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An Analysis of Disparity between Korean Farms: measuring production efficiencies by farm size

Gim, Uhn-Soon

농가계층간 격차 확대의 비교 분석: 생산기술효율의 계측

김은순

요 약

이 연구는 근래 한국 농가계층간에 경쟁력 수준의 격차가 확대되는 원인을 생산기술효율 측면에서 계측하고 비교분석하는 것을 목적으로 한다. 비모수적 접근방법을 사용하여 농지규모계층별 농가의 생산기술효율을 측정하고, 이는 다시 순수기술효율과 규모효율로 분리 계측되어 농가계층간 격차의 원인을 비교분석하였다. 1998-2002년 기간에 한국농가평균 순수기술효율은 0.54, 규모효율은 0.93으로 계측되었고, 대농층으로 갈수록 순수기술효율은 높은데 비해 규모효율은 낮게 나타났다. 그러나 5년(1998-2002년)기간 동안 대농층일수록 순수기술효율과 규모효율 모두 여타의 계층보다 빠르게 증가하는 추세를 보였으며, 이는 결과적으로 시간이 경과함에 따라서 대농층과 여타농과의 기술의 격차가 확대되고 있는 것으로 해석된다.

핵심어 : 농가의 격차, 생산의 기술효율, 규모효율

Ⅰ. Introduction

One of the big issues faced with Korean agricultural economy in recent decades is the widening income disparity between small scale farms and large scale farms in agricultural sector.

충남대학교 농업생명과학대학 농업경제학과 (Department of Agricultural Economics, Chungnam National University, Daejeon 305-764, Korea)
교신저자 : 김은순 (E-mail : ugim@cnu.ac.kr, Tel : 042-821-6750)

Many researches have been done to examine the reasons for the issue, particularly it has been debated with mainly focused on relative low output prices and high input costs in farming after the economy crisis in Korea, which has been worsening by globalization or open market economy under WTO. Yet rarely few researches have been done to analyze the issue in view of production efficiency between farms.

This study intends to analyze sources of the widening disparity between Korean farms in view of production efficiencies in Korean farm households, particularly measuring technical efficiency and scale efficiency by farm size. Data envelopment analysis(DEA) as a non-parametric analysis[1] is utilized to estimate output technical efficiency, where technical efficiency is decomposed into "pure" technical efficiency and scale efficiency.

Measures of production efficiency of farm households are derived and calculated using the output distance function by way of linear programming. OnFront 2.0 computer program is used for measuring the efficiencies.

The panel data of Farm Household Economy Suvey by KNSO(Korea National Statistical Office) in the recent 5 years, 1998-2002, are used for the analysis. The size of the panel data set is 2348 of farm households who had the serial data during the five years. Farm households are classified into five groups depending on farmland size.

In the next section, theoretical model is briefly explained, and the empirical data and results will be followed. Finally concluding remarks will close the discussion.

II. Model

Data Envelopment Analysis(DEA)

Data envelopment analysis(DEA) is the non-parametric mathematical programming approach to production frontier estimation. The purpose of DEA is to construct a non-parametric envelopment frontier over the data points such that all observed points lie on or below the production frontier.

A farm household in Korea as a decision making unit(DMU) produces several outputs by applying several inputs, and at the same time some undesirable outputs such as agricultural pollutants are produced. It is assumed there is no regulation[2] for emitting agricultural pollution from farm production.

We label desirable outputs as $y \in R^m_+$,

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1) An advantage of nonparametric methods for measuring production efficiency is that they do not need to make assumptions about the production functionor producer behavior. They have been demonstrated to treat quantitative data effectively. Coelli et al. (1998) discuss the differences between parametric and nonparametric methods.

2) This is referred to 'free disposability' or 'strong disposability', which implies pollution can be emitted without any costs (to be treated) to the bearer. Here, however, we do not intend to go further to 'weak disposabilty' which implies to regulate polluters to bear some costs.

undesirable outputs as $w \in R^{I}_{+}$, inputs $x \in R^{n}_{+}$, where Y ($=y_1, y_2, \cdots, y_m$) is the observed output matrix, W ($= w_1, w_2, \cdots, w_I$) is the observed undesirable output matrix , and X ($=x_1, x_2, \cdots, x_n$) is the observed input matrix. We define F(.) as the output production set, assumed to be closed bounded, and convex. Then non-parametric representation of the production possibility set of each farm household or DMU is defined as follows, under constant returns to scale(CRS):

$$F^C(x, y, w) = \{(y, w) : ZY \geq y, ZW \geq w, ZX \leq x, Z \geq 0\} \quad (1)$$

where, Z denotes k ×1 density vector implying existence of k DMUs.

The CRS linear programming problem can be easily modified to account for variable returns to scale(VRS) by adding the convexity constraint $\sum Z=1$ to (1):

$$F^V(x, y, w) = \{(y, w) : ZY \geq y, ZW \geq w, ZX \leq x, \sum Z=1, Z \geq 0 \} \quad (2)$$

Farrell Output Distance Function: under CRS

To measure production efficiencies for a farm household or a DMU, we use the output distance function. The output distance function is usually measured by comparing the actual output vector over maximum output vector given input vectors. The output distance function considering pollutants, under constant returns to scale(CRS), is defined as follows:

$$D^C(x, y, w) = \inf \{ \lambda : ((y, w)/ \lambda) \in F^C \} \quad (3)$$

The value obtained will be the efficiency score for the i-th DMU. It will satisfy value $\lambda \leq 1$, with a value of 1 indicating a point on the production frontier and hence a technically efficient DMU, according to the Farrell(1957) definition (EMQ, 1998).

Farrell Output Distance Function: under VRS

The CRS(constant returns to scale) assumption is only appropriate when all DMUs are operating at an optimal scale(i.e., one corresponding to the flat portion of the long-run average cost curve). Imperfect competition, constraints of finance, etc. may cause a DMU to be not operating at optimal scale. Banker, Charnes, and Cooper(1984) suggested an extension of the CRS DEA model to account for VRS(variable returns to scale) situation. The use of the CRS specification when not all DMUs are operating at the optimal scale, will result in measures of technical efficiencies(TE) which are confounded by scale efficiencies(SE). The use of the VRS specification will permit the calculation of TE devoid of these SE effects(EMQ, 1998).

$$D^V(x, y, w) = \inf \{ \lambda : ((y, w)/ \lambda) \in F^V \} \quad (4)$$

Calculation of Scale Efficiencies

Many studies have decomposed the TE

scores obtained from a CRS DEA into two components, one due to scale efficiency and one due to "pure" technical efficiency. If there is a difference in the two TE scores for a particular DMU, then this indicates that the DMU has scale inefficiency, and that the scale inefficiency can be calculated from the difference between the VRS TE score and the CRS TE score (Coelli, 1996).

$$SE(x, y, w) = D^C(x, y, w) / D^V(x, y, w) \quad (5)$$

That is, the CRS technical efficiency measure is decomposed into "pure" technical efficiency and scale efficiency. Scale inefficiency is defined as 1-SE(x, y, w) = 1, which implies the most possible reduction rate of production cost if a DMU produces in an optimal scale.

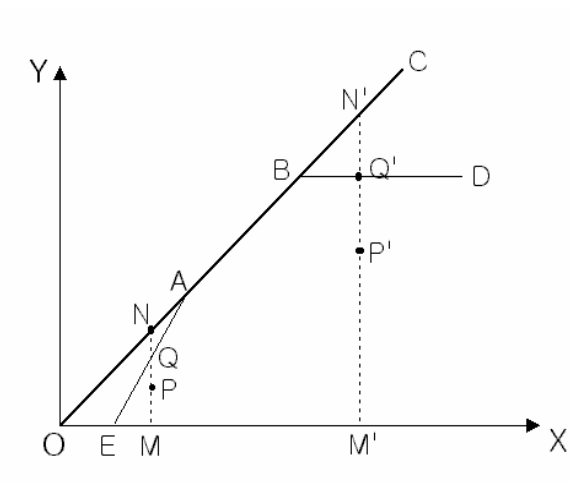

Fig. 1. Calculation of Technical and Scale Efficiencies in DEA

Note: Line OABC implies production frontier under CRS, where EABD implies VRS, EA implies IRS, and OABD implies NIRS.

Fig. 1 depicts production frontier under different technology with a case of one input and one output. Line OABC implies production frontier under CRS, where EABD implies VRS, EA implies IRS(increasing returns to scale), and OABD implies NIRS(non-increasing returns to scale). At point N, a DMU, who is produced on the production frontier, is technically efficient. i.e D^c = 1. However at point P, a DMU is technically inefficient, i.e. D^c < 1. At point P, D^c (TE under CRS) is defined as MP/MN and D^v (TE under VRS) is defined as MP/MQ. Hence scale efficiency(SE) is defined as MQ/MN.

III. Empirical Data

The panel data of Farm Household Economy Suvey by KNSO(Korea National Statistical Office) in the recent 5 years, 1998-2002, are used for the analysis. The size of the panel data set is 2348 of farm households who had the serial data during the five years. The farm household data used in the empirical analysis include cultivated land, farming labor, capital assets, good output, bad output, i.e. pollutants, and all variable inputs. Gross farm receipts of each farm is substituted as the good outputs because many different farm products can not be quantified as the same metric unit. As the undesirable outputs from farm production, pollution amounts of nitrogen(N) and phosphorus(P) by each farm are counted through the overuse of chemicals(fertilizer and pesticide) and livestock breeding(Refer Gim et al. 1999). Capital assets are counted as the agricultural capital stocks including farm building, machinery, large animals and fruit trees. Farming labor includes family labor hours plus yearly hired labor hours. Variable inputs include all kinds of purchased inputs for farming such as fertilizer, pesticides, hired labors, electricity, and other miscellaneous materials.

Farm households are classified into five groups depending on farmland size: less than 1 hectare, 1-2 hectares, 2-3 hectares, 3-5 hectares, more than 5 hectares.

Table 1 shows the summary data of the Farm Household Economy Suvey data in year 2002 by the farmland size group. First, it is noteworthy that larger the farmland size shows smaller the land productivity. Especially, land productivity in the smallest farm size group is about 4-6 times higher than the rest farm groups. This implies the smallest farms use the most limited resource, i.e. land, so intensively comparing to larger size farms.

Unlike the land productivity, labor productivity and capital productivity are higher in the larger farm size groups. Labor productivity in the largest farm size group is about 3 times higher than in the smallest farm size group. Capital productivity is not drastically different between farmsize groups comparing to the other two productivities.

Ⅳ. Results

Decomposition of Output Technical Efficiencies

CRS technical efficiency measure is decomposed into "pure"technical efficiency and scale efficiency as discussed in equation (5). Table 2 shows the three efficiency measures calculated by applying the Korean farm household survey data over 1998-2002. Over the recent 5 years(1998-2002),

Table 1. Summary of Raw Data by Farm Size Group, Year 2002

Farm Size	Productivity			Pollution Emission		Total Labor Input
	Land	Labor	Capital	N	P	
(unit)	(won/pyeong)	(won/hour)	(won/won)	(ton)	(ton)	(hours)
-1ha	20,114	13,696	1.74	0.021	0.0022	639
1-2ha	4,773	18,412	1.77	0.047	0.0032	1,297
2-3ha	4,021	21,475	1.76	0.070	0.0055	1,622
3-5ha	3,675	27,057	2.04	0.091	0.0079	1,939
5ha+	3,170	39,929	2.05	0.131	0.0101	2,012
Average	10,692	18,551	1.79	0.046	0.0029	1,152

* 1 ha(hectare) = 3,025 pyeong

** Gross output in each group can be calculated by the labor productivity multiplied by the total amount of labor input.

Data Source: KNSO, 'Farm Household Economy Survey' Raw data, 2003.

average technical efficiency(TEcrs) including all farm groups is 0.505, implying 49.5% of technical inefficiency exists, which in turn implies 49.5% of technical efficiency could be improved in overall Korean farms. In general larger farm size group shows less technically inefficient. The technical inefficiency may be caused by either pure technical inefficiency or non-optimal farm size operation as explained in the above. The technical efficiency measure of the largest farm size group was 0.54 over 1998-2002, whereas the technical efficiency measure of the smallest farm size group was 0.49 over the same period, hence there exists about 5% efficiency gap between the most efficient farm size group and the least efficient farm size group.

1) Pure Technical Efficiencies (TEvrs)

Over 1998-2002, the pure technical efficiency measures(TEvrs) were averaged 0.543 including all farm groups, implying 45.7% pure technical inefficiency exists in overall Korean farms. By farm size group, lager the farm size shows higher the pure technical efficiencies(TEvrs) : The TEvrs of the largest farm size group (5ha+) was 0.724 over 1998-2002, whereas the TEvrs of the smallest farm size group(-1ha) was 0.523 over the same period, hence there exists about 20% efficiency gap between the most technically efficient group and the least efficient group.〈Table 2〉

2) Output Scale Efficiencies(SE)

Unlike the pure technical efficiency, scale efficiency(SE) measure showed quite close to 1 overall. On the average over 1998-2002, output scale efficiency is measured 0.93 including all farm groups, implying in general 7% of scale inefficiency exists in overall Korean farms. In turn, 7% of long run average production costs can be saved in Korean farms by operating all the individual farms at the optimal farm scale.

Table 2. Decomposition of Output Technical Efficiency Measures by Farm Size, Mean 1998-2002

Farm Size	TEcrs	SE	TEvrs
-1ha	0.494(0.513)	0.944(0.950)	0.523(0.540)
1-2ha	0.507(0.526)	0.951(0.964)	0.533(0.545)
2-3ha	0.515(0.537)	0.907(0.923)	0.568(0.582)
3-5ha	0.514(0.526)	0.861(0.867)	0.597(0.607)
5ha+	0.540(0.538)	0.745(0.736)	0.724(0.731)
Average	0.505(0.524)	0.930(0.940)	0.543(0.557)

* Numbers in the parentheses imply the efficiency measures excluding 2002 data. In year 2002 there was heavy rainfall including flooding, which may cause all the efficiency measures in year 2002 show somewhat outliers.

By farm size group, larger the farm size showed smaller the scale efficiency(SE) in general. Particularly, over the period 1998-2002, average farms operated in 1-2 hectare farmland size showed the highest SE 0.951, whereas the largest farm size group(5ha+) showed the smallest SE 0.724 〈Table 2〉. In another word, the largest farm size group can decrease long run average costs by 27.6% through operating all the individual farms at the optimal scale, whereas the 1-2ha farm size group can decrease long run average costs by 5% only. This has important implication in Korean agriculture. Average farmland size of

Korean farms is around 1.5 hectares, hence most average farms are operating close to optimal farm size, whereas higher rates of farms in larger farm size groups are operating at less optimal size[3), either at IRTS or DRTS[4).

Trends of TEvrs and SE

Fig. 2 shows the time trends of pure technical efficiencies(TEvrs) over 1998-2002 by farm size group. For the last five years, TEvrs had been slowly increasing in most farm size groups over time except year 2002. (In year 2002, there were heavy rainfalls over the year, which might cause all the efficiency measures decreased in 2002.) It is also noteworthy that over the last five years the increasing rate of TEvrs in the largest farm size group(5 ha+) is somewhat faster than the rests, which leads the technical efficiency gap between the largest farm size group and the rests had become wider.[5)

Fig. 3 shows the time trends of scale efficiencies(SE) over 1998-2002 by farm size group. Over the last five years, most farm size groups showed increasing trend of SE except year 2002. Particularly, SE in the largest farm size group(5ha+) had been increasing more rapidly than the rests, which implies more farms had been operating in optimal farm size in the largest farm group over time. However, the SE in the smallest farm size group(-1ha) was stagnant over the period. As a result, the scale efficiency gap between the largest farm size group and the rests had become narrower over time. This result along with the widening gap of the TEvrs between the largest farm size group and the rests as seen in the above has leaded that the largest farms had become more competitive in terms of both technical efficiency and scale efficiency over time, which may partially explain the widening (income) disparity between large farms and small farms in Korean agriculture over the recent decade.

Ⅴ. Concluding Remarks

The objective of this study was to analyze the sources of widening (income) disparity between Korean farms in view of production efficiencies in Korean farm households. Data envelopment analysis(DEA) as a non-parametric analysis was utilized to estimate output technical efficiency,

[3) However, the question such that how much rates of farms are operating at the optimal size(constant returns to scale), increasing returns to scale(IRTS), or decreasing returns to scale(DRTS) can not answered until we observe each farms. This will be the future work.

[4) A farm operating at IRTS(increasing returns to scale) needs to enlarge farm scale since it operates under capacity including farmland, family labor, capital assets, etc., whereas a farm at DRTS(decreasing returns to scale) needs to reduce farm scale due to operating over capacity .

[5) This trend may explain partially the widening income disparity between large farms and small farms in Korean agriculture over the recent decade. Yet we should be careful to judge with only five year experience.

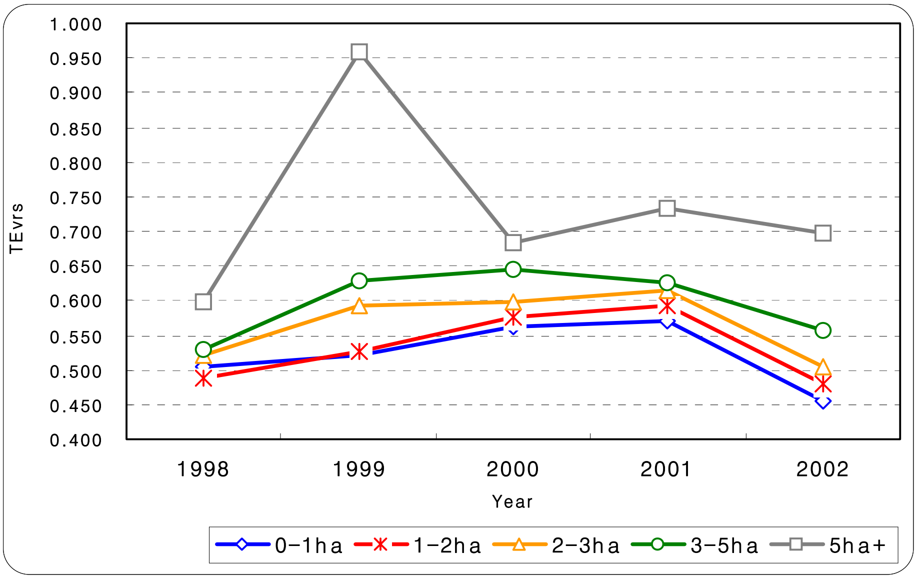

Fig. 2. Trends of Pure Technical Efficiencies(TEvrs) by Farm Size over 1998-2002

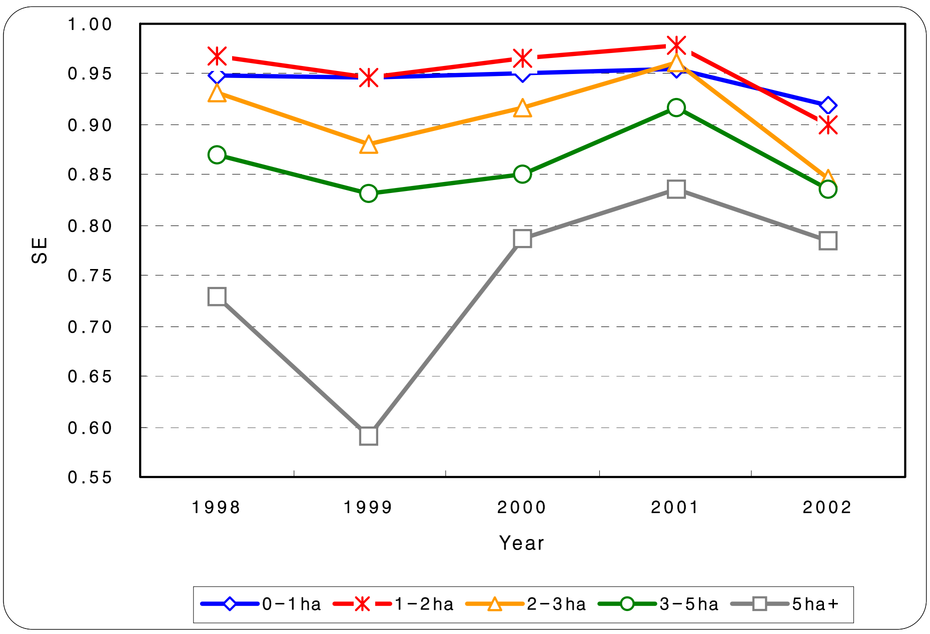

Fig. 3. Trends of Scale Efficiencies(SE) by Farm Size over 1998-2002

where technical efficiency is decomposed into "pure" technical efficiency and scale efficiency. Farm households are classified into five groups depending on farmland size. The panel data of Farm Household Economy Suvey by KNSO (Korea National Statistical Office) in the recent 5 years, 1998-2002, were used for the analysis.

Over the recent 5 years(1998-2002), average output technical efficiency(TEcrs) including all farm groups is 0.505, implying 49.5% of technical inefficiency exists. In general larger farm size group showed less technically inefficient. The technical inefficiency may be caused by either pure technical inefficiency or non-optimal farm size operation.

During the last five years, average output scale efficiency was measured 0.93 including all farm groups, implying in general 7% of scale inefficiency exists in overall Korean farms. That is, at the most 7% of long run average production costs can be saved in Korean farms by operating all the individual farms at the optimal farm scale. In general larger farm size group showed lower scale efficiency. Yet, most farms around average farm size(1-2ha) were operating close to optimal farm size, whereas higher rates in larger size farms were operating at non-optimal scale, either at IRTS or DRTS.

Over the last five years, "pure" technical efficicency(TEvrs) was slowly increasing in most farm size groups except 2002, yet the increasing rate of TEvrs in the largest farm size group(5 ha+) was somewhat faster than the rests, which leads the technical efficiency gap between the largest farm size group and the rests had become wider.

Likewise, over the last five years except year 2002, most farm size groups showed increasing trend of SE. Particularly, SE in the largest farm size group(5ha+) had been increasing more rapidly than the rests, which implies more farms had become operating at the optimal farm size in the largest farm group over time. As a result, the scale efficiency gap between the largest farm size group and the rests had become narrower over time.

In sum, over the last five years, both TEvrs and SE had been increasing faster in the largest farm size group comparing to the rests, which has leaded the largest farms had become more competitive in terms of both technical efficiency and scale efficiency over time. This result may partially explain the widening (income) disparity between large farms and small farms in Korean agriculture over the recent decade.

Here, however, we can raise the questions what is the optimal farm scale to Korean farms and how much percentages of farm households are operating at the optimal size, IRTS, or DRTS by farm size groups. These questions will be answered in the future studies.

Also it is very important to understand the reasons and factors that affect farms under DRTS who need to decrease farm scale, likewise it is also important to find out the factors that affect farms under IRTS who can be better off by enlarging farm scale. This kind of questions can be answered by factor analysis by farm size. The related future analysis can give many answers for Korean agricultural policy how to derive farm size enlargement and how to meet the small farms' needs. These studies are left for the future works.

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