context of subsistence rice production, while a policy which focuses on efficiency in cropping of farm households in a context of market-orientation would focus on the importance of crop diversification in a combination of rice and cash crops. In this context, even though rice is the principle crop for food security, farm households in Northern Vietnam should not specialise in rice.

There is technical and scale inefficiency of annual cropping among farm households in the North. Thus there is room to increase efficiency. A further study should be conducted to investigate the determinants of technical efficiency.

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