Relating estimates of fishing capacity obtained from Data Envelopment Analysis to traditional measures of fishing capacity

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ABSTRACT

Estimates of fishing capacity, *i.e.* the capacity to remove fish from a stock, are provided by readily available data such as gross registered tonnages (GRTs), fish-carrying capacities or lengths of the vessels, or even the numbers of vessels. Data envelopment analysis (DEA) of potential catch provides estimates of fishing capacity that are more consistent with the formal economic definition of fishing capacity, but much more detailed data are required to carry these out. In this paper, estimates of the fishing capacity of United States purse-seine vessels that operated in the western and central Pacific Ocean during 1983-2002 obtained from GRT data and DEA are compared. The two estimates are positively, but weakly, correlated, indicating that estimates of fishing capacity obtained from GRT data are of limited value.

1. INTRODUCTION

The notion of fishing capacity continues to generate substantial differences in opinion regarding its definition and, more generally, its conceptual meaning. In its broadest usage, capacity refers to the maximum amount something can contain. Capacity, in its widespread usage among policy makers, industry and other stakeholders, often refers to a measure of the capital stock, so that the capital stock is used as an indicator of the capacity base. Measures of the capital stock used as measures of capacity include gross registered tonnage (GRT), fish-carrying capacity, vessel length and even vessel numbers. Capacity has very precise and several alternative definitions and measures within the economics literature (Morrison 1985, Nelson 1989) and in its application to fishing and other natural resource industries (FAO 1998 and 2000, Kirkley and Squires 1999). The formal FAO definition (FAO 2000) is, "Fishing capacity is the maximum amount of fish over a period of time (year, season) that can be produced by a fishing fleet if fully utilized, given the biomass and age structure of the fish stock and the present state of the technology. Fishing capacity is the ability of a vessel or vessels to catch fish." Broadly speaking, economic theory, national governments and the formal FAO definition of fishing capacity measure the capacity base by a measure of potential output or catch.[1]

The question that arises is how closely does capacity measured by the capital stock correspond to the FAO definition of fishing capacity as a measure of potential catch? A reasonably close correspondence between the capital stock and fishing capacity measured by potential catch would suggest that measures of the capital stock can be accurately used, or that they can be used interchangeably, but a distant correspondence would suggest that caution be exercised.

Specifically, the question that is empirically evaluated in this paper is how well do estimates of capacity output by data envelopment analysis (DEA), providing a measure of the capacity base, compare to changes in a readily available measure of the capital stock? If there is a close relationship between capacity output and the capital stock, then empirical evidence is provided that changes in the capital stock track changes in capacity output and that measures of the capital stock provide reasonably accurate measures of fishing capacity, *i.e.* of capacity output. If there is not a close relationship, then the empirical evidence does not support use of the capital stock as a surrogate measure of the capacity base, rather than capacity output. In either instance, the evidence provided is from a single fleet.

The fleet that is evaluated is the United States tuna purse-seine fleet, using annual data for vessels with at least 98 days absence during the year in question in the western and central Pacific Ocean over the 1983-2002 period. Gross registered tonnage (GRT) serves as the measure of the capital stock. Yellowfin and bigeye tuna caught in either unassociated schools or in schools associated with drifting floating objects are specified as one output and skipjack tuna caught in either of the two types of schools is specified as the second output. Both outputs were further specified on a per-day basis by dividing annual catch for each output by the total number of days absent.

2. EMPIRICAL ANALYSIS

The analysis proceeds in two steps. The first step estimates capacity output by DEA, which is described in greater detail below. The second step regresses capacity output per day on GRT plus a constant term. The better the fit of the regression analysis, then the closer the correspondence between potential catch and the capital stock for

[1] In economics, there are both primal and dual measures of potential output. In other words, potential output can be measured as a maximum potential output that can be produced, given that all variables are fully utilized and given the capital stock, or it can be measured as the short-run cost-minimizing, profit-maximizing or revenue-maximizing output levels. In fisheries, the primal or maximum potential output is used.

the fishery analyzed. This regression analysis is conducted for ten different functional forms described in the next section.

2.1. Regression analysis of capacity output and capital stock

The simplest functional form is linear, which can be specified as follows:

$$y = \alpha + \beta K + \varepsilon \tag{1}$$

where y denotes potential catch or capacity output per day, K denotes the capital stock as measured by GRT, α is the constant term, β denotes the coefficient for K or slope and ε denotes a random disturbance term.

Functional forms other than the linear form can describe the relationship between potential output (capacity output) and the capital stock (GRT). The logarithmic functional form can be written as:

$$\mathrm{y} = \alpha + \beta \ln \mathrm{K} + \varepsilon \tag{2}$$

where *ln* denotes the natural logarithm.

The quadratic functional form may be written:

$$y = \alpha + \beta_1 K + \beta_2 K^2 \tag{3}$$

The cubic functional form may be written:

$$y = \alpha + \beta_1 K + \beta_2 K^2 + \beta_3 K^3. \tag{4}$$

The exponential functional form may be written:

$$y = \alpha e^{\beta K} \tag{5}$$

The power functional form may be written:

$$\mathrm{y} = \alpha \mathrm{K}^{\beta} \varepsilon \tag{6}$$

The inverse functional form may be written:

$$y = \alpha + \beta \frac{1}{K} + \varepsilon \tag{7}$$

The logistic functional form may be written:

$$y = \frac{1}{1 + \beta e^{K}} \tag{8}$$

The compound functional form may be written:

$$\mathrm{h}\ \mathrm{y} = \ln \alpha + \mathrm{h}\ \beta\,\mathrm{K} + \varepsilon \tag{9}$$

The S functional form may be written:

$$\mathrm{h}\ \mathrm{y} = \alpha + \beta \frac{1}{\mathrm{K}} + \varepsilon \tag{10}$$

2.2. Estimate of capacity output from data envelopment analysis

For the purpose of estimating capacity, an output-oriented DEA problem is solved. We desire to determine the maximum potential output levels that can be produced, given existing fixed factors (here, critically, the capital stock) and the potential level of variable inputs. Capacity for each observation is estimated by solving one mathematical programming problem (in actuality, a linear programming, LP, problem) for each observation. This facilitates the determination of a best-practice frontier, and permits capacity to be estimated for each observation. The basic LP problem is as follows:

$$TE_{ocj} = \underset{\theta,z,\lambda}{Max}\,\theta \tag{11}$$

subject to $\theta u_{jm} \leq \sum_{j=1}^{J} z_j u_{jm}, m = 1,\ldots, M,$

$$\sum_{j=1}^{J} z_j x_{jn} \leq x_{jn}, n \in F_x$$

$$\sum_{j=1}^{J} z_j x_{jn} = \lambda_{jn} x_{jn}, n \in V_x$$

$$\sum_j z_j = 1.0$$

$$z_j \geq 0, j = 1,2,\ldots, J$$

$$\lambda_{jn} \geq 0,$$

where θ (2 $ 1.0) is a measure of technical efficiency, TE, and is the inverse of an output distance function; *F* is a vector of fixed inputs; *V* is a vector of variable inputs; *z* is a vector of intensity variables used to construct the piece-wise technology; and *u* is a vector of outputs. If we multiply the observed output by 2, we obtain an estimate of capacity output. Capacity can also be estimated by solving the same problem without the variable input constraints, which indicates that they are, in fact, decision variables. With either the equality constraint included on the variable inputs or the omission of the variable inputs, the solution to problem (11) yields values of *z* that can then be used to calculate the level of variable inputs required to produce the capacity output.

Problem (11) imposes strong disposability in outputs and variable returns to scale. Strong disposability imposes the assumption that a producer (vessel operation) has the ability to dispose of any unwanted commodities without incurring any production cost or experiencing a loss in revenue. Variable returns to scale imposes the assumption that increasing all inputs by the same proportion will cause outputs to change by varying proportions (*e.g.* if all input are doubled, output levels might increase by a factor of 2, less than 2 or more than 2). The important aspect of variable returns to scale is that it permits varying rates of change in output levels, given different rates of change in input levels. The constraint that the sum of $z_j = 1.0$ imposes variable returns to scale.

Färe *et al.* (1989) initially proposed the DEA specification given in problem (1) for assessing capacity when data were limited to input and output quantity information. In other words, economic data such as cost and earnings information and information on input and output prices were not available. Problem (1) is a technological-engineering concept of capacity, but since estimates are based on actual data, estimates of capacity obtained from solutions to problem (1) implicitly reflect the underlying economics.

In addition to obtaining an estimate of capacity, problem (11), together with the same problem, but including all inputs, may be used to estimate an unbiased measure of capacity utilization (CU). Färe *et al.* (1989) demonstrated that the ratio of an output-oriented measure of TE (TE_{oj}), with fixed and variable inputs included, to an output-oriented measure of TE (TE_{ocj}), with variable inputs excluded, yielded a relatively unbiased measure of CU:

$$CU_j = \frac{TE_{oj}}{TE_{ocj}} \tag{12}$$

The CU measure of Färe *et al.* (1989) permits an assessment of whether deviations from full capacity are because of inefficient production or less than full utilization of the variable and fixed inputs.

The relationship between capacity output (estimated by DEA) and the capital stock, the latter measured by GRT, for the entire fleet is supplemented by a more disaggregated analysis for disaggregated groupings of vessels as defined by cluster analysis. The premise is that analysis with more finely tuned groups of data might reveal finer resolution of the results than a more aggregated analysis. Since this analysis is simply a "first-cut" analysis, further investigation of the relationship between capacity output and the capital stock can define more systematic classifications of the vessels.

An additional analysis of the relationship between capacity output (estimated by DEA) and capital stock, measured by GRT, includes the variables for biomass of the target species and sea-surface temperature to control the influence of the environment and an annual time trend. In this case, with a linear functional form, the regression analysis is written as:

$$\begin{aligned} y = \beta_0 + \beta_1 \mathrm{GRT} + \beta_2 \mathrm{BiomassYellowfinBigeye} + \beta_3 \mathrm{BiomassSkipjack} + \\ \beta_4 \mathrm{SeaSurfaceTemperature} + \beta_5 \mathrm{Trend} + \varepsilon \end{aligned} \quad (13)$$

3. EMPIRICAL RESULTS

The result of regression of total capacity output per day, calculated as the sum of the individual capacity outputs per day, upon the measure of the capital stock, GRT, is reported in Table 1 for the ten alternative functional forms considered (Equations 1-10) and illustrated in Figure 1.

The regression results (Table 2) indicate a statistically significant overall regression for each functional form (Equations 1-10), as indicated by the F-statistic, but a very weak fit, as indicated by the R^2 of regression. Some of the functional forms gave marginally superior results, as indicated by the overall F-statistic for significance of regression and the R^2, but the overall results remain weak. Considerable dispersion around the fitted regression line can be seen in Figure 1, reinforcing the notion that there is only a limited

FIGURE 1
Observed and fitted values of total (yellowfin, bigeye, and skipjack) capacity output per day obtained from DEA vs. gross registered tonnage, with different functional forms

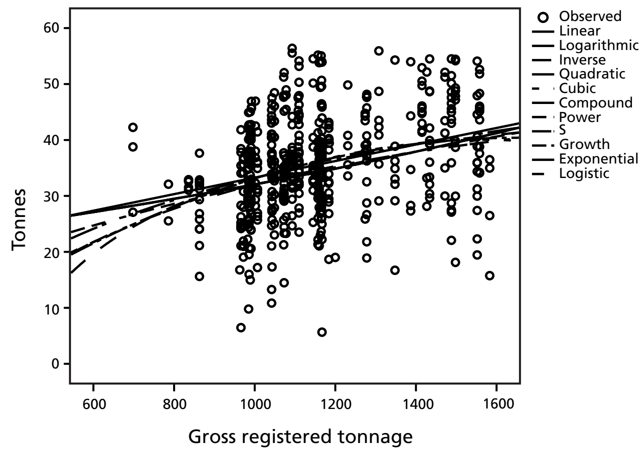


TABLE 1
Regression of total capacity output per day against GRT, given different functional forms

Functional form	R square	Degrees of freedom	F	Significance	β_0	β_1	β_3	β_4
Linear	0.090	498	49.40	0.000	18.4997	0.0148		
Logarithmic	0.093	498	50.94	0.000	-89.798	17.8097		
Inverse	0.092	498	50.60	0.000	53.6528	-20376		
Quadratic	0.096	497	26.31	0.000	-5.9402	0.0560	-2×10^{-5}	
Cubic	0.097	497	26.64	0.000	-1.998	0.0385		-5×10^{-9}
Compound	0.070	498	37.58	0.000	21.0888	1.0004		
Power	0.073	498	38.97	0.000	0.9682	0.5065		
S	0.072	498	38.89	0.000	4.0481	-580.69		
Growth	0.070	498	37.58	0.000	3.0487	0.0004		
Exponential	0.070	498	37.58	0.000	21.0888	0.0004		
Logistic	0.070	498	37.58	0.000	0.0474	0.9996		

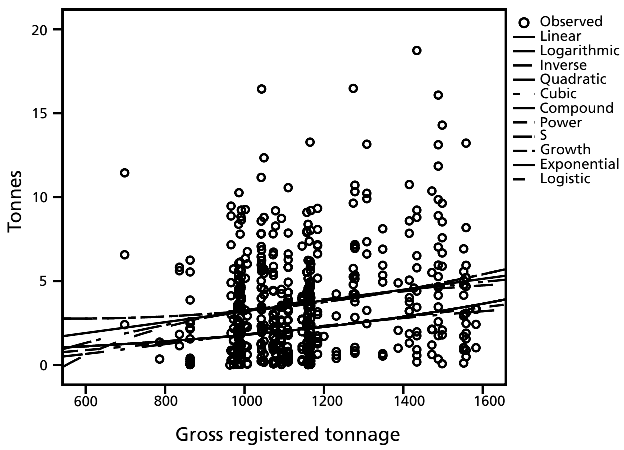
The total capacity output per day is the sum of the capacity output per day of yellowfin and bigeye plus the capacity output per day of skipjack.

TABLE 2
Statistical results of regressions of total capacity output per day absent against independent variables

Variable	Unstandardized coefficients		Standardized coefficients	t-statistic	Significance
	Coefficient β	Standard error	Beta		
Constant	111.273	403.672		0.276	0.783
GRT	0.015	0.002	0.306	9.409	0.000
Biomass of yellowfin and bigeye	0.000	0.000	0.605	7.110	0.000
Biomass of skipjack	0.000	0.000	0.714	10.516	0.000
Sea-surface temperature	2.368	0.883	0.167	2.683	0.008
Year	-0.176	0.183	-0.076	-0.961	0.337

Note: adjusted R-square = 0.473.

FIGURE 2
Observed and fitted values of yellowfin and bigeye capacity output per day obtained from DEA vs. gross registered tonnage, with different functional forms



statistical relationship. Eight of the ten equations indicated a positive coefficient for GRT. The only exceptions are the inverse and S functional forms, Equations (7) and (10), respectively, in which the capital stock enters as the inverse and in which the expected sign of the coefficient for capital stock is negative, as expected. These results for all equations suggest a positive relationship between the capital stock and total capacity output per day. In sum, a statistically significant and positive relationship exists between total capacity output and the capital stock, but the result is so weak that it indicates no close association between the two. Regression of total capacity output per day for yellowfin and bigeye, illustrated by Figure 2, reinforces this conclusion.

Total capacity output regressed against the explanatory variables of Equation (13) indicated a much stronger relationship, with an adjusted R^2 of 0.473 and a statistically significant overall F-statistic of 90.869 (degrees of freedom = 5, 495). The coefficient for GRT was positive, as expected, and statistically significant, thereby suggesting a positive relationship between the capital stock and total capacity output. This relationship reinforces the previous conclusion that a positive, but weak, relationship exists between the two. In addition, as expected, greater biomasses increase total capacity output per day, given GRT, indicated by the statistically significant and positive regression coefficient. A higher sea-surface temperature also increases total capacity output per day, indicated by the statistically significant and positive regression coefficient.

Disaggregated analysis of the relationship between capacity output and capital stock (GRT) by vessel size groups determined by cluster analysis indicates a stronger relationship between the two (Tables 3-17).

Tables 3, 4, 5, 6, 8, 10, 12, 14 and 16 summarize total capacity output, GRT, and other related statistics for each of the five clusters and overall. Tables 7, 9, 11, 13 and 15 summarize the results for the regression of total capacity output on the capital stock or GRT for Clusters 1, 2, 3, 4 and 5, respectively, for the functional forms given by Equations (1)-(10). Table 17 summarizes the analysis of variance results for differences

TABLE 3
Summary statistics of cluster analysis

Cluster	Min. GRT	Max. GRT	Mean GRT	Median GRT	SE of mean	Min. total Q	Max. total Q	Mean total Q	Median total Q	SE total Q
3	698	863	828.6	863	12.34	15.62	42.26	29.97	31.38	1.27
2	963	1078	1016.9	1002	2.75	0.00	52.04	32.69	33.56	0.64
4	1093	1231	1146.1	1160	2.64	5.66	56.39	36.41	35.64	0.67
5	1274	1434	1354.6	1348	8.05	16.72	55.92	39.28	39.33	1.11
1	1472	1583	1521.7	1498	4.80	15.76	54.50	39.88	41.24	1.32

TABLE 4
Estimated capacity outputs by cluster

Cluster	Mean GRT	YFT+BET CCPDA, unassociated schools	SKJ CCPDA, unassociated schools	YFT+BET CCPDA, floating-object schools	SKJ CCPDA, floating-object schools
3	828.59	4.57	12.31	3.76	9.33
2	1016.90	4.54	13.66	3.77	10.72
4	1146.12	4.48	14.65	4.22	13.06
5	1354.60	6.66	15.06	4.48	13.09
1	1521.70	6.49	15.28	4.51	13.60

YFT = yellowfin; BET = bigeye; SKJ = skipjack; CCPDA = capacity catch per day absent.

TABLE 5
Summary of mean GRT, observed (obs.) output, capacity output, and ratio (mean of ratios) of capacity to observed output

Cluster	Mean GRT	YFT+BET CCPDA, unassociated schools			SKJ CCPDA, unassociated schools		
		Capacity output	Obs. output	Ratio	Capacity output	Obs. output	Ratio
3	828.59	4.57	2.91	1.57	12.32	7.90	1.56
2	1016.87	4.54	3.18	1.43	13.66	9.22	1.48
4	1146.12	4.48	2.94	1.52	14.65	9.44	1.55
5	1354.62	6.66	5.03	1.32	15.06	11.69	1.29
1	1521.66	6.49	4.61	1.41	15.28	11.10	1.38
Total	1154.18	5.03	3.50	1.44	14.30	9.77	1.46

TABLE 5 (continued)

Cluster	Mean GRT	YFT+BET CCPDA, floating-object schools			SKJ CCPDA, floating-object schools			Total capacity output		
		Capacity output	Obs. output	Ratio	Capacity output	Obs. output	Ratio	Capacity output	Obs. output	Ratio
3	828.59	3.76	2.66	1.41	9.33	7.05	1.32	29.97	20.53	1.46
2	1016.87	3.77	2.65	1.42	10.72	7.41	1.45	32.69	22.45	1.46
4	1146.12	4.22	2.82	1.50	13.06	8.83	1.51	36.41	23.82	1.53
5	1354.62	4.48	3.01	1.49	13.09	8.92	1.47	39.28	28.65	1.37
1	1521.66	4.51	2.84	1.59	13.60	8.21	1.66	39.88	26.76	1.49
Total	1154.18	4.10	2.77	1.48	12.07	8.08	1.49	35.49	24.13	1.47

YFT = yellowfin; BET = bigeye; SKJ = skipjack; CCPDA = capacity catch per day absent.

TABLE 6
Estimated capacity outputs for Cluster 1

	GRT	YFT+BET CCPDA, unassociated schools	SKJ CCPDA, unassociated schools	YFT+BET CCPDA, floating-object schools	SKJ CCPDA, floating-object schools	Total capacity output
Number of observations	59	59	59	59	59	59
Minimum	1472	0.00	0.00	0.00	0.00	15.76
Maximum	1583	16.08	36.21	15.62	45.89	54.50
Mean	1521.66	6.4922	15.2771	4.5098	13.5993	39.8785
Median	1498	5.9500	15.0100	3.6600	11.9300	41.2400
Standard error of mean	4.803	0.57754	1.20806	0.45772	1.48937	1.31737

YFT = yellowfin; BET = bigeye; SKJ = skipjack; CCPDA = capacity catch per day absent.

TABLE 7
Regression of total capacity output on capital stock for Cluster 1

Equation	Model summary					Parameter estimates			
	R square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	0.056	3.355	1	57	0.072	138.281	-0.065		
Logarithmic	0.055	3.321	1	57	0.074	758.351	-98.055		
Inverse	0.055	3.287	1	57	0.075	-57.856	148,632.794		
Quadratic	0.056	3.389	1	57	0.071	89.268	0.000	0.000	
Cubic	0.081	2.468	2	56	0.094	-2,925.078	2.953	0.000	0.000
Power	0.050	3.029	1	57	0.087	17,082,558,687.665	-2.718		
S	0.050	2.997	1	57	0.089	0.940	4,118.265		
Growth	0.051	3.062	1	57	0.086	6.376	-0.002		
Exponential	0.051	3.062	1	57	0.086	587.659	-0.002		
Logistic	0.051	3.062	1	57	0.086	0.002	1.002		

The independent variable is GRT and the dependent variable is total capacity output.

TABLE 8
Estimated capacity outputs for Cluster 2

	GRT	YFT+BET CCPDA, unasso-ciated schools	SKJ CCPDA, unasso-ciated schools	YFT+BET CCPDA, floating-object schools	SKJ CCPDA, floating-object schools	Total capacity output
Number of observations	191	191	191	191	191	191
Minimum	963	.00	.00	.00	.00	.00
Maximum	1078	16.44	31.27	11.77	40.43	52.04
Mean	1016.87	4.5446	13.6594	3.7701	10.7153	32.6893
Median	1002	3.4700	12.7900	3.5200	9.3000	33.5600
Standard error of mean	2.745	0.28773	0.62069	0.18837	0.61752	0.64259

YFT = yellowfin; BET = bigeye; SKJ = skipjack; CCPDA = capacity catch per day absent.

TABLE 9
Regression of total capacity output on capital stock for Cluster 2

Equation	Model summary					Parameter estimates			
	R square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	0.037	7.140	1	188	0.008	-11.050	0.043		
Logarithmic	0.037	7.261	1	188	0.008	-275.252	44.502		
Inverse	0.038	7.384	1	188	0.007	77.983	-45,814.383		
Quadratic	0.051	5.043	2	187	0.007	-1,111.089	2.197	-0.001	
Cubic	0.051	5.043	2	187	0.007	-1,111.089	2.197	-0.001	0.000
Power	0.033	6.327	1	188	0.013	0.001	1.500		
S	0.033	6.446	1	188	0.012	4.973	-1,545.883		
Growth	0.032	6.211	1	188	0.014	1.972	0.001		
Exponential	0.032	6.211	1	188	0.014	7.186	0.001		
Logistic	0.032	6.211	1	188	0.014	0.139	0.999		

The independent variable is GRT and the dependent variable is total capacity output.

TABLE 10
Estimated capacity outputs for Cluster 3

	GRT	YFT+BET CCPDA, unassociated schools	SKJ CCPDA, unassociated schools	YFT+BET CCPDA, floating-object schools	SKJ CCPDA, floating-object schools	Total capacity output
Number of observations	22	22	22	22	22	22
Minimum	698	0.03	0.00	0.51	2.85	15.62
Maximum	863	13.43	23.00	7.88	19.16	42.26
Mean	828.59	4.5727	12.3150	3.7559	9.3282	29.9718
Median	863	3.2400	11.6650	3.1050	8.4100	31.3750
Standard error of mean	12.344	0.88034	1.54917	0.41665	0.88131	1.27080

YFT = yellowfin; BET = bigeye; SKJ = skipjack; CCPDA = capacity catch per day absent.

TABLE 11
Regression of total capacity output on capital stock for Cluster 3

Equation	Model summary					Parameter estimates			
	R square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	0.177	4.294	1	20	0.051	65.834	-0.043		
Logarithmic	0.177	4.306	1	20	0.051	257.193	-33.827		
Inverse	0.177	4.314	1	20	0.051	-1.955	26,315.426		
Quadratic	0.177	2.045	2	19	0.157	96.218	-0.121	0.000	
Cubic	0.177	2.045	2	19	0.157	96.218	-0.121	0.000	0.000
Power	0.138	3.213	1	20	0.088	44,300.963	-1.090		
S	0.138	3.197	1	20	0.089	2.354	845.204		
Growth	0.139	3.227	1	20	0.088	4.538	-0.001		
Exponential	0.139	3.227	1	20	0.088	93.501	-0.001		
Logistic	0.139	3.227	1	20	0.088	0.011	1.001		

The independent variable is GRT and the dependent variable is total capacity output.

TABLE 12
Estimated capacity outputs for Cluster 4

	GRT	YFT+BET CCPDA, unasso-ciated schools	SKJ CCPDA, unasso-ciated schools	YFT+BET CCPDA, floating-object schools	SKJ CCPDA, floating-object schools	Total capacity output
Number of observations	164	164	164	164	164	164
Minimum	1093	0.00	0.00	0.00	0.00	5.66
Maximum	1231	14.79	33.94	15.62	45.89	56.39
Mean	1146.12	4.4753	14.6516	4.2222	13.0639	36.4130
Median	1160	3.8550	14.8100	3.5300	10.6900	35.6350
Standard error of mean	2.641	0.28856	0.72584	0.24970	0.84713	0.67383

YFT = yellowfin; BET = bigeye; SKJ = skipjack; CCPDA = capacity catch per day absent.

TABLE 13
Regression of total capacity output on capital stock for Cluster 4

Equation	Model summary					Parameter estimates			
	R square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	0.008	1.297	1	162	0.256	62.470	-0.023		
Logarithmic	0.008	1.328	1	162	0.251	221.833	-26.324		
Inverse	0.008	1.357	1	162	0.246	9.855	30,412.166		
Quadratic	0.012	0.974	2	161	0.380	573.458	-0.916	0.000	
Cubic	0.012	0.987	2	161	0.375	405.433	-0.472	0.000	0.000
Power	0.011	1.793	1	162	0.182	29,892.410	-0.957		
S	0.011	1.832	1	162	0.178	2.597	1,105.976		
Growth	0.011	1.751	1	162	0.188	4.510	-0.001		
Exponential	0.011	1.751	1	162	0.188	90.967	-0.001		
Logistic	0.011	1.751	1	162	0.188	0.011	1.001		

The independent variable is GRT and the independent variable is total capacity output.

TABLE 14
Estimated capacity outputs for Cluster 5

	GRT	YFT+BET CCPDA, unassociated schools	SKJ CCPDA, unassociated schools	YFT+BET CCPDA, floating-object schools	SKJ CCPDA, floating-object schools	Total capacity output
Number of observations	65	65	65	65	65	65
Minimum	1274	0.00	0.00	0.20	1.05	16.72
Maximum	1434	18.74	36.21	15.62	41.97	55.92
Mean	1354.62	6.6582	15.0560	4.4792	13.0874	39.2808
Median	1348	6.9200	14.8500	2.9300	11.6900	39.3300
Standard error of mean	8.053	0.56290	1.12953	0.45631	1.09950	1.11491

YFT = yellowfin; BET = bigeye; SKJ = skipjack; CCPDA = capacity catch per day absent.

TABLE 15
Regression of total capacity output on capital stock for Cluster 5

Equation	Model summary					Parameter estimates			
	R square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	0.027	1.747	1	63	0.191	8.471	0.023		
Logarithmic	0.027	1.735	1	63	0.192	-181.683	30.646		
Inverse	0.027	1.723	1	63	0.194	69.791	-41,235.812		
Quadratic	0.029	0.912	2	62	0.407	290.407	-0.395	0.000	
Cubic	0.029	0.911	2	62	0.408	194.120	-0.184	0.000	0.000
Power	0.028	1.808	1	63	0.184	0.067	0.880		
S	0.028	1.789	1	63	0.186	4.517	-1,182.813		
Growth	0.028	1.827	1	63	0.181	2.755	0.001		
Exponential	0.028	1.827	1	63	0.181	15.721	0.001		
Logistic	0.028	1.827	1	63	0.181	0.064	0.999		

The independent variable is GRT and the independent variable is total capacity output.

TABLE 16
Mean GRT and capacity output per day and standard errors of mean values

Cluster and standard error	Mean GRT and standard error	Mean capacity output per day and standard error
Cluster 3	828.6	30.0
Standard error	12.3	1.3
Cluster 2	1,016.9	32.7
Standard error	2.7	0.6
Cluster 4	1,146.1	36.4
Standard error	2.6	0.7
Cluster 5	1,354.6	39.3
Standard error	8.1	1.1
Cluster 1	1,521.7	39.9
Standard error	4.8	1.3
Total	1,154.2	35.5
Standard error	8.3	0.4

TABLE 17
Analysis of variance for differences in total capacity output between clusters

Cluster	Coefficient β_i	Standard error	t-statistic	Significance
Constant	39.878	1.139	35.005	0.000
Cluster 2	-7.017	1.304	5.381	0.000
Cluster 3	-9.097	2.186	-4.532	0.000
Cluster 4	-3.465	1.328	-2.609	0.009
Cluster 5	-0.598	1.574	-0.380	0.704

The dependent variable is total capacity output. Cluster 1 is constant and Clusters 2-5 are dummy variables.

in total capacity output by GRT size class, as defined by the clusters, and indicates statistically significant differences among clusters.

The regression results of total capacity output on capital stock for Clusters 1-5 give very low values for the R^2 and the F-statistics for overall regression that are almost always not statistically significant at the 5-percent level, although it is significant at the 10-percent level for each of the functional forms. In summary, the disaggregated results at the level of individual GRT size classes does not materially improve the combined analysis, and, in fact, gives results that are not statistically significant.

4. CONCLUDING REMARKS

How closely does capacity measured by a vessel's capital stock correspond to the FAO definition of fishing capacity as a measure of potential catch? A reasonably close correspondence between the capital stock and fishing capacity measured by potential catch would suggest that measures of the capital stock can be accurately used, or that they can be used interchangeably, but a distant correspondence would suggest that caution be raised.

This chapter empirically evaluated how well estimates of capacity output by DEA, providing a measure of the capacity base, compare to changes in a readily available measure of the capital stock. For the sample of United States tuna purse-seine vessels analyzed, there is only a very limited relationship between GRT, as a measure of the capital stock, and the FAO definition of fishing capacity as a potential output or maximum potential catch. Further analysis of the potential relationship between vessel size groupings and capacity output should be conducted, if additional data on vessel characteristics can be obtained.

In summary, for the United States tuna purse-seine vessels analyzed, there is only a limited relationship between an individual vessel's capital stock, measured by its GRT, and that vessel's fishing capacity, estimated by DEA and following the FAO definition. For this fleet, at least, changes in the capital stock over time do not closely or accurately correspond to changes in fishing capacity over time, although there is a very limited positive relationship.

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