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Review of fisheries studies applying DEA

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Review of fisheries studies applying DEA

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Summary

This report summarizes the studies which applied Data Envelopment Analysis (DEA) to study the fishing activity. Table 1 includes for each study the following information: bibliographic reference of the study, application context, methods applied, the description of the efficiency models, the list of inputs and outputs included in the study and some relevant aspects regarding the study.

Table 1. Review of fisheries studies applying DEA.

Author	Case study	Method	Efficiency model	Inputs	Outputs	Relevant aspects
(Andersen & Bogetoft, 2007)	Danish fisheries (includes netters, Danish seiners, trawlers and purse seiners)	DEA	Technical, output-oriented (variable returns to scale).	Variable costs per year: - Fuel and lubricants - Ice and provisions - Landings and sale - Crew Fixed costs per year: - Costs of maintenance - Insurance and various services	Catch per year in weight (variable outputs): - Cod - Other gadoids - Plaice - Other flatfish - Herring - Mackerel - Lobster and shrimp - Other consumption species - Industrial species	Objective to assess the benefits of a potential introduction of individually transferable fishing quotas. The study concludes that "pure reallocation is as important as pure learning, i.e. quota reallocation without catching-up is as valuable as learning best practice with fixed allocations." Data from 2001 288 vessels analysed
(Dupont, Grafton, Kirkley, & Squires, 2002)	Scotia–Fundy mobile gear ground fishery	DEA	Technical efficiency , output-oriented (variable returns to scale) Capacity and capacity utilization (CU).	Fixed input: -The capital stock of each vessel (measured by its length overall LOA). -Biomass levels (additional fixed environmental parameters, z variables): cod; haddock; Pollock.	- the round weight of each species landed (kg) per vessel per day fished.	Analysis of CU in a multi-species fishery with both ITQ and non-ITQ components Objective to determine the maximal or capacity output per fisher Analysis of the relationship between ITQs (individual transferable quotas), excess capacity and CU. Vessels are the DMUs.

Table 2. Review of fisheries studies applying DEA (continued).

Author	Case study	Method	Efficiency model	Inputs	Outputs	Relevant aspects
(Esmaeli & Omrani, 2007)	Hamoon Lake (freshwater lake in Iran) fishery	DEA under two assumptions: constant and variable returns to scale.	The study includes: -Technical efficiency (with additional two components: net technical efficiency and scale efficiency) -Allocative efficiency -Economical efficiency	-The number of harvesters of group -The number of motor-powered boats -The number of harvesters transferring automobiles -Net size -Annual cost of timber -Annual insurance cost of the group's members -Annual cost of harvesting permission -Annual costs of strip -Annual cost of fuel	Profit from each species: -Common carp -Grass carp -Silver carp -Big head -Schizothorax	The main objective of this study is to analyse the technical efficiency of fishery industry in the Iranian zone of the lake. Differences in efficiency among vessels were find to be small It is stated that the technology used by vessels is similar, and so the skippers' skill is indicated as the possible main factor to influence the efficiency differences.
(Färe, Kirkley, & Walden, 2006)	US Georges Bank multi-species otter trawl fishery (tow level basis). The species studied were, haddock, yellowtail, cod flounder, pollock, winter flounder, witch flounder, windowpane flounder, redfish American plaice, white hake, monkfish.	DEA	Technical	Horsepower Vessel length Gross tonnage Crew size Tow duration (is not allowed to change in the model)	For each of the species - Cod, Haddock, Yellowtail flounder, Monkfish, Other roundfish (pollock, white hake, and redfish), Other flatfish (winter flounder) , Witch flounder, Windowpane flounder, and American plaice - good output is the "landings" and bad output is the "discards".	Alternative concept of technical efficiency (recognizes that measures of efficiency should be adjusted for discards levels). This perspective opposite to the traditional measures of efficiency that do not consider the resources used in order to discard. Framework based on DEA to assess efficiency in the presence of undesirable outputs. Efficient vs inefficient tows Results extended to the trip level (conclusion considering the potential impact of trip-limit regulation).

Table 3. Review of fisheries studies applying DEA (continued).

Author	Case study	Method	Efficiency model	Inputs	Outputs	Relevant aspects
(Felthoven, 2002)	Bering Sea and Aleutian Islands pollock fishery (US)	-DEA (output oriented, VRS) -SPF	- Fishing capacity - Technical harvesting efficiency (TE) - Capacity utilization (CU)	Variable inputs: -Total annual days at sea -Annual tow duration (in hours) -Annual crew (in man-weeks); Fixed inputs: - Vessel length -Tonnage -Horsepower Non-discretionary inputs: -Annual stock estimates of: -Pollock -Flatfish -Pacific cod	Total annual catch of: - Pollock - Flatfish - Pacific cod	Objective of examine the effects of the American Fisheries Act (AFA) into the fishing capacity, technical harvesting efficiency (TE) and capacity utilization (CU). The study includes the annual catch for 30 vessels between 1994 and 2000.
(Herrero, 2005)	Spanish Trawl fleet operating in Moroccan waters	-DEA -Stochastic production frontiers -Panel data -Distance functions	Technical standard BBC output oriented model	Size of vessels (GRT) Engine power (horse power) Number of trips each month	Multi-output: total value of the catch of two groups of species over a month (crustaceans and finfish) Single output: total value of total catch (all species together) over a month	Comparison between the four methods, with focus on technical efficiency. The study concludes that using “multi” or “single” output feature leads to higher differences in the efficiency estimates. It is also stated that ignoring or considering random error influences the results.

Table 4. Review of fisheries studies applying DEA (continued).

Author	Case study	Method	Efficiency model	Inputs	Outputs	Relevant aspects
(Herrero, 2004)	Gibraltar Strait: sea bream fishery and tuna fishery	Four DEA models: A standard BCC output oriented for the SBR fishery (1) and for the BFT fishery (2). Each unit operating in SBR is compared with all units operating in BFT (3), and the same is repeated to for the BFT fleet (4).	Technical efficiency (within-fishery) Programme efficiency, PE (between-fishery)	Monthly number of trips (variable input) Fixed inputs: -Size of the boat (GRT) -Engine power (HP) -Number of crew	Value of total catch	Fleet operates in the Gibraltar Strait (coastal fishery) 91 vessels Data of the year 2000, with a monthly base Target species: Sea bream (SBR) Bluefin tuna (BFT)
(Herrero, Pascoe, & Mardle, 2006)	Spanish fresh fish trawlers operating in Moroccan Waters	DEA	Mix efficiency Technical efficiency	Size of the boat (GRT) Engine power (HP) Number of trips per month	Monthly observations of the value of Shellfish and Finfish	24 vessels
(Hoff, 2006)	Fleet of Danish seiners operating in the North Sea and the Skagerrak.	DEA in combination with bivariate smoothed Simar–Wilson bootstrap problem (input-orientated)	-Total efficiency (CRS) -Pure efficiency (VRS) -Technological changes (TC) -Scale changes (SC) input-orientated	Fishing time (days at sea) Fishing power (tonnage)	Catch weight: -Cod -Plaice -Other codfish -Other flatfish -Other species	Assessment of significant Total Factor Productivity (TFP) changes in the case study between 1987 – 1999 Estimating of confidence intervals of the Malmquist index Bootstrap analysis.

Table 5. Review of fisheries studies applying DEA (continued).

Author	Case study	Method	Efficiency model	Inputs	Outputs	Relevant aspects
(Hoff, 2007)	Danish fishery (Danish liners and gillnetters in 2002, monthly)	DEA Four different models to compare the 2nd stage results -Tobit regression -Papke – wooldridge -Unit-inflated beta model -Ordinary least squares, OLS regression		Vessel length Maximum horse power Number of crew members	CPUE (kg/days at sea) for the species group -Cod -Other cod fish -Plaice -Other flatfish -Other species	Exploration of two alternative approaches to second stage DEA (where tobit regression is normally applied). The results are compared to the tobit approach, using the Danish fishery case study. Comparisons of the second stage have been done for the months for January, March, May, July, September and November.
(Holland & Lee, 2002)		DEA	Capacity output Output oriented, CRS and VRS Conclusions extended to average efficiency			Estimation of capacity and capacity utilization (CU) for fisheries (applied through an independent approach to each DMU). Also, it presents results of VRS model. Application of the FGK model with CCR and VRS This study uses Monte Carlo simulations: it was found that DEA capacity estimates and DEA estimates of average efficiency are very sensitive to "noise" and to the specifications of the model.
(Kirkley & Squires, 1999)	U.S. Northwest Atlantic Sea Scallop Fishery	DEA	-Capacity -Capacity utilization -Input utilization (with and without resource levels). Variable returns to scale	Fixed inputs: -resource abundance (discretionary) -GRT -engine horsepower -dredge width Variable inputs: -Days at sea -Crew size per trip	-Pounds of sea scallop meats landed per trip.	technological-economic and economic definitions of capacity 10 scallop vessels observations for 1987-1990

Table 6. Review of fisheries studies applying DEA (continued).

Author	Case study	Method	Efficiency model	Inputs	Outputs	Relevant aspects
(Kirkley J. E., Squires, Alam, & Ishak, 2003)	Peninsular Malaysian purse seine fishery	DEA	Capacity output Technical efficiency output orientated	Fixed inputs: -gross registered tonnage (GRT) - length of hull in meters - engine horsepower - length of net in meters Variable inputs: -days at sea per month -total number of crew per month	Catch weight: -hardtail scad -selar scad - tuna - Indian Mackeral - yellow striped trevally - round scad - ox-eye scad - sardine -mixed species.	Illustrates a method for estimating capacity when information is limited The unit of observation is the vessel. Multiple inputs and multiple outputs Variable returns to scale
(Kjaersgaard, 2010)	Danish commercial fishing fleet (entire commercial fishery sector in Denmark)	Two-stage model -First stage: output-based DEA (seven analysis are performed: the vessels compared are grouped by its length) -Second stage: Multi-Objective Programming (MOP)	-Capacity utilization (CU), variable returns to scale	Fixed inputs: -Gross tonnage (GT) -Horse power (HP) Variable inputs: -Labour -Days at sea	Outputs: -Cod, - Other codfish, -Mackerel, -Herring, -Shrimp and Norway Lobster - Industrial species - Other species - Plaice - Other flatfish - Northern prawn - Mussels	Explores overcapacity and optimal capacity within fisheries (accounts for multiple objectives) A two-stage model (produces information for management: tradeoffs, policy frontiers, objective values and optimal fleet structure) Data from the year 2003.

Table 7. Review of fisheries studies applying DEA (continued).

Author	Case study	Method	Efficiency model	Inputs	Outputs	Relevant aspects
(Lindebo, 2005)	North Sea flatfish fishery (ICES Division IV) – Europe.	DEA	Capacity	Fixed inputs: Gross tonnage (GT) Engine power (kW) Variable inputs Days at sea (DAS)	Weight of catches: -sole -plaice -other flatfish -other fish	Data from the year 1998. Objective of identify overcapacity and possible reductions of the current fleet.
(Lindebo, Hoff, & Vestergaard, 2007)	Danish North Sea trawlers	DEA	output oriented	Fixed inputs: Tonnage Engine power Length Variable inputs: Crew Days at sea	Catch revenues: - Crustacea - Codfish - Flatfish - Harring / mackerel - Fish for reduction - Other consumption species Related output prices	economic measure of capacity (opposing to the physical approach)
(Madau, Idda, & Pulina, 2009)	Northwest Sardinian fleet in Italy	DEA	output oriented	Fixed inputs: Length of the hull Gross tonnage Engine power Value of the capital Variable inputs Number of crew Expenditure for nets Expenditure for fuel	Value of catches (€) 1st class catches 2nd class catches 3rd class catches 4th class catches Molluscs Crustaceans Other species	DEA used to estimate fishing capacity, technical efficiency, scale efficiency, capacity utilization

Table 8. Review of fisheries studies applying DEA (continued).

Author	Case study	Method	Efficiency model	Inputs	Outputs	Relevant aspects
(Oliveira, Camanho, & Gaspar, 2010)	Portuguese artisanal dredge fleet operating in the south coast of Portugal	DEA	-technical-efficiency (TE) - revenue efficiency output oriented	Fixed inputs: - Vessel engine power (kW) - Overall vessel length (m) - Tonnage (grt) - Indicator of stock biomass (for each target species in g per 5-min dredge tow) Variable inputs: -Number of days at sea	Catch weight: - Surf clam - Donax clam - Striped venus Catch revenue: - Surf clam - Donax clam - Striped venus	Three species Data between 2005 and 2007 "annual fishing quota per vessel (kg) was used as a contextualizing factor that bounded the output expansion allowed for each vessel"
(Oliveira, Gaspar, Paixão, & Camanho, 2009)	Portuguese artisanal dredge fleet operating in the south coast of Portugal	DEA	-Efficiency change (EC) -Technological change (TC) output oriented	Fixed inputs: - Vessel length (m) - Vessel tonnage (GRT) - Vessel power (kW) Variable inputs: - No. days at sea (per year)	Single output: -Annual quantity landed (all species aggregated).	Variation in productivity over 10 years (between 1995 and 2004). Comparison of the performance of two fleet segments (local and coastal). Comparison of the performance of five homeports. Assessment of the impact on productivity levels of: changes in stock conditions and changes in regulatory policies.

Table 9. Review of fisheries studies applying DEA (continued).

Author	Case study	Method	Efficiency model	Inputs	Outputs	Relevant aspects
(Pascoe, 2007a)	UK demersal trawl fleet	DEA	-Technical efficiency -Capacity Utilization -Scale efficiency (of CU and TE) - Both CRS and VRS)	Fixed inputs: -Length -Engine power Variable inputs: -Fuel costs	Revenue	Due to the poor data available, the data was adjusted: the DEA analysis was used to estimate capital utilization (CU) and inefficiency. Cost function were estimated and used in the determination of: optimal scale and potential rents for the fleet, and the reduction in the size of the fleet that would be necessary to achieve the rent. Two approaches: -Fully utilized level of output with fixed inputs (capacity output); -Translog cost function (using adjusted data to determine the long-run cost function and the cost-minimizing level of production)
(Pascoe, 2007b)	This paper does not present a practical application of DEA. It provides a reflection concerning the study of fisheries capacity (both with DEA and SPF) and the real policies adopted in fisheries (the practical application).					
(Pascoe & Herrero, 2004)	The method is applied to an artificial data set (validation) The method is then applied to two Spanish fisheries in the South Atlantic: -a single-species -a multi-species	DEA	Technical efficiency, output-oriented.	-Physical measure of the boat (GRT) -Engine power (HP) -Number of trips per month	First case study: octopus -The amount of octopus catch Second case study -Six different outputs: the 5 most important species and the rest of the species	DEA is used to estimate changes in stock of fish, over time by estimating the shift in production frontiers between different periods. The method is intended to provide more robust estimates of production functions when information concerning stock abundance is not known. Application to an artificial data set and two Spanish fisheries.

Table 10. Review of fisheries studies applying DEA (continued).

Author	Case study	Method	Efficiency model	Inputs	Outputs	Relevant aspects
(Pascoe & Mardle, 2003)	This paper does not present a practical case study. It provides a review of SPF and DEA concepts and it reviews the application of these methods to EU fisheries.					
(Pascoe & Tingley, 2006)	Scottish fleet segments in the Scottish fishing fleet.	DEA	- Technical efficiency - Physical capacity - Economic capacity - Optimal capacity idleness	Fixed inputs: - Boat size (the product of length and breadth) - Engine power - Days at sea. - Gross tonnage - Length - Vessel capacity units (VCUs) - Days fished (rather than days at sea)	Revenue	The vessels defining the frontier operate through a profit maximising behaviour. Data relate to 2001. The boats were only compared with boats from the same fleet segment.
(Pascoe, Coglan, & Mardle, 2001)	The Western Channel fishery (UK otter trawlers and netter-liners)	DEA	Capacity and technical efficiency, output oriented.	Fixed inputs: -length -breadth -engine power Variable inputs: -days fished	Quantity of catch from each species	Application of DEA to measure the fishing capacity, on a species-by–species basis, in the UK. The DMU corresponds to a boat. The model was run separately for each month (only boats that fished in the same month could be compared).
(Reid, Squires, Jeon, Rodwell, & Clarke, 2003)	Western and central Pacific Ocean (WCPO) purse seine fishery	DEA	-Technical efficiency - Potential catching capacity - Excess capacity			Objective of assess the implications of changing the management regime to "a based on limiting the total number of fishing days in the fishery."

Table 11. Review of fisheries studies applying DEA (continued).

Author	Case study	Method	Efficiency model	Inputs	Outputs	Relevant aspects
(Tingley & Pascoe, 2003)	Scottish Fishing Fleet	DEA and SPF	-Capacity utilization (CU) -technical efficiency (TE)	Fixed inputs: - Vessel 'boat size' (calculated as vessel overall length x breadth) - Engine power (kW) - Annual fixed costs (excluding depreciation and interest) Variable inputs: -Variable costs per day at sea -Crew costs (estimated as a percentage of net revenue) -Annual days at sea	Separate landings revenue and weight for: - 36 species - the category 'other' species landed	Aim to estimate the Level of Excess Capacity in the fishery analysed.
(Tingley & Pascoe, 2005a)	Scottish Fishing Industry	DEA	-Capacity utilization -Technical efficiency	-Boat size (the product of length and breadth) -Engine power -Days at sea.	Revenue	Assessment of the excess capacity in the Scottish fleet using a variant of the DEA model (it considers the additional costs of increasing fishing effort to achieve full utilisation). Data from 2001.
(Tingley & Pascoe, 2005b)	Four UK fleet segments operating in the English Channel	DEA	Capacity utilization (CU) Technical efficiency (TE)	Fixed inputs: -Engine power (kW) - Deck area (m2) Variable inputs: -Number of days fished -- Target metier -- Other métiers	Revenue - Top five species - Other species - Other me´ tiers	The effects of stock abundance, output prices, fuel prices and fleet size on the rate of capacity utilisation are examined for each fleet segment. It is concluded that changes in stock abundance are the main factor affecting CU. Note: "A fishing métier describes a specific fishing activity undertaken in a defined fishing area, targeting certain species and using a particular gear type."

Table 12. Review of fisheries studies applying DEA (continued).

Author	Case study	Method	Efficiency model	Inputs	Outputs	Relevant aspects
(Tingley, Pascoe, & Coglan, 2005)	English channel fisheries	SPF and DEA (comparison of the two)		Average annual days fished Engine power (kW) Overall length (m)	Adjusted average annual revenue	Comparison of SPF and DEA results for the case study. DEA is suggested as an alternative to SPF technique when there is difficulty in specifying the correct SPF model. Regarding the factors affecting TE (technical efficiency), there is consistency between SPF and DEA results. Separated analysis of each of the three fishing activities Separated DEA analysis were performed for each year
(Tingley, Pascoe, & Mardle, 2003)	UK fleet operating in the English Channel	DEA	-Technical efficiency -Capacity utilization (CU)	Base analysis: -Days fished -Deck size (vessel length x breadth) -Engine power In the modified analysis there is an extra input: -Days fished in other métiers in the same month	-Single output and revenue based measures -Multi-output and revenue based measures -Single output and weight based measures -Multi-output and weight based measures	The study is focused on the multi-purpose fleets (includes fleets which fish different species).
(Tsitsika, Maravelias, Wattage, & Haralabous, 2008)	Eastern Mediterranean (Greek) purse seiners ((multi-species fishery with seasonal targeting).	DEA	-Capacity utilization -Technical efficiency (output oriented)	Fixed inputs: -boat capacity (GT) -engine power (HP) Variable inputs: -Days fished per vessel	The landing weights of: -Anchovy -Sardine -Mackerel -Others	Purse seining is the fishing method, used to capture pelagic species (the pelagic trawling is prohibited). Two fleet segments (by length): 12–24 m and 24–40 m. Monthly analysis from March–November between 2000–2005. Length was not considered as an input since it was found to be correlated with gross tonnage.

Table 13. Review of fisheries studies applying DEA (continued).

Author	Case study	Method	Efficiency model	Inputs	Outputs	Relevant aspects
(Vestergaard, Squires, & Kirkley, 2003)	Multi-species Danish Gill-net fleet fishery	DEA	Capacity and Capacity, output oriented utilization (CU) Technical efficiency	GRT Length Width Depth Hold capacity Engine power	Catch of each species: -Cod -Haddock -Saithe -Plaice -Sole -Other	Analysis used data from 1993 (annual data). The paper states that the results obtained may not indicate the capacity and CU under different regulatory / natural resources conditions.
(Walden, Kirkley, & Kitts, 2003)	U.S. Northeast ground fish vessel buyout program	DEA	Technical efficiency, variable returns to scale	Fixed inputs: - gross registered tonnage (GRT) - vessel length in feet (L) - vessel horsepower (HWP) Variable input: -Vessel crew size	Outputs: Landings (in weight) per day at sea for each of the ten "large mesh" species.	Objective is the assessment of a limited assessment of the Northeast ground fish buyout program. Estimations of daily capacity.
(Zheng & Zhou, 2005)	Chinese Marine Fleets	-Peak to peak (PTP) -DEA	Technical efficiency, constant returns to scale output- and input-oriented	Number of vessels Gross tonnage kW	Catch (weight)	Data relative to 1999. Chinese coastal provinces are considered as DMUs. "Comparing the PTP and the DEA method, it is clear that PTP methodology is helpful for a longitudinal analysis in time arrays, but DEA approach is very suitable for the transverse comparison of fishing capacity."

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