Measuring Efficiency in Fisheries in the Presence of Nondiscretionary Inputs

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Overview

- Brief Literature Review
- Description of the technology (Lovell, Ruggiero)
- Exogenous Non-Discretionary Factors of Production
- Measure of Environmental Influence
- Empirical Application
- Other related issues: RTS, Multiple Stage Models for multiple nondiscretionary factors (Ray), Productivity

Literature Review

Nonparametric Efficiency

- Farrell (1957)
- Afriat (1972)
- Charnes, Cooper and Rhodes (1978)
- Banker, Charnes and Cooper (1984)
- Ray (1991)
- Färe, Grosskopf and Lovell (1994)
- Lovell (1994), Ruggiero (1996, 1998), Johnson and Ruggiero (2012)

Notation

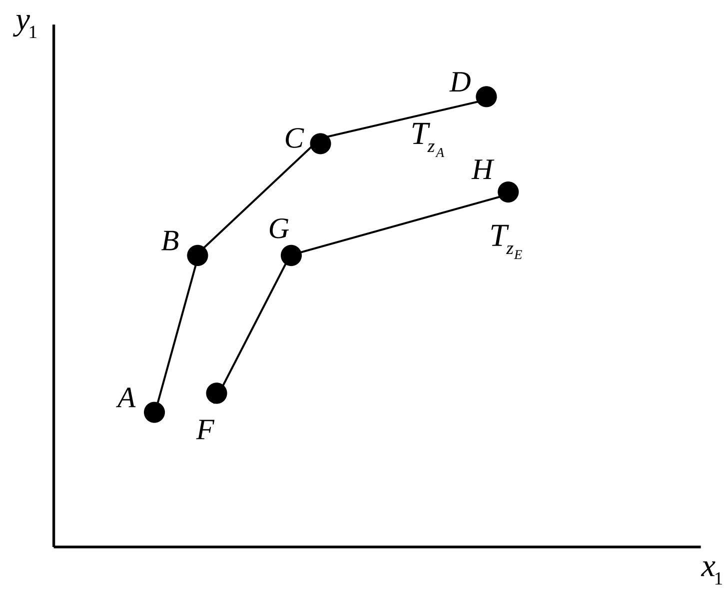
- n vessels
- $X = (x_1, \ldots, x_m)$
- $Y = (y_1, \ldots, y_s)$
- z
- Vessel j:

$$X_j = (x_{1j}, \ldots, x_{mj}),\ Y_j = (y_{1j}, \ldots, y_{sj}),\ z_j$$

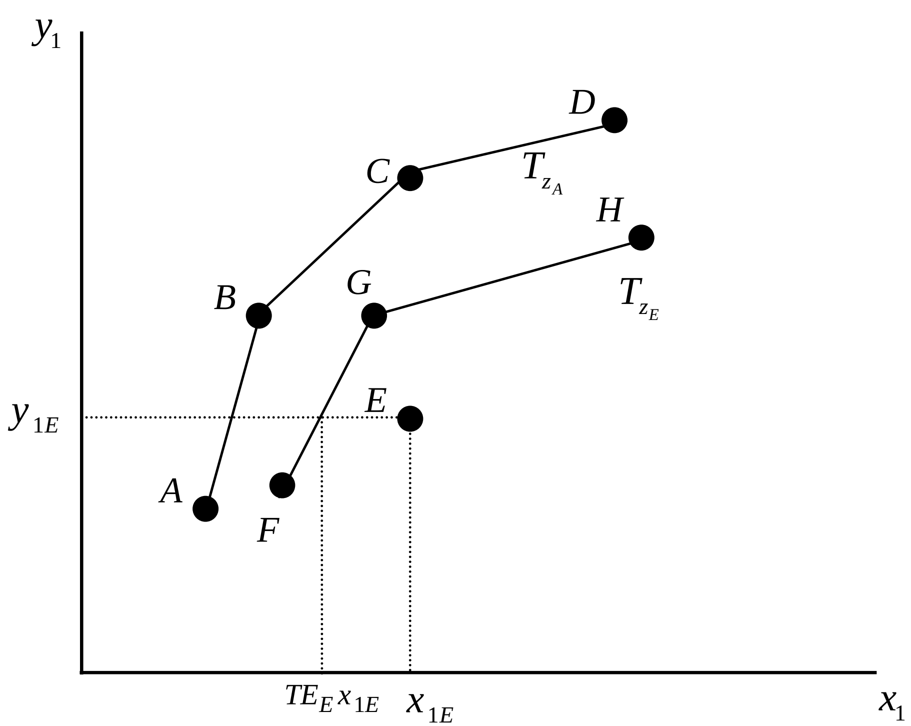
Technology

$$
\begin{aligned}
T_V(z) = \{(Y, X, z) : & \sum_{j=1}^{n} \lambda_j y_{kj} \geq y_k, \, k = 1, \ldots, s; \\
& \sum_{j=1}^{n} \lambda_j x_{lj} \leq x_l, \, l = 1, \ldots, m; \\
& \sum_{j=1}^{n} \lambda_j = 1; \\
& \lambda_j = 0 \text{ if } \mathrm{z}_j > z, \; j = 1, \ldots, n; \\
& \lambda_j \geq 0, \; j = 1, \ldots, n\}.
\end{aligned}
$$

Production with Nondiscretionary Factor



Measuring Efficiency



Measuring Efficiency

$$TE_i = Min\ \theta$$

$$s.t.$$

$$\sum_{j=1}^{n} \lambda_j y_{kj} \geq y_{ki},\ k = 1,\dots,s;$$

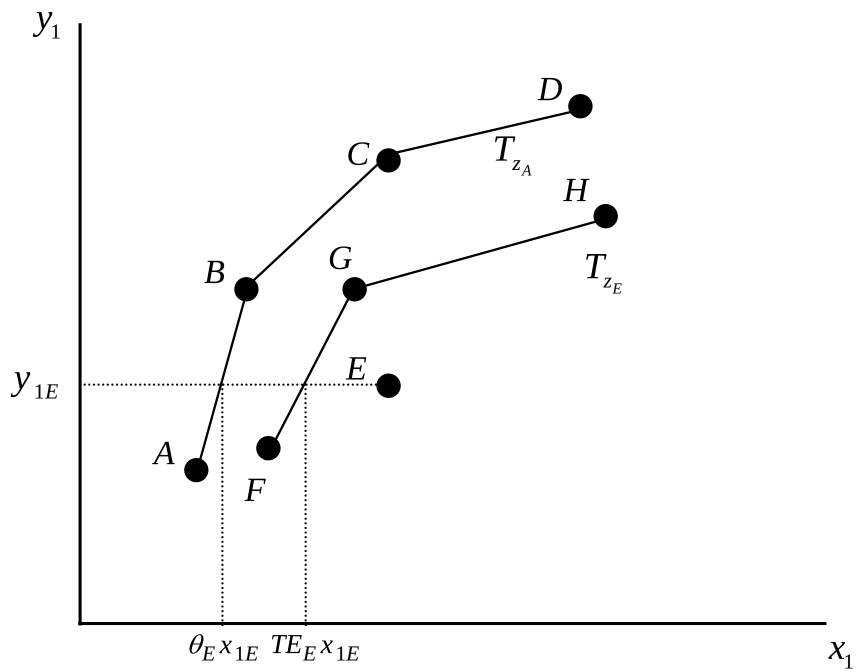
$$\sum_{j=1}^{n} \lambda_j x_{lj} \leq \theta x_{li},\ l = 1,\dots,m;$$

$$\sum_{j=1}^{n} \lambda_j = 1;$$

$$\lambda_j = 0 \text{ if } \mathrm{z}_j > z_i,\ j = 1,\dots,n;$$

$$\lambda_j \geq 0,\ j = 1,\dots,n.$$

Nondiscretionary Effect



Effect of Environment

$$\theta_i = Min\ \theta$$

$$s.t.$$

$$\sum_{j=1}^{n} \lambda_j y_{kj} \geq y_{ki},\ k = 1, \ldots, s;$$

$$\sum_{j=1}^{n} \lambda_j x_{lj} \leq \theta x_{li},\ l = 1, \ldots, m;$$

$$\sum_{j=1}^{n} \lambda_j = 1;$$

$$\lambda_j \geq 0,\ j = 1, \ldots, n.$$

Measures

- Technical Efficiency TE_i
- Input Compensation $(TE_j - \theta_j)x_{lj}$
- Environmental Harshness Index

$$(\theta_j / TE_j) \leq 1$$

Measures reduction in discretionary inputs possible if vessel faced the best environment

Illustrative Example

- California groundfish trawl fishery
- Regulated by species-specific catch limites
- Data for 2007
- One output: groundfish revenue
- Nondiscretionary inputs: vessel length, measure of crowding (weighted average of effort in a particular grid over a 14-day period).

Descriptive Statistics

Table 1: Descriptive Statistics (N = 989)

Variable	Average	Std. Dev.
Output	6,267.11	4,842.21
Tow Hours	16.15	12.07
Days at Sea	2.13	1.05
Vessel Length	57.87	10.69
Crowding Measure	23.44	21.05

Calculations by authors.

Results by Month

Table 2: Average Results, Year 2007					
		Efficiency		Environmental Index	
Month	N	Average	Std. Dev.	Average	Std. Dev.
January	70	0.813	0.202	0.769	0.216
February	41	0.801	0.259	0.840	0.201
March	69	0.896	0.183	0.883	0.202
April	79	0.865	0.193	0.768	0.219
May	144	0.865	0.205	0.773	0.257
June	92	0.876	0.215	0.808	0.221
July	98	0.810	0.272	0.894	0.186
August	110	0.869	0.202	0.847	0.191
September	96	0.717	0.297	0.905	0.184
October	97	0.840	0.206	0.827	0.193
November	64	0.898	0.170	0.851	0.173
December	29	0.877	0.174	0.937	0.119

Calculations by authors.

Other Issues

- Returns to Scale

  Environmental variable nondiscretionary in the long run

- Multiple *z* and the curse of dimensionality

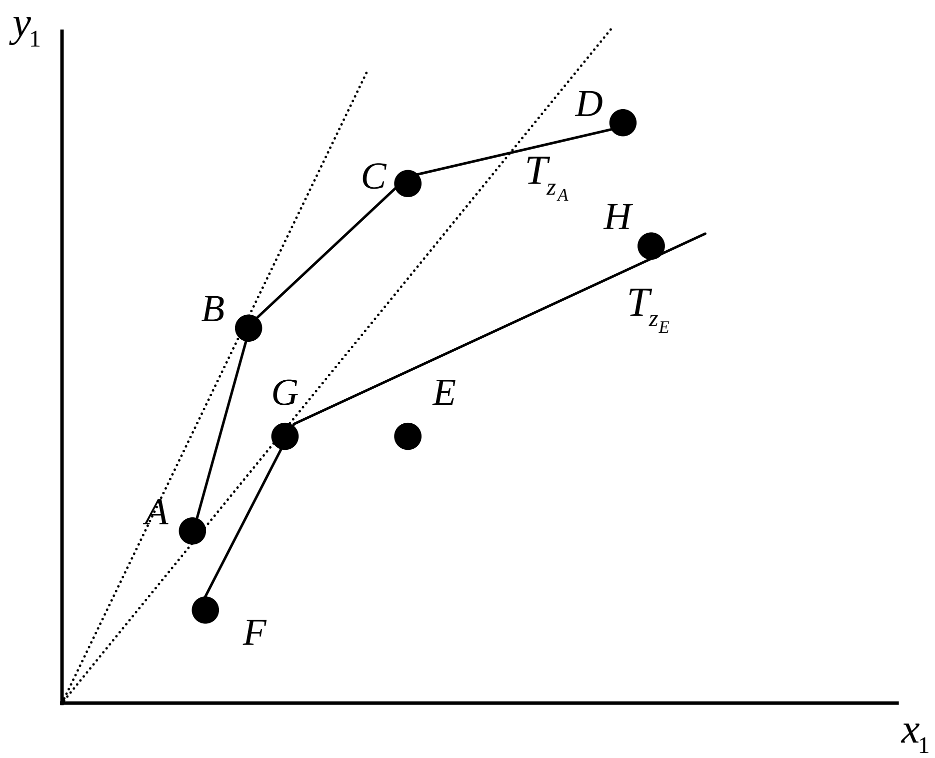
  Multiple-Stage Model

- Productivity measurement

Returns to Scale

- Non-discretionary variables in the long-run
- With conditional estimator, measure returns to scale for a given environment
- From before, distance between conditional and unconditional model provides a measure of returns due to improved environment

RTS



Multiple z

- As the number of nondiscretionary inputs increase, the conditional estimator suffers from the curse of dimensionality.
- DMUs will be identified as efficient by default and the efficiency estimator will be biased upward.
- Conditional estimator is unable to provide weights on the tradeoff between multiple z.

Two Stage Model

- Due to Ray (1991)
- Estimate unconditional model

$$
\begin{aligned}
&\theta_i = Min\ \theta \\
&s.t. \\
&\qquad \sum_{j=1}^{n} \lambda_j y_{kj} \geq y_{ki},\ k = 1,\ldots,s; \\
&\qquad \sum_{j=1}^{n} \lambda_j x_{lj} \leq \theta x_{li},\ l = 1,\ldots,m; \\
&\qquad \sum_{j=1}^{n} \lambda_j = 1; \\
&\qquad \lambda_j \geq 0,\ j = 1,\ldots,n.
\end{aligned}
$$

Second Stage

- The resulting index contains two components, unobserved inefficiency and the effect that the nondiscretionary variables have on production.
- $Z = (z_1, \ldots, z_r)$
- $Z_j = (z_{1j}, \ldots, z_{rj})$
- Second Stage regression
- $\theta = \alpha + \sum_{i=1}^{r} \beta_i z_i + \varepsilon$

Estimating Efficiency

- Ray used the second stage regression to control for environmental factors. The residual provides a measure of efficiency.
- Simulations: works great.
- Second stage regression: OLS, Tobit, Fractional Logit, Nonparametric regression
- Index of Environment:

$$z=\sum_{i=1}^{r} \beta_i z_i$$

Third Stage

$$TE_i = Min\ \theta$$

$$s.t.$$

$$\sum_{j=1}^{n} \lambda_j y_{kj} \geq y_{ki},\ k = 1,\ldots,s;$$

$$\sum_{j=1}^{n} \lambda_j x_{lj} \leq \theta x_{li},\ l = 1,\ldots,m;$$

$$\sum_{j=1}^{n} \lambda_j = 1;$$

$$\lambda_j = 0 \text{ if } \mathrm{z}_j > z_i,\ j = 1,\ldots,n;$$

$$\lambda_j \geq 0,\ j = 1,\ldots,n.$$

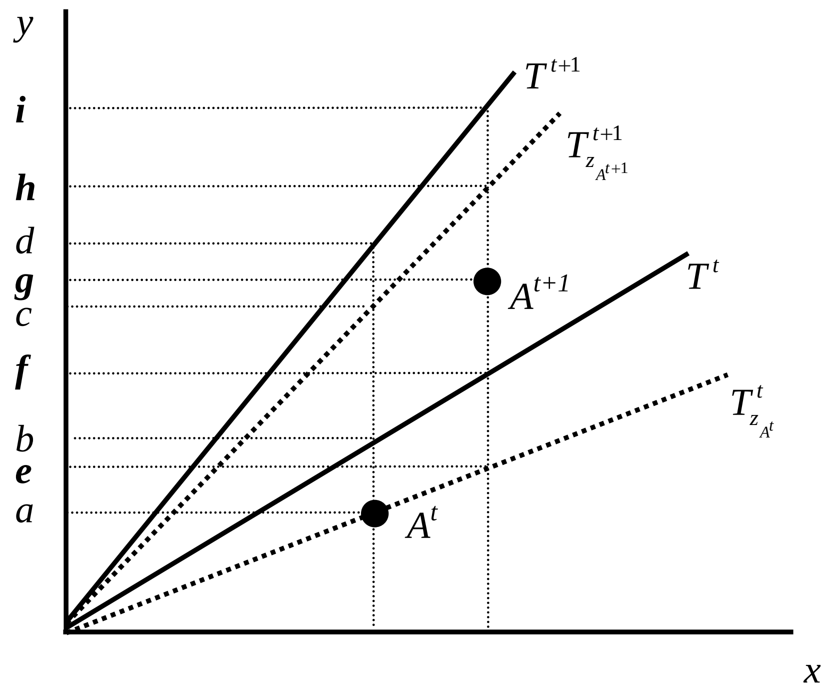
Productivity

- Malmquist Productivity
- Fare, Grosskopf, Ray, Lovell
- Johnson and Ruggiero (2012) – decomposition for public sector models characterized by the influence of environmental factors
- Assume CRS

Technology at time t

$$
\begin{aligned}
T_z^t = \{(Y^t, X^t, z^t)\colon \sum_{n=1}^{N} \lambda_n y_{ns}^t \geq y_s^t,\ s = 1, \ldots, S; \\
\sum_{n=1}^{N} \lambda_n x_{nm}^t \leq x_m^t,\ m = 1, \ldots, M; \\
\lambda_n = 0\ if\ z_n^t > z^t,\ n = 1, \ldots, N; \\
\lambda_n \geq 0,\ n = 1, \ldots, N\}.
\end{aligned}
$$

Intuition



Environmental Harshness

- $E^t(Y_j^t, X_j^t, z_j^t)$
  $$= D^t(Y_j^t, X_j^t)/D^t(Y_j^t, X_j^t, z_j^t) \leq 1$$

Environmental Harshness is the ratio of the unconstrained (first stage) model and the conditional estimator.

Defining each data point relative to each time period technology, we substitute into the Malmquist index …

Decomposition

$$EMPI(Y_j^{t+1}, X_j^{t+1}, z_j^{t+1}, Y_j^t, X_j^t, z_j^t) = \frac{D^{t+1}(Y_j^{t+1}, X_j^{t+1}, z_j^{t+1})}{D^t(Y_j^t, X_j^t, z_j^t)} * \frac{E^{t+1}(x_j^{t+1}, y_j^{t+1}, z_j^{t+1})}{E^t(x_j^t, y_j^t, z_j^t)}$$

$$* \left[\frac{D^t(Y_j^{t+1}, X_j^{t+1}, z_j^{t+1})}{D^{t+1}(Y_j^{t+1}, X_j^{t+1}, z_j^{t+1})} \frac{D^t(Y_j^t, X_j^t, z_j^t)}{D^{t+1}(Y_j^t, X_j^t, z_j^t)}\right]^{\frac{1}{2}}$$

$$* \left[\frac{E^t(x_j^{t+1}, y_j^{t+1}, z_j^{t+1})}{E^{t+1}(x_j^{t+1}, y_j^{t+1}, z_j^{t+1})} \frac{E^t(x_j^t, y_j^t, z_j^t)}{E^{t+1}(x_j^t, y_j^t, z_j^t)}\right]^{\frac{1}{2}}.$$

Productivity

- Components:

  change in efficiency

  change in environmental harshness

  technical progress (with environment)

  environmental technical change

Thank you!