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STOCK PROXIES IN EFFICIENCY ANALYSIS OF FISHERIES

Nguyen Ngoc Duy – Nha Trang University, Vietnam

Ola Flaaten – UiT Tthe Artic University of Norway

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1. Introduction

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- Estimating frontier production functions ideally requires information of both effort and stock
- Information of stock abundance is often unavailable
- Some proxy measures are thus required
- A composite stock index is required for multi-species fisheries
- Failure to take into account the stock effects will lead to the potential for bias.

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1. Introduction

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Questions and objectives

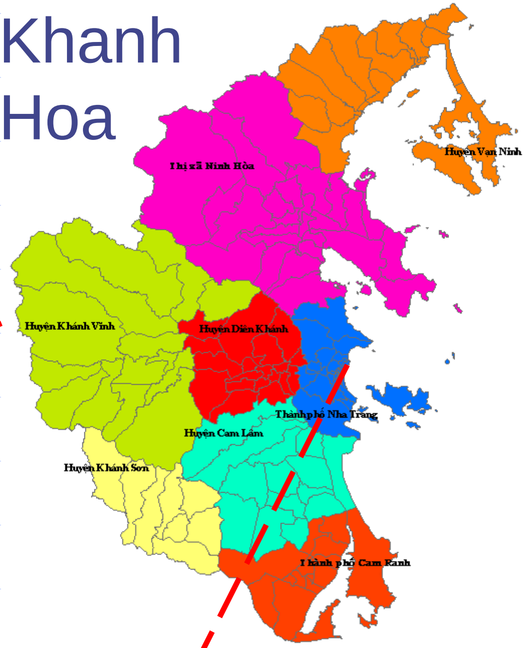
- How to know changes in fish stocks when lacking stock estimates?
- Which proxy measures of fish stocks can be used: CPUE or others?
- How to provide an appropriate fish stock proxy measure?

➔ to analyze three technical efficiency (TE) estimation methods with three different fish stock proxy measures using the stochastic production frontier (SPF) approach

Geographical area

East Sea (South China Sea)

Khanh Hoa



2. Theory and methodology

Different stock proxy measures in SPF model

- Method 1: CPUE index as an explanatory variable in SPF model

  Assumption: constant returns to both effort and stock.

- Method 2: CPUE index is used to adjust the output measure

  Assumption: constant return to effort

- Method 3: DEA index (M_o^{*s}) is used to adjust the output measure (Pascoe & Herrero, 2004):

  No restrictive assumptions on effort and stock.

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3. Model and data

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❖ Model 1

$$
\begin{aligned}
lnY_{it} &= \beta_0 + \beta_1 lnCPUE_t + \beta_2 lnHP_{it} + \beta_3 lnGEAR_{it} + \beta_4 lnDAY_{it} + \beta_5 (lnHP_{it})^2 \\
&+ \beta_6 (lnGEAR_{it})^2 + \beta_7 (lnDAY_{it})^2 + \beta_8 lnHP_{it} lnGEAR_{it} + \beta_9 lnHP_{it} lnDAY_{it} \\
&+ \beta_{10} lnGEAR_{it} lnDAY_{it} + V_{it} - U_{it} \qquad (1),
\end{aligned}
$$

where Y_{it} is defined as Q_{it}:

$$
Q_{it} = \sum_{j=1}^{J} q_{ji,t} w_{j,t} \qquad (2)
$$

where the revenue share of species *j* is $w_{j,t} = q_{ji,t} p_{j,t} / \sum_{j=1}^{J} q_{ji,t} p_{j,t}$.

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3. Model and data (cont.)

❖ Models 2 and 3

$$lnY_{it}^{*} = \beta_0 + \beta_1 lnHP_{it} + \beta_2 lnGEAR_{it} + \beta_3 lnDAY_{it} + \beta_4 (lnHP_{it})^2 + \beta_5 (lnGEAR_{it})^2 + \beta_6 (lnDAY_{it})^2 + \beta_7 lnHP_{it} lnGEAR_{it} + \beta_8 lnHP_{it} lnDAY_{it} + \beta_9 lnGEAR_{it} lnDAY_{it} + V_{it} - U_{it} \qquad (3),$$

Model 2: the dependent variable was modified by the formula

$$Y_{it}^{*} = Q_{it}/CPUE_t \qquad (4)$$

Model 3: the dependent variable adjusted using the stock effect measure derived by DEA analysis is given by

$$Y_{it}^{*} = Q_{it}/M_o^{*S} \qquad (5)$$

where M_o^{*S} is a composite stock index reflecting changes in stock.

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3. Model and data (cont.)

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❖ Output data

	Catch (tonnes)		Price (1000 VND/kg)	
	2011	2012	2011	2012
Gillnet (N = 57):				
Output 1: Striped and skipjack tuna	68.3 [22.2]	64.7 [22.1]	23.2	19.4
Output 2: Mackerel	12.3 [8.2]	12.4 [6.1]	65.0	56.0
Output 3: Others	17.6 [12.6]	11.2 [9.4]	6.3	4.7
Average total catch	98.2 [28.0]	88.3 [26.5]	-	-
Hand-line (N = 39):				
Output 1: Yellowfin and bigeye tuna	21.1 [4.7]	19.1 [4.7]	93.0	81.0
Output 2: Others	1.1 [0.3]	0.9 [0.2]	32.0	23.0
Average total catch	22.2 [4.9]	20.0 [4.9]	-	-

Source: Own data and calculations.Note: Standard deviation in square brackets.

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3. Model and data (cont.)

❖ Input data

	Gillnet (N = 57)				Hand-line (N = 39)			
	2011		2012		2011		2012	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
HP	311.9	117.7	311.9	117.7	264.2	96.6	264.2	96.6
GEAR	278.1	52.9	278.1	52.9	181.4	68.3	181.4	68.3
DAY	237.9	35.5	240.8	34.5	209.5	27.0	208.9	26.6

Source: Own data and calculations.

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4. Results

Stock indices

Estimates of the CPUE and DEA indexes

	Gillnet		Hand-line	
	2011	2012	2011	2012
Geometric mean of catch per unit of fishing day (kg/day)	207.744	189.520	97.529	88.221
$CPUE_t$	1	**0.9123**	1	**0.9046**
DEA index (M_o^{*S})	1	**0.9265**	1	**0.9268**

Source: Own data and calculations.

4. Results (cont.)

Stochastic production frontiers

	Gillnet			Hand-line		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Intercept	-4.432[a]	-4.361[a]	-4.250[a]	-7.406[a]	-7.404[a]	-7.180[a]
lnCPUE	0.944[a]	-	-	1.002[a]	-	-
lnHP	0.269[a]	0.273[a]	0.280[a]	-2.227[a]	-2.259[a]	-2.605[a]
lnGEAR	0.719[a]	0.692[a]	0.706[a]	-2.108[b]	-2.082[b]	-1.653[b]
lnDAY	0.595[a]	0.607[a]	0.563[a]	7.085[a]	7.092[a]	7.006[a]
$(\ln HP)^2$				-0.410[a]	-0.408[a]	-0.302[b]
$(\ln GEAR)^2$				0.252	0.258	0.223
$(\ln DAY)^2$				-0.527[b]	-0.537[b]	-0.524[b]
lnHP*lnGEAR				0.702[a]	0.689[a]	0.613[b]
lnHP*lnDAY				0.603[c]	0.621[c]	0.543
lnGEAR*lnDAY				-0.760[b]	-0.762[b]	-0.701[b]
Sigma-squared (σ^2)	0.054[a]	0.055[a]	0.055[a]	0.015[a]	0.015[a]	0.017[b]
Gamma (γ)	0.963[a]	0.962[a]	0.962[a]	0.867[a]	0.870[a]	0.881[a]
Mu (μ)	0.456[a]	0.461[a]	0.460[a]	0.229[a]	0.228[a]	0.242[a]
Eta (η)				-	-	-0.109[b]
Log-likelihood	80.742	80.631	80.183	81.369	81.221	81.365
LR test of frontier	138.406	138.203	137.348	43.325	43.028	44.245

[a], [b] and [c] are significant at 1%, 5% and 10% levels respectively.

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4. Results (cont.)

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Test for assumptions

		Model 1		Model 2		Model 3	
		Elasticity	t-statistic	Elasticity	t-statistic	Elasticity	t-statistic
Gillnet	CPUE	**0.944**	*10.340*[a]	-		-	
	HP	**0.269**	*2.996*[a]	**0.273**	*3.312*[a]	**0.280**	*3.085*[a]
	GEAR	**0.719**	*3.596*[a]	**0.692**	*3.242*[a]	**0.706**	*3.243*[a]
	DAY	**0.595**	*3.753*[a]	**0.607**	*4.338*[a]	**0.563**	*3.624*[a]
	Total	**2.526**		**1.571**		**1.549**	
Hand-line	CPUE	**1.002**	*9.702*[a]	-		-	
	HP	**0.076**	*0.986*	**0.085**	*1.131*	**0.114**	*1.552*[b]
	GEAR	**0.373**	*3.938*[a]	**0.367**	*3.883*[a]	**0.340**	*3.227*[a]
	DAY	**0.859**	*5.801*[a]	**0.856**	*5.665*[a]	**0.789**	*4.956*[a]
	Total	**2.310**		**1.308**		**1.243**	

[a] and [b] are significant at 1% and 15% levels.

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4. Results (cont.)

Descriptive Statistics of the TE Scores and Comparison Tests

Gillnet	Model 1	Model 2	Model 3	Chi-squared (χ^2) value[a]	
				Kruskal-Wallis rank test	Friedman test
Mean TE score	0.6354	0.6332	0.6339	0.0580	2.3889
Median	0.6131	0.6112	0.6094		
Standard deviation	0.1396	0.1393	0.1388		
Spearman's rank correlation:					
Model 1	1.0000				
Model 2	0.9989***	1.0000			
Model 3	0.9983***	0.9980***	1.0000		

[a] with 2 degrees of freedom. *** is significant at 1% level.

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4. Results (cont.)

Descriptive Statistics of the TE Scores and Comparison Tests

Hand-line	Model 1	Model 2	Model 3	Chi-squared (χ^2) value[a]	
				Kruskal-Wallis rank test	Friedman test
Mean TE score	0.7904	0.7916	0.7890	0.0690	0.3889
Median	0.7809	0.7815	0.7709		
Standard deviation	0.0806	0.0812	0.0812		
Spearman's rank correlation:					
Model 1	1.0000				
Model 2	0.9986***	1.0000			
Model 3	0.9716***	0.9690***	1.0000		

[a] with 2 degrees of freedom. *** is significant at 1% level.

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5. Conclusion

- Based on the assumptions of models, the DEA index provides more robust estimates of production elasticities.
- Based on the consistency conditions of the efficiency estimates, the CPUE measures can provide robust estimates of efficiency scores.
- The CPUE index can be a good empirical approximation for stock size changes
- Both the CPUE and DEA measures indicate decrease in stock abundances.

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Thank you for your listening!

2. Theory and methodology

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Efficiency estimation and SPF

- The general SPF model (Battese and Coelli, 1992):

$$Y_{it} = \boldsymbol{X}_{it}\boldsymbol{\beta} + V_{it} - U_{it} \qquad (1)$$

where Y_{it} is the (logged) output produced

$\boldsymbol{X}_{it}$ is a (1×k) vector of (logged) input quantities

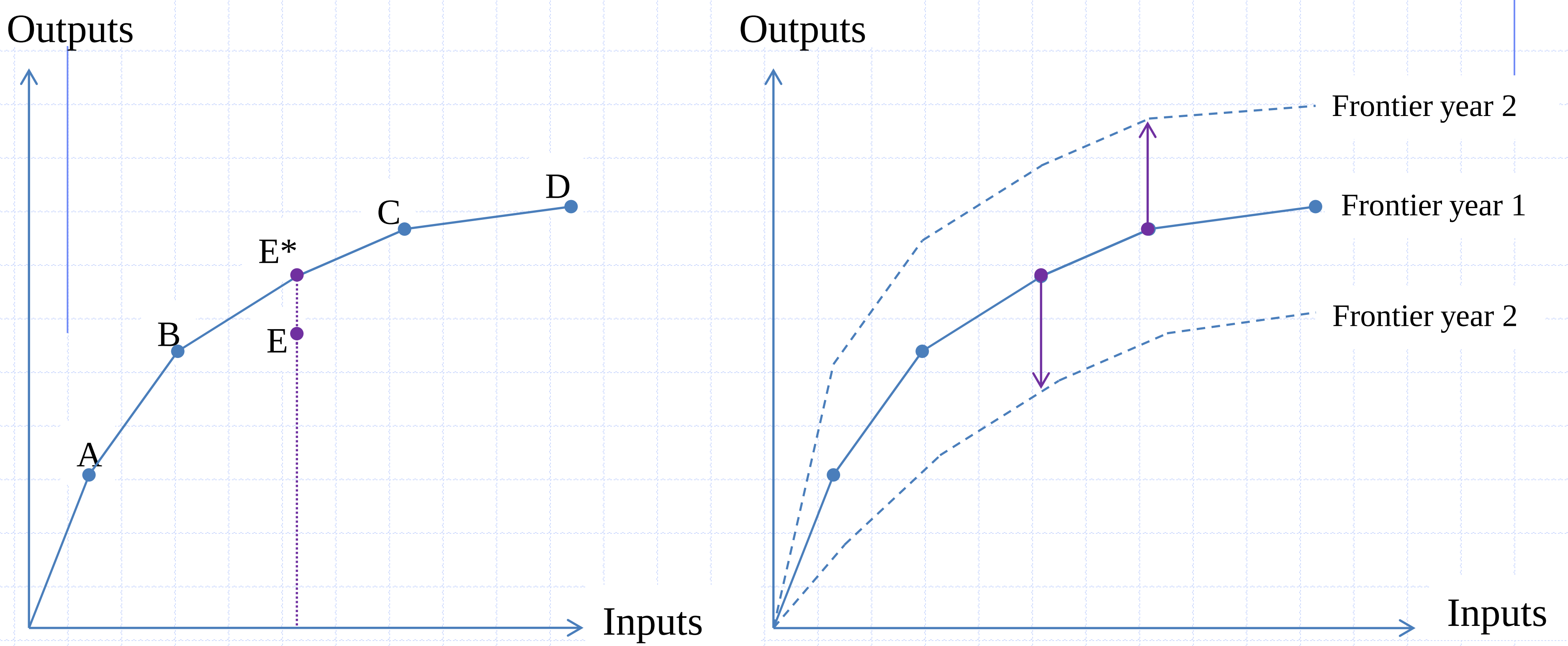
$\boldsymbol{\beta}$ is a (k×1) vector of unknown parameters

V_{it} are the random errors, U_{it} are non-negative random variables

- The measure of TE: $TE_{it} = \frac{E(Y_{it}|U_{it},X_{it})}{E(Y_{it}|U_{it}=0,X_{it})} = e^{-U_{it}}$
- Time-varying inefficiency measure: $U_{it} = U_i e^{-\eta(t-T)}$

2. Theory and methodology

DEA-based stock index



Frontiers with single input and output

4. Results

4.2. Test for specification of the models

For gillnet	Null hypotheses	Conclusion
Model 1	+ Ho: $\beta_{ij} = 0$ (Cobb Douglas function)	Accept Ho
	+ Ho: $\gamma = 0$ (No stochastic frontier)	Reject Ho
	+ Ho: $\eta = 0$ (Time invariant efficiency)	Accept Ho
	+ Ho: $\mu = 0$ (half-normal distribution)	Reject Ho
Model 2	+ Ho: $\beta_{ij} = 0$ (Cobb Douglas function)	Accept Ho
	+ Ho: $\gamma = 0$ (No stochastic frontier)	Reject Ho
	+ Ho: $\eta = 0$ (Time invariant efficiency)	Accept Ho
	+ Ho: $\mu = 0$ (half-normal distribution)	Reject Ho
Model 3	+ Ho: $\beta_{ij} = 0$ (Cobb Douglas function)	Accept Ho
	+ Ho: $\gamma = 0$ (No stochastic frontier)	Reject Ho
	+ Ho: $\eta = 0$ (Time invariant efficiency)	Accept Ho
	+ Ho: $\mu = 0$ (half-normal distribution)	Reject Ho

4. Results

4.2. Test for specification of the models

For hand-line	Null hypotheses	Conclusion
Model 1	+ Ho: $\beta_{ij} = 0$ (Cobb Douglas function)	Reject Ho
	+ Ho: $\gamma = 0$ (No stochastic frontier)	Reject Ho
	+ Ho: $\eta = 0$ (Time invariant efficiency)	Accept Ho
	+ Ho: $\mu = 0$ (half-normal distribution)	Reject Ho
Model 2	+ Ho: $\beta_{ij} = 0$ (Cobb Douglas function)	Reject Ho
	+ Ho: $\gamma = 0$ (No stochastic frontier)	Reject Ho
	+ Ho: $\eta = 0$ (Time invariant efficiency)	Accept Ho
	+ Ho: $\mu = 0$ (half-normal distribution)	Reject Ho
Model 3	+ Ho: $\beta_{ij} = 0$ (Cobb Douglas function)	Reject Ho
	+ Ho: $\gamma = 0$ (No stochastic frontier)	Reject Ho
	+ Ho: $\eta = 0$ (Time invariant efficiency)	**Reject Ho**
	+ Ho: $\mu = 0$ (half-normal distribution)	Reject Ho
	+ Ho: $\eta = 0, \mu = 0$	Reject Ho

Reference

BATTESE, G. E. & COELLI, T. J. 1992. Frontier production functions, technical efficiency and panel data: With application to paddy farmers in India. In: GULLEDGE, T., JR. & LOVELL, C. A. K. (eds.) *International Applications of Productivity and Efficiency Analysis*. Springer, Netherlands.

Thank you very much!