Analysis of technical efficiency: Factors affecting efficiency of West Java rice farms

Data envelopment analysis

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Presentation outline

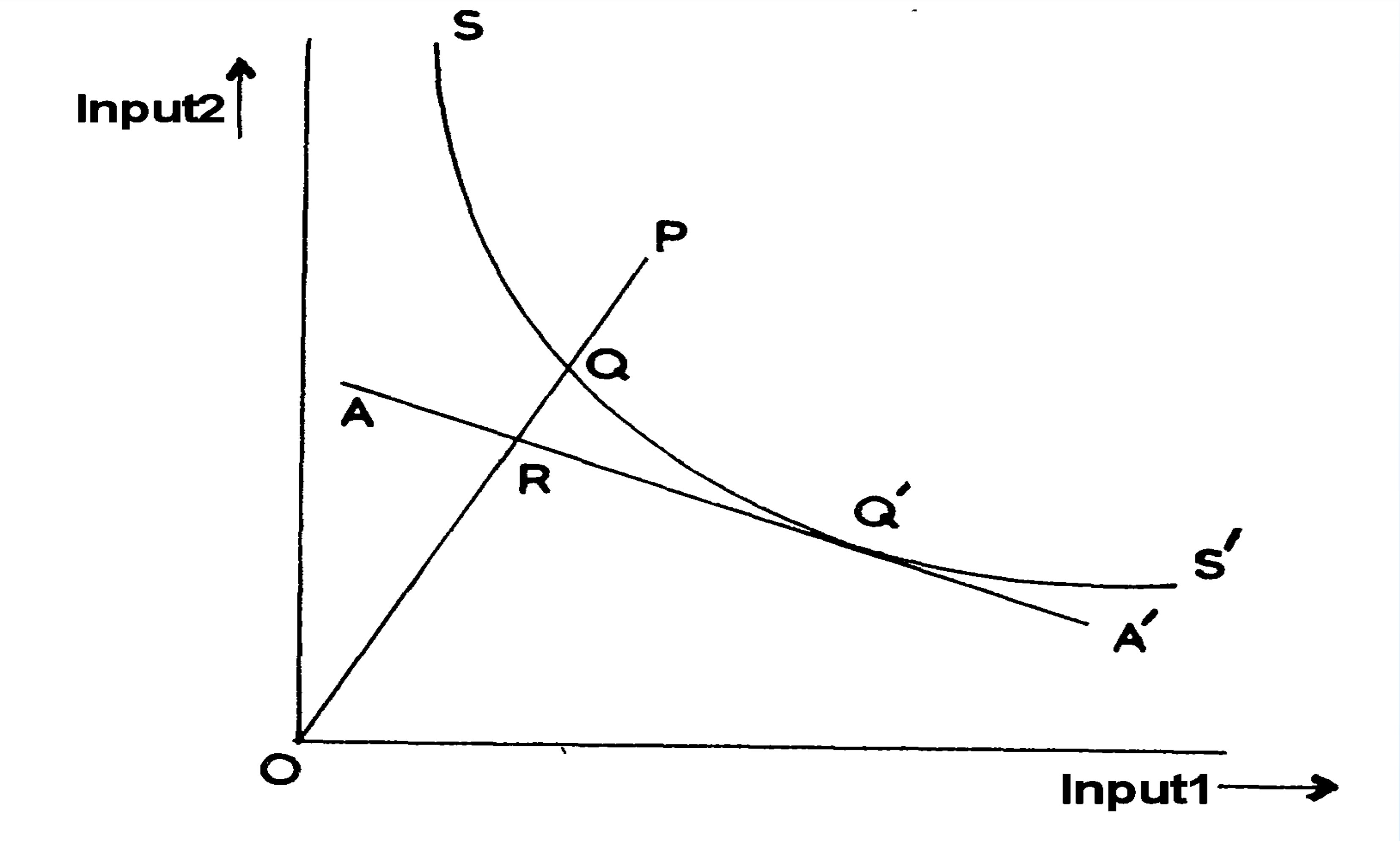
- DEA methodology
  - Literature review
  - Example
  - Methodology
- Application: Rice farming in Indonesia
  - Stage 1: Efficiency computation
  - Stage 2: Analysis of efficiency scores
  - Tobit model for efficiency
  - Assessment of farm size – productivity relation
  - Other factors related to productivity

DEA methodology

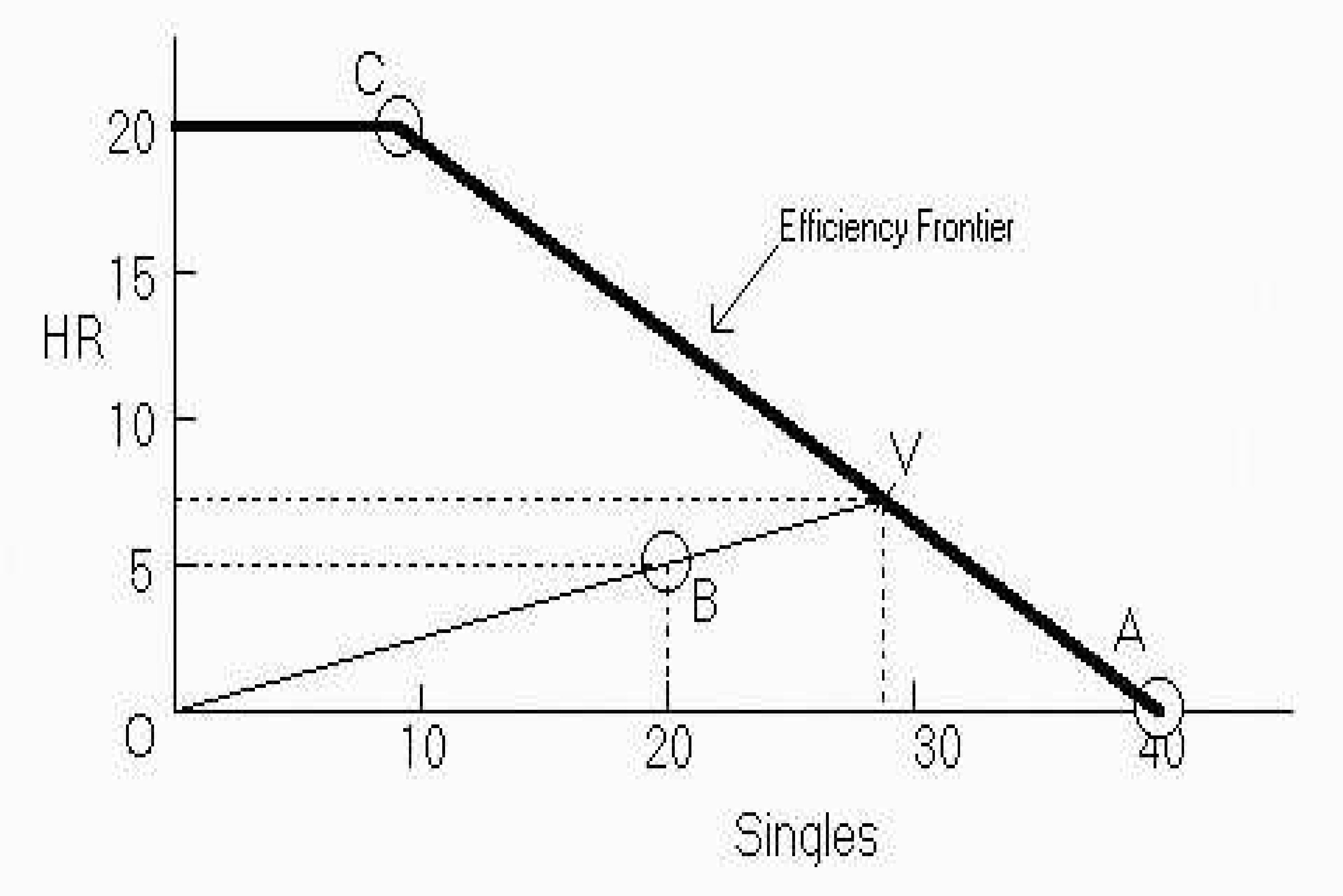
- Farrell (1957) – concept of multiplicative efficiency: OE=TE*AE
- E. Rhodes (1978) – evaluated the educational program for disadvantaged students
- Charnes, Cooper and Rhodes (1978) – first paper introducing DEA
- Banker, Charnes and Cooper (1984) – variable returns to scale in DEA
- Löthgren and Tambour (1996) – summary of returns to scale identification approaches

Efficiency concepts

OE=0R/0P, TE=0Q/0P, AE=0R/0Q



DEA score - computation



DEA Methodology - summary

- n homogenous DMUs: m inputs and s outputs
- $T \subset \mathbb{R}_+^{m+s}$ is general a production possibility set, where $T = \{(x, y) \mid \text{using inputs } x \text{ outputs } y \text{ are produced}\}$
- Properties of production possibility set:
  - Convexity
  - Inefficiency property – free disposal
  - Minimum extrapolation
  - No free lunch
- Efficiency dominance: DMU is dominated when there exist a DMU that can produce the same levels of outputs with less intensive use of inputs

DEA problem

- Input oriented model:

$$\min_{\lambda_j,\theta_j,e_j,s_j} \theta_j$$

$$\begin{aligned} s.t. \quad \theta_j x_{ij} - {}_i x \lambda_j - e_{ij} &= 0, \quad && i = 1, \ldots, m; \\ {}_r y \lambda_j - s_{rj} &= y_{rj}, && r = 1, \ldots, k; \\ \varphi(\mathbf{1}^T \lambda_j) &= \varphi; \\ \lambda_j, e_j, s_j &\geq 0, \end{aligned}$$

- θ proportional reduction of inputs
- e_j, s_j non-proportional slacks
- λ intensity variable
- $\varphi = 1$ variable returns to scale
- $\varphi = 0$ constant returns to scale

Application: Rice farms

- Motivation:
  - Success of “Green Revolution”
    - Growth of Indonesian rice production over 1950–1980 period
- Goals:
  - Test farm size–productivity relation
    - Townsend, Kirken and Vink (1998), Helfand and Levine (2004): farm size–productivity relationship reconsideration
  - Evaluate impact of intensification program and other factors on farm’s efficiency
    - Farm specific factors: labor, fertilizers, ...
    - Economic factors: prices of inputs
    - Environmental factors: location, wet-dry period, ...

Application: Methodology

- Stage 1 – DEA:
  - Price distortions: Input oriented model
  - Time invariant production frontier
  - Time varying production frontier
- Stage 2 – Tobit:
  - Efficiency scores – censored variable
  - Efficiency model estimation
    - Random effect model
    - Mundlak's correction used to control for correlation of individual characteristics and unobserved heterogeneity

Application: Results

- Stage 1:
  - High correlation of average DEA score ranking with SFA rankings: 0.7127 – 0.8214
  - Average technical efficiency scores range from 0.60 to 0.77
  - High average scale efficiency 0.90
  - Apx. 70% of farms are located in DRS region of production possibility set
  - Afficiency scores are consistent across models
  - No significant technological change over considered period – Malmquist index
  - Conjecture: Production growth was mainly driven by growth in area used for production
  - High degree of heterogeneity in scores

Application: Results

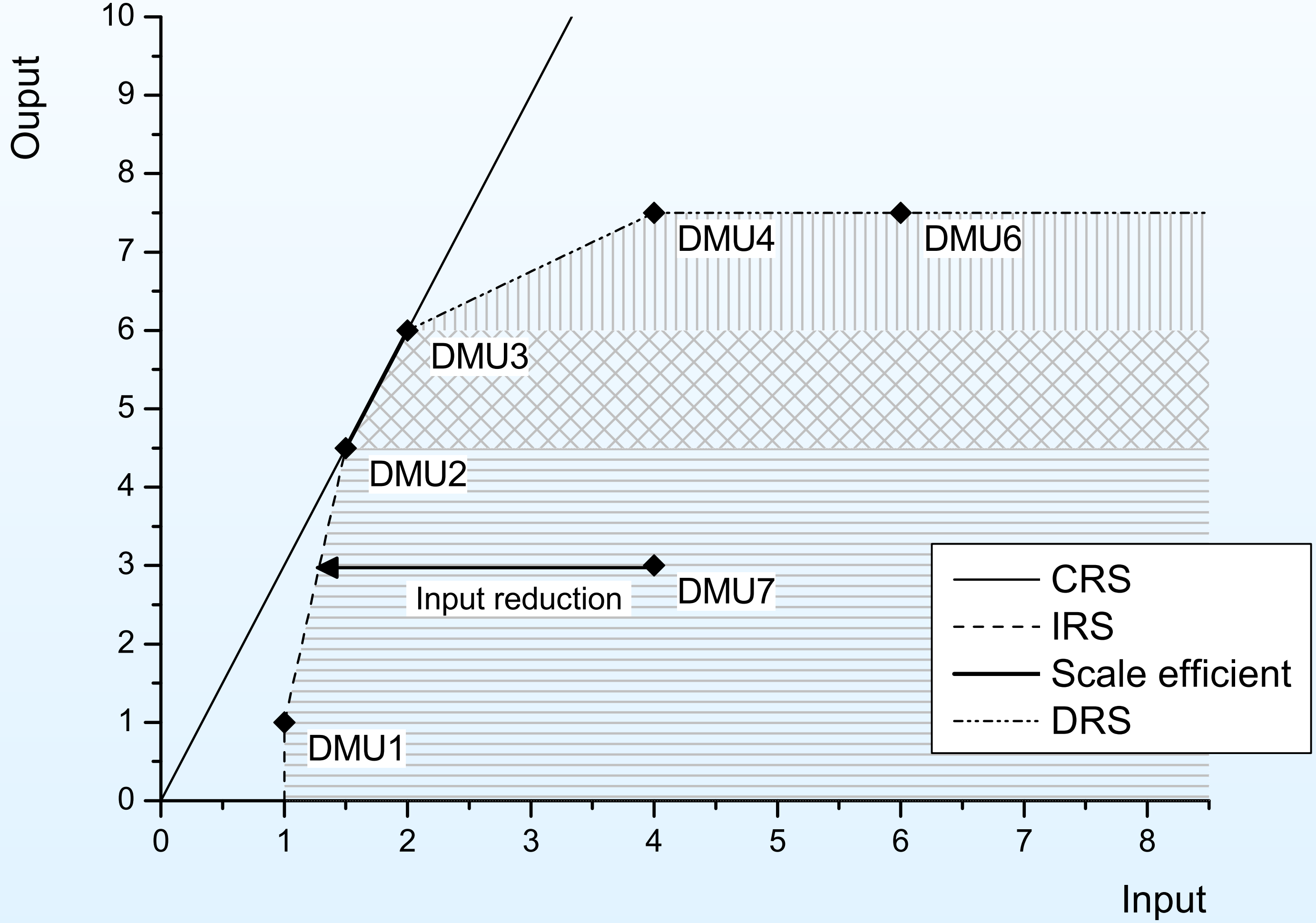
- Stage 2:
  - HYV employment and sharecropping positively related with efficiency score
  - no significant efficiency benefit from intensification program participation
  - No significant effect of wet period
  - Positive effect of family labor share
  - Size–efficiency relation:
    - “U” shaped relation – quadratic
    - Threshold – apx. 1.41 ha and apx. 1.9 (using Mundlak’s correction)
    - Threshold coincides size of farm in other islands

Conclusions

- Adopt “best–practice” production mixes: 23%–42% proportional reduction of all inputs
- Positive returns of HYV employment
- Adjust farm size – pooling plots
- Reform of subsidies system to avoid overuse of inputs – pesticides prices
- Personalization of intensification program

Appendix: Input reduction

- Input orientation in DEA



Appendix: SDEA-SFA correlation

- Spearman rank correlation

	Model type			
	CCR_N	BCC_N	CCR_{LN}	BCC_{LN}
SFA-SDEA				
FE	0.2534***	0.2448***	-0.0224	-0.0292
FE_{sp}	0.2115***	0.2399***	-0.0835***	-0.0762**
SFA-DEA a.				
FE	0.8214***	0.7127***	0.2949***	0.8539***
FE_{sp}	0.7988***	0.6297***	0.1130***	0.8263***

Appendix: Efficiency score summary

- DEA scores:

Model		Obs.	Mean	Std.Dev.	Min	Max
Two–outputs						
	χ–CCR	960	0.6199	0.2221	0.1612	1
	θ–CCR	960	0.7069	0.1942	0.2795	1
	χ–BCC	960	0.7016	0.2216	0.2065	1
	θ–BCC	960	0.7757	0.1884	0.3294	1
	Scale efficiency	960	0.9126	0.1123	0.4493	1
Pooled DEA two–outputs						
	χ–CCR	960	0.5155	0.2024	0.1647	1
	θ–CCR	960	0.5866	0.1948	0.2116	1
	χ–BCC	960	0.5913	0.2012	0.2309	1
	θ–BCC	960	0.6533	0.1988	0.2591	1
	Scale efficiency	960	0.9003	0.1183	0.3618	1

Appendix: Analysis of scores

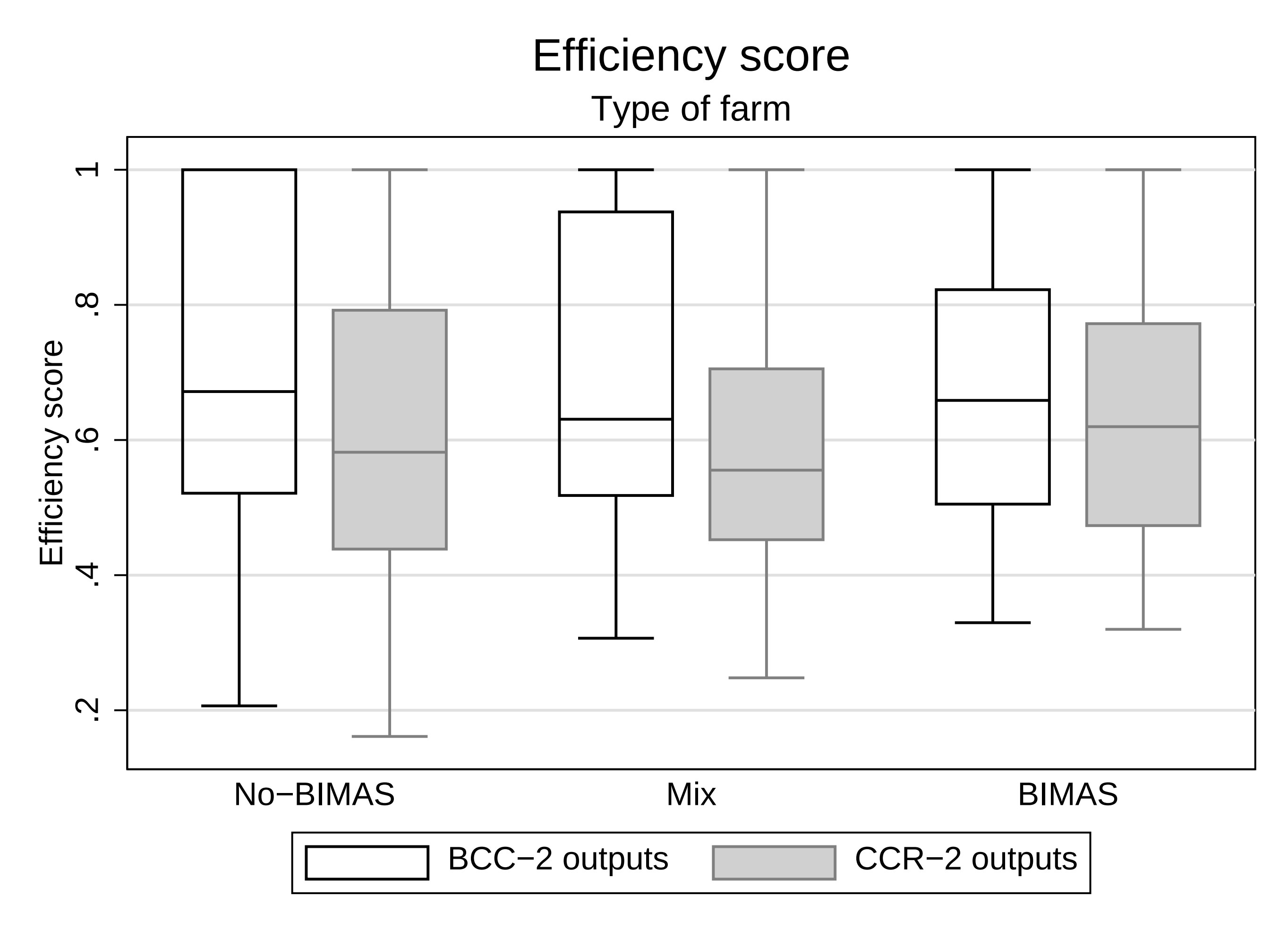
- Returns to scale

Model	DRS	CRS	IRS
One–output	66%	12%	22%
Two–outputs	62%	16%	22%
Pooled two–outputs	77%	5%	18%
Thailand*	19%	32%	49%
Bangladesh**	63%	16%	21%

* From Krasachat (2004), ** From Wadud and White (2000)

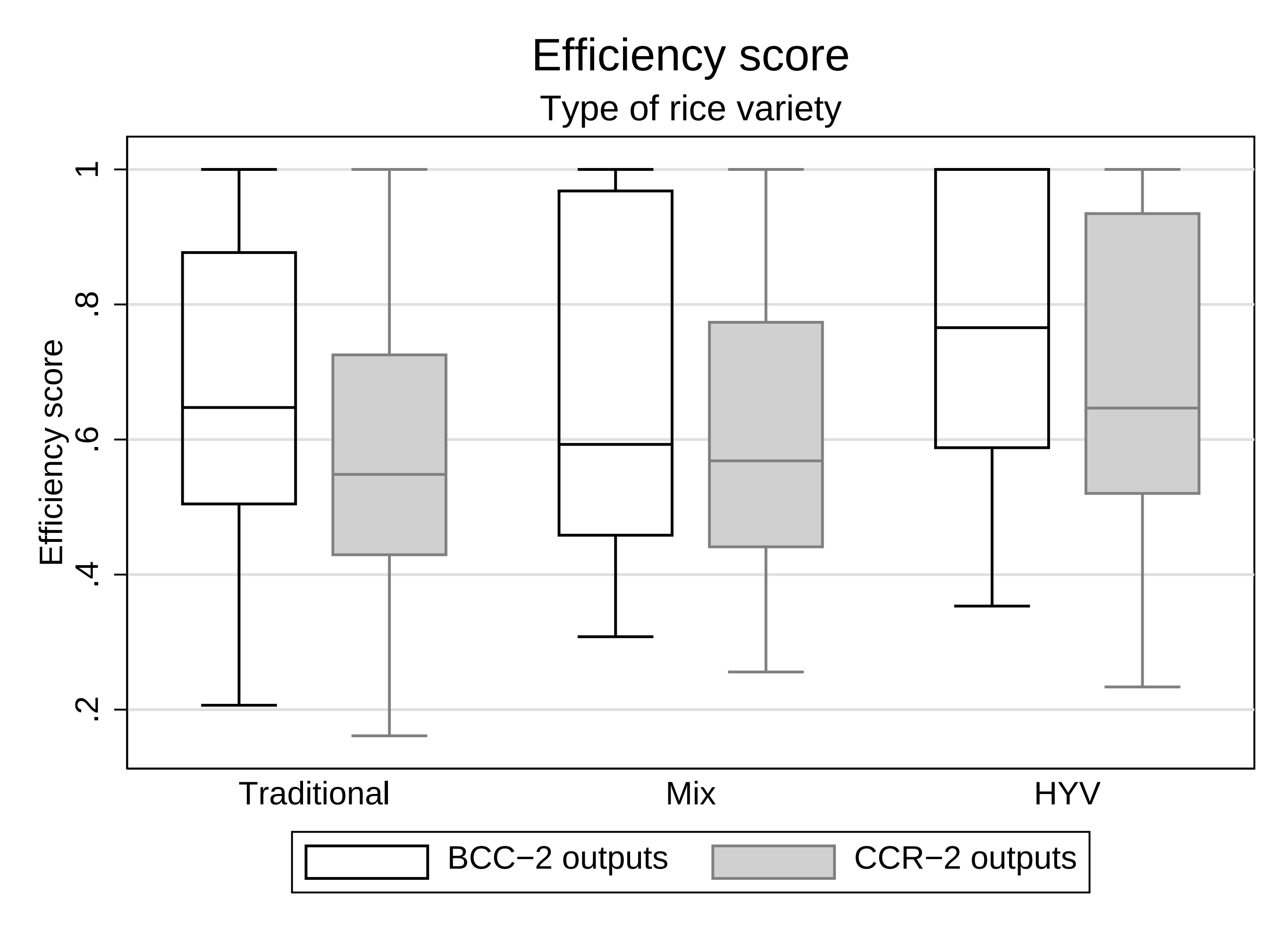
Appendix: Productivity factors

- Intensification program participation



Appendix: Productivity factors

- Modern variety employment



Appendix: Technical and efficiency change

- Malmquist Index Summary Of Annual Means

Year	Eff.ch.	Tech.eff.ch.	Prod.ch.	Sc.eff.ch.	TFP Ch.
2	0.947	1.036	0.980	0.967	0.981
3	1.148	0.758	1.042	1.101	0.870
4	0.851	1.063	0.894	0.952	0.905
5	1.066	1.147	1.030	1.035	1.223
6	1.045	0.960	1.046	0.999	1.004
Mean	1.006	0.983	0.997	1.010	0.989

Appendix: Estimation details

- Tobit:
  - $\chi^*_{ij} = \beta^T x + \nu_i + \epsilon_{ij}$, where χ_{it} is censored variable
  - random effects, ν_i, are iid $N(0, \sigma^2_\nu)$ and ϵ_{it} are iid $N(0, \sigma^2_\epsilon)$ independently of ν_i
- Unobserved heterogeneity modelling:
  - Mundlak (1978): unobserved heterogeneity can be modelled as a function of means of included regressors
  - $\nu_i = \bar{\beta}\bar{x}_i + \alpha_i$
    - α_i is a part of farm's unobserved heterogeneity and uncorrelated with regressors
    - $\bar{x}_i$ is vector of farm i means for individual regressors x_i over the observed period

Appendix: Parametric methods

- Kumbhakar and Lovell's (2000) review
- COLS:
  - Estimate: $\ln(y_j) = \beta_0 + \sum_{k=1}^{m} \ln(x_{jk})\beta_j - u_j$
  - Correct OLS residuals: $-\hat{u}_j^* = \hat{u}_j - \max_j\{\hat{u}_j\}$
  - Calculate efficiency: $TE(COLS)_j = \exp(-\hat{u}_j^*)$
- SFA:
  - Estimate: $\ln(y_j) = \beta_0 + \sum_{i=1}^{m} \beta_i \ln(x_{ij}) + v_j - u_j,$
    - u_j represents non–negative technical inefficiency
    - v_j is the symmetric two sided random shock component.