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Optimal Scheme Selection of Agricultural Production Structure Adjustment — Based on DEA Model; Punjab (Pakistan)

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Abstract: This paper used the modern evaluation method of DEA (Data Envelopment Analysis) to assess the comparative efficiency and then on the basis of this among multiple schemes chose the optimal scheme of agricultural production structure adjustment. Based on the results of DEA model, we dissected scale advantages of each discretionary scheme or plan. We examined scale advantages of each discretionary scheme, tested profoundly a definitive purpose behind not-DEA efficient, which elucidated the system and methodology to enhance these discretionary plans. At the end, another method had been proposed to rank and select the optimal scheme. The research was important to guide the practice if the modification of agricultural production industrial structure was carried on.

Key words: agricultural industrial structure adjustment, agricultural production structure, DEA efficient, DMU's ranking, Punjab

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Introduction

In the course of research of evaluation of multiple agricultural production structure adjustment schemes of Punjab Province (Pakistan) based on DEA (Data Envelopment Analysis) model and results gained by multi-objectives optimization programming model, four possible schemes have been proposed and then their comparative efficiencies have been also weighed (Zeeshan *et al.*, 2015). On the other hand, it is important to search clearly the definitive reason for not-DEA efficient schemes and simplify the methodology to modify and enhance them. DEA methodology has the benefit of assessment of discretionary schemes, particularly in case of multiple-inputs and multiple-outputs (Wu, 2002; Wang, 2000) in addition to this, it also provides some helpful management information which can be practical and applied to enhance not-DEA efficient DMUs (Decision Making Units) (Wei, 2001; Li, 2000; Li, 2010).

In this manuscript, we explored the definite causes of ineffective schemes on the basis of DEA model by bringing the concept of redundancy rate of input and deficiency rate of output, later expressed the method to enhance or modify the input and output indexes of relevant scheme so that it could also become a DEA efficient DMU.

In conventional DEA model, it's hard to choose

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the optimal scheme amongst DEA efficient DMUs, even if it is a challengeable assignment for decision makers. In this manuscript, new methodology of ranking DMUs had been anticipated to choose the optimal scheme.

DEA Efficiency of Each Optimal Scheme

Every scheme was considered as a DMU in DEA model. As per the outcome of optimizing programming model, four possible schemes had been proposed and their comparative efficiencies had been assessed on the basis of DEA method (evaluation results are shown in Table 1). Using $D^{\varepsilon} C^2 R$ model of DEA (Quan, 1998; Peihua *et al*., 2013), we got the evaluating results as given.

Outcomes of DEA models had categorized the four schemes into three ranks: rank 1 involved scheme DMU_1 and scheme DMU_2, both of which were technically and scale efficient; rank 2 was weak DEA efficient scheme DMU_4. And the optimal solution of DEA model after assessing the comparative efficiency of scheme DMU_4 was:

$\theta^*=1$ and $S_1^{*-}=0$, $S_2^{*-}=19.57$, $S_3^{*-}=31.286$, $S^{*+}=0$

It resulted in weakening DEA efficiency, scheme DMU_3 was the after everything else hence rank 3. The solutions of resultant DEA model were given as follows:

$\theta^*=0.93317$, $S_1^{*-}=6.729$, $S_2^{*-}=0$, $S_3^{*-}=21.424$, $S_1^{*+}=53.147$, $S_2^{*+}=11.389$, $S_3^{*+}=0$, $S_4^{*+}=0$, $S_5^{*+}=69.279$

This implied that it was not-DEA efficient. Now it could be found the vital causes for inefficiency and enhanced it as per the analysis in section-4.

Table 1 Assessment section of four DMUs ($C^2 R$)

Item	Scheme 1 DMU 1	Scheme 2 DMU 2	Scheme 3 DMU 3	Scheme 4 DMU 4
Optimal solution	θ*=1 $S^-=0$ $S^+=0$	θ*=1 $S^-=0$ $S^+=0$	θ*=0.9433 $S^-\neq 0$ $S^+\neq 0$	θ*=1 $S^+\neq 0$ $S^+=0$
Efficiency	DEA efficient	DEA efficient	Not-DEA efficient	Weak DEA efficient

Analysis of Scale Advantage and Enhancement on not-DEA Efficient DMU

Considering the ongoing conversation, we looked into the definite causes for not-DEA efficient DMUs by assessing more carefully scale advantages and comparative efficiency of each input and output indexes. Later we explained and discussed different methods of enhancement.

Analysis of scale advantage

On the basis of the solution of DEA evaluation in the given Table 1, defining $k=\sum_{j=1}^{n}(\lambda_j)$ and k was known as the scale advantage of DMU_j. Its potential value included the given scenarios.

If $k=1$, then it showed that scale advantages of DMU_j could be improved by adding inputs appropriately.

If $k=1$, then it showed that DMU_j was on the point with optimal scale advantages.

If $k=1$, it meant the scale advantages of DMU_j declines as its inputs raised.

For each input and output index for DMU_j, identifying redundancy rate α_{tj} for inputs x_{tj} and deficiency rate β_{rj} for outputs Y_{tj} correspondingly as follows:

$\alpha_{tj}=S_{tj}^{*-}/X_{tj}$, $\beta_{rj}=S_{tj}^{*+}/Y_{tj}$

At this point, α_{tj} indicated the ratio of i input could be decreased with outputs being constant.

At the same time, β_{rj} represented the ration of j output could be increased with inputs being constant. Careful analyses of the results of each scheme are given in Table 2.

Table 2 Results assessment section of four DMUs (C^2R)

Scheme	Scale benefit	Redundancy rate of output	Deficiency rate of output
1	k=1	α_i=0, i=1, 2, 3	β_{r1}=0, r=1, 2, 3, 4, 5
2	k=1	α_{i2}=0, i=1, 2, 3	β_{r2}=0, r=1, 2, 3, 4, 5
3	k=0.963<1	α_{13}=0.0051, α_{23}=0, α_{33}=0.062	β_{13}=0.1232, β_{23}=0.0171, β_{33}=0, β_{43}=0, β_{53}=0.1314
4	k=1	α_{14}=0, α_{24}=0.1247, α_{34}=0.06985	β_{r4}=0, r=1, 2, 3, 4, 5

Table 3 gave an idea about schemes 1 and 2 had been the optimal scale advantage position. Even though scheme 4 was weak DEA efficient, along with this it also had the optimal scale advantages point. Simply scheme 3 was the only scheme which was not scale efficient. The redundancy β_{rj} for both 1st and 5th output indexes was 12.32% and 13.14% correspondingly. This meant that scheme 3 didn't get the proper attention for raising the stocks in the industry, which resulted in the constraint to the benefit of stock rising to affect.

Evaluation and enhancement of schemes

Assuming the optimal outcomes of DEA models (D^{ε} C^2 R) were λ^0, S^{0-}, S^{0+}, and θ^0. Characterizing $\hat{X}_{j0}=\theta^0 X_{j0}-S^{0-}$, $\hat{Y}_{j0}=\hat{Y}_{j0}-S^{0+}$, seemingly ($\hat{X}_{j0}$, $\hat{Y}_{j0}$) was DEA efficient and it was mentioned and known as projection of DMU_j. Now planed scheme 3 to the efficient exterior of DEA (Table 3), which was quite a methodology to enhance it.

Table 3 Projection of scheme 3

Index	Actual vale	Slack variable	Objection (DMU3)
X_1 ($hm^2\times10^4$) planting areas	1 854	S_1^{*-}=6.729	1 742.1492
X_2 ($t\times10^4$) fertilizer	285	S_2^{*-}=0	268.8405
X_3 (0000 rupees)	58 529.70	S_3^{*-}=21.424	55 189.642
Y_1 (0000 rupees) Total income	63 382.29	S_1^{*+}=53.147	63 435.437
Y_2 (0000 rupees) Total production value	121 912	S_2^{*+}=11.389	121 923.39
Y_3 ($t\times10^4$) Total production stockholding	10 340	S_3^{*+}=0	10 340
Y_4 ($t\times10^4$) Total production of economic crops	5 109	S_4^{*+}=0	5 109
Y_5 ($t\times10^4$) Total production of corn	2 208	S_5^{*+}=69.279	2 277.279

Here, X={X_{13}, X_{23}, X_{33}} and Y={Y_{13}, Y_{23}, Y_{33}, Y_{43}, Y_{53}} indicated the input output vector of the scheme 3 correspondingly. After planning or projecting DMU_3 had been modified into a DEA efficient DMU, which illustrated that the methodology to enhance and modify DMU_3, even though it was curtail to examine whether the modified DMU_3 was according to or satisfied the restraint conditions of optimizing model. This process redounded to act out as novel DMUs which in case was extra efficient and rational.

Categorizing and Choosing Optimal Scheme

In conventional DEA model, it's not easy to differentiate which one is the suited one amongst numerous DEA efficient DMUs. Currently, there has been quite some research and debates on the methodology of ranking and then choosing the optimal schemes amongst numerous DEA efficient DMUs (Zilla *et al*., 1998; Li *et al*., 2004; Meilin *et al*., 2009). In this manuscript, we implemented a novel ranking methodology which illustrated an ideal DMU (in current case DMU_L). The inputs of DMU_L were of the smallest amount whereas the outputs were the greater and most amongst other DMUs. Conceptualizing a new DEA model focusing on maximizing the efficiency of DMU_L to take a set of mutual weights named λ_j^0 (j=1, 2, . . . n), after this applied the mutual weights for evaluating each DMU's comparative efficiency, which actually was the foundation of ranking.

Setting up an ideal DMU (DMU_j)

The nominal input $X_{\min k}$ and the highest output $Y_{\max r}$ of the four DMUs were composed of the inputs and outputs of DMU_L correspondingly as follows: X_{1L}=1 784, X_{2L}= 307, X_{3L}=62 930; outputs: Y_{1L}=56 933.18 , Y_{2L}=119 864, Y_{3L}=10 500 , Y_{4L}=6 441, Y_{5L}=2 715.

Developing evaluation DEA model

Indentifying indicated the efficiency index of DMU_L, developing a DEA model focused on maximizing efficiency of DMU_L. As given below,

$$(P)\begin{cases} \text{Max } h'=\dfrac{U^TY_{\max}}{V^TX_{\min}} \\ \text{s.t.} \\ \dfrac{U^TY_j}{V^TX_j}\leqslant 1 \qquad j=1, 2, 3, 4 \\ \dfrac{U^TY_{\max}}{V^TX_{\min}}\leqslant 1 \\ U\geqslant 0,\ V\geqslant 0 \end{cases}$$

Whereas, $U=(u_1, u_1, \cdots, u_1(s^1))^T$, $V=(v_1, v_2, \cdots, v_1(m^1))^T$. Considering that the optimal outcome of the above given model (P) was U^* & V^*, indicated that U^* & V^* were the communal ranking weights of all DMU_j. Concurrently, identifying $h_j^*=\dfrac{U^{*T}Y_j}{V^{*T}X_j}$(whereas j=1, 2, ⋯, n) was the efficiency index for DMU_j (whereas j=1, 2, ⋯, n).

DMUs ranking

After using the optimal programming software LINGO (Xie *et al*., 2011), we acquired the model (P) solution as:

$h'^*=1$, $U^*=(7.8244, 3.402, 4.613)^T$, $V^*=(1.06948, 5.01931, 0.7138, 0, 4.8397)^T$.

The comparative efficiency index calculations of each DMU are being shown in Table 4.

Table 4 Efficiency ranking index of all DMUs

Efficiency index	Scheme 1	Scheme 2	Scheme 3	Scheme 4
h_j^*	0.8750	0.9199	0.7990	0.8090
Ranking result	2	1	4	3

Conclusions

In the manuscript, detailed evaluations of four schemes were given using DEA model from both theoretical and practical perspectives. We analyzed and computed scale efficiency of each scheme. In addition to this, by defining the concept of redundancy rate and insufficiency rate, discovered the definite causes for the not-DEA efficient DMU, shed light on how to improve it. By applying the concept of projection theorem, scheme 3 then had been improved to be a DEA efficient DMU. At the end, a novel methodology of DEA ranking had been applied to choose the best and optimal scheme for implementation purposes.

The scheme 2's efficiency and benefits in material form were more rational for the respective agricultural industrial production structure. The scheme developed the mainly most of comparative advantages of agriculture resources in Punjab Province (Pakistan), which as a result helped a lot to exercise powerful dragging effect of stocks raising and speeding up the industry to build up more synchronization. This research work in fact would get some guiding significance to carry through structure adjustment of agricultural industrial production structure of the province.

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