Efficiency and Capacity Utilization of India's Marine Fisheries

Ghirmai Tesfamariam Teame[1,*]

[1]Department of Economics, Rabindra Bharati University, Kolkata, India

*Correspondence: Department of Economics, Rabindra Bharati University, Kolkata, India. E-mail: santarosaye@gmail.com

Received: July 3, 2017 Accepted: July 14, 2017 Online Published: July 25, 2017

doi:10.5430/mos.v4n3p14 URL: https://doi.org/10.5430/mos.v4n3p14

Abstract

For decades, the problems of excess capacity and overfishing have been the subject of considerable attentions, since they are the primary reasons for the depletion of fish stocks, reduction of the profitability and economic performance of the fishery sectors at the national and international levels. As a result, estimations of technical efficiency, harvesting capacity, and capacity utilization has become an increasingly important practice in the fishery, since they provide useful information about the optimum allocation of inputs and outputs, and guide policy formulation to combat biological and economic losses. Based on the Johansen (1968) definition of capacity we have examined the technical efficiency, capacity and capacity utilization of the marine fishery sectors of the India's 9 marine states and 4 union territories using an output oriented data envelopment analysis approach. The result of the study shows that majority of the states/union territories have been inefficient and have the capacity to harvest considerably more than what they have actually been harvesting by using the existing resources in an efficient configuration and showed how serious the problem of excess capacity is in the India's marine fishery.

Keywords: *Technical efficiency, capacity, capacity utilization, data envelopment analysis, marine state/union territory*

1. Introduction

Many of the major fishery resources worldwide are currently being exploited by excessive number of vessels and are in a state of decline due to overfishing that has been caused, in part, by the unrestricted expansion of fishing effort, permitted under open access regimes and unregulated common property (common-pool) fisheries which characterized many fisheries globally. Even after the introduction of various controlled access schemes, the fishing effort has kept increasing and resulting in excess capacities which involve over-investment in stock resources such as capital (plant and equipment) and variable inputs. According to Kirkley, Paul & Squires (2004), this implies inefficient allocation and a waste of economic resources, because it generates pressure to continue harvesting past the point of sustainability, and generally, leads to the decline in the economic health of fishermen, industries, and regions that rely on fisheries for their livelihoods. As a result, measuring the economic performance of fisheries has been a serious issue for the past decades.

Since Warming's (1911) and Gordon's (1954) original concerns about severe capitalization in fisheries, there has been many research, reports and conferences addressing the need to estimate and control excess harvesting capacity in fisheries (Vestergaard et al., 2002). For example, Garcia and Newton (1989) and Mace (1997) have estimated the global excess fishing capacity at 25-53 percent and 50 percent respectively. Likewise, Boopendranath (2007) has indicated that the world fleet is two and a half times in excess of what the world stocks could sustain. Similarly, if we look at the India's context, the substantial increase in the fishing effort since the 1970s has resulted in excessive fishing capacity which in turn led to the decrease in per capita area per active fishermen and per boat in the inshore fishing grounds, and according to Boopendranath (2007), roughly speaking, the current fishing vessel capacity in India is estimated to be approximately three times higher than the optimum level, reflecting that important economic gains could have been achieved by an appropriate reduction in fleet capacities.

Despite the long history of recognizing the need to control the challenges and impacts of overcapitalization and excess capacity on the sustainability of fishing operations, until the end of the 1990s, there was no universally accepted definition and technique of estimation of efficiency, capacity and its utilization in fisheries. For, capacity related concepts within the fishery sector have been defined and employed by biologists, resource managers, and economists in a way that addresses their own particular concerns, and relative to the available information. In the recent years, however, many researchers and various international organizations (like FAO) and national governments have worked on developing a coherent definition and estimation of fishing capacity and efficiency in order to have an international consensus and cooperation for global and regional plans of action to reduce excess capacity. As a result, to move to this direction, economists and ultimately policy makers have identified the technological-economic definition of capacity which is commonly estimated using either a stochastic production frontier (SPF) or data envelopment analysis (DEA) techniques. Though, estimations of efficiency and capacity have considerable impacts on the effectiveness of effort controls and maintaining the sustainability of fisheries, no attempt has been made to analyze the technical efficiency (TE), capacity (C) and capacity utilization (CU) of the India's marine fishery sector, especially at the states or union territories (UTs) level. Therefore, based on this definition, and using the DEA technique, our study focuses on measuring the TE, C and CU of marine fishery sectors of India's 9 marine states and 4 UTs for four time periods (1990, 1995, 2000 and 2005). Since most of the previous studies focus on fleet level capacity analysis, our study will be a value added to the economic literature, as it is the first of its kind to compare state/UTs' level efficiency and capacity of the fisheries sector.

2. Measuring Efficiency and Capacity

2.1 Basic Efficiency Concepts

Efficiency is generally defined as the ratio of output to input, where more output per unit of input, or the ability to use few inputs to produce many outputs reflects relatively greater efficiency (Avkiran, 2001). In his path-breaking and belatedly influential paper, Farrell (1957) is credited for pioneering the measurement of productive efficiency and recognizing the importance of measuring the extent to which outputs can be increased through higher efficiency and without using additional inputs (Esmaeili, 2006 and Färe, Grosskopf, & Lovell, 1984).

Farrell's (1957) efficiency analysis has proposed that the total economic efficiency of a firm consists of technical efficiency and allocative efficiency. Technical efficiency refers to the ability of a firm to obtain maximal output from a given set of inputs, whereas allocative efficiency refers to the firm's ability to use inputs in optimal proportions, given the production technology and input prices (Coelli, Grifell-Tatje & Perelman, 2001). The focus of our study is on technical efficiency so that we can concentrate on possible improvements in performance without requiring prices or other *a priori* weights, which are required for computing allocative efficiency but scarce in the fishery.

2.2 Technical Efficiency, Capacity, Capacity Utilization and Excess Capacity

Generally, TE refers to the ability to avoid waste, either by producing as much output as technology and input usage allows or by using as little input as required by technology and output production. It is a relative measure that indicates how close the actual production is to the best practice production frontier or to the maximal production that could be produced given the available fixed and variable factors of production. TE also refers to the minimum levels of inputs necessary to produce a given level of output relative to the levels of inputs actually used to produce that same level of output. Thus, the analysis of TE follows either an output-augmenting orientation or an input-conserving orientation in estimating the best practice production frontier (Fried, Lovell & Schmidt, 2008).

In the economics literature, there are at least four bases upon which capacity can be defined. These are the engineering definition which is of limited practical use; the economic definition which explains capacity as an output level that would be produced in order to satisfy some underlying economic behavioral objectives, such as profit maximization or cost minimization; and the point of short-run profit maximization.(Note 1) However, the widespread and consistent applicability of the last two definitions of capacity, which requires price and cost data, is hindered due to the paucity of price and cost data in many industries (especially in natural resource based industries like fisheries). In such situations, we turn our attention to Johansen's (1968) "pure physical" or "technological-economic" definition of capacity, with slight modifications to the fishery given as, "the maximum amount of fish over a period of time (year, season) that can be produced by a fishing fleet (industry) if the availability of the variable factors is unbounded and fully utilized, given the fixed factors, the biomass and age structure of the fish stock and the present state of the technology" (FAO, 1998). This definition treats fishing capacity as a short-run concept, where fisheries face constraints in terms of the resource stock and their use of fixed inputs (Dupont, Grafton, Kirkley & Squires, 2002).

Capacity utilization represents the proportion of the available capacity that is utilized and is usually measured as a ratio of actual (observed) output to the capacity output, which is the standard approach and is called CU-observed (Morrison, 1985; Nelson, 1989; Tingley, Pascoe & Mardle, 2003; and Felthoven, Horrace, & Schnier, 2009). However, measures of CU based on the numerator being observed output might yield downward-biased estimates of CU, because the observed outputs may not necessarily be produced in a technically efficient manner. For that reason, an unbiased measure of CU (CU-unbiased), which will be followed in our study, may be obtained by dividing technically efficient output to the capacity output. For each producer, the CU-unbiased provides a measure that reflects the potential increase in output solely from increased variable input use, and not from increased technical efficiency (Färe, Grosskopf & Kokkelenberg, 1989; Färe, Grosskopf & Lovell 1994; and Felthoven et al., 2009).

Full CU represents full capacity and its value cannot exceed one. If the value of the CU=1, it implies that productive capital, other fixed inputs and variable inputs are fully utilized and the producer is efficient and lies on the production frontier. A CU<1 on the other hand, indicates that the producer lies below the production frontier and is inefficient, therefore, there is potential for greater production without having to incur major expenditures for new capital or equipment, implying the presence of excess capacity. Excess capacity implies that there are too much idle and thus wasted resources, given the existing output levels; or the current output being too low to fully utilize the existing level of capacity. These concepts are essentially dual to each other where the first is input-oriented while the second is output-oriented ideas (Kirkley et al., 2004 and Dupont et al., 2002).

2.3 Data Envelopment Analysis

Data Envelopment Analysis (DEA) which was originally developed for estimating technical efficiency, but further extended to examine capacity and capacity utilization of firms, is a very powerful service management and benchmarking technique which estimates a deterministic rather than stochastic best practice production frontier (maximum potential output) and gives information on how far a given observation is from that frontier. The frontier (figure 1) is considered as a sign of relative efficiency, which has been achieved and defined by at least one efficient observation (entity) usually called as decision-making unit (DMU), and any DMU that is below the frontier, DMU " E" in our case, is considered as inefficient. Depending on the assumptions followed about fixed and variable inputs, the production frontier determines the reference relative to which the capacity output or technically efficient outputs of the different DMUs are judged (Bogetoft & Otto, 2010).(Note 2) The range of DEA models which have been developed to measure TE and C in different industries fall into the categories of being either input-oriented or output-oriented.

Input-oriented DEA helps us as to determine by how much the input quantities use of an inefficient DMU "E" could proportionally be reduced if used efficiently without changing the output quantities produced. This can be shown through a horizontal projection from point "E" onto the frontier. On the other hand, the output-oriented measures of DEA allow managers, for example, to identify by how much an inefficient DMU's "E" potential output can proportionally be expanded without altering the input quantities used if it operated as efficiently as DMUs along the best practice frontier, that is the vertical movement to the frontier (Coelli, Rao, O'Donnell, & Battese,1998 and Pasiouras, 2008).

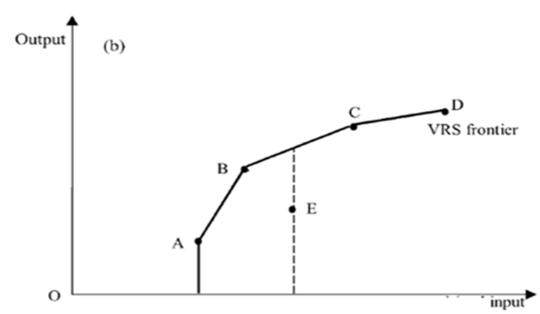

Figure 1. Variable Returns to Scale (VRS) Production Frontier

2.4 The DEA Framework

Taking the pros and cons (Note 3) of using DEA technique into consideration as well as FAO's and the available economics and fishery literature's recommendations, we follow Färe et al.'s (1989 and 1994) output-oriented DEA approaches to examine the TE, C and CU of the India's marine states/UTs marine fishery sectors, under the assumption of variable returns to scale, where their frameworks are presented in the following sections. We start with the following assumptions: let there be $j = 1,..., J$ DMUs (states/UTs), in an industry producing a scalar output $u_{jm}>0$ by means of a vector of inputs $x_{jn}>0$. Following Shephard (1970), it is assumed that

(a) for each n, $$\sum_{j=1}^{J} x_{jn} > 0, \qquad (1)$$

(b) and for each j, $$\sum_{n=1}^{N} x_{jn} > 0$$

The first assumption states that each input is used by some state/UT and the second assumption indicates that each state/UT uses some input.

2.4.1 Technical Efficiency Using DEA

To obtain the technically efficient level of output of the j^{th} state/UT's marine fishery sector, Färe et al. (1989, 1994), Coelli et al. (1998), Kirkley and Squires (1999), and Felthoven et al. (2009) have suggested solving an output-oriented DEA which is given in the form of linear programming problem (Problem 1).

$$\begin{aligned} & Max_{\theta,z}\theta \\ & s.t.\ \theta u_{jm} \le \sum_{j=1}^{J} z_j u_{jm}, \quad \text{m = 1, 2,.....M} \\ & x_{jn} \ge \sum_{j=1}^{J} z_j x_{jn}, \quad \text{n = 1, 2,.......N} \qquad \text{(Problem 1)} \\ & z_j \ge 0, \quad j = 1, 2, ...J \\ & \sum_{j=1}^{J} z_j = 1 \end{aligned}$$

Where the estimated parameter θ (the technical efficiency score) which is greater or equals to one, indicates the possible proportional increase in output for the j^{th} state/UT by using both fixed and variable inputs in an efficient configuration and if they are constrained to their current levels, i.e. under full TE. x_{jn} measures the amount of input n used by the j^{th} state/UT and the input vector x includes both fixed (α) and variable $(\hat{\alpha})$ inputs, u_{jm} measures output by state/UT j of product m. The first three constraints ensure that the observed output bundles stay on or within the feasible set. The third constraint is the non-negativity condition on the reference technology or intensity variable of the j^{th} state/UT (z_j vector) which allows us to decrease or increase observed production activities (input and output levels) in order to construct unobserved but feasible activities. The vector also provides weights that are used to construct the linear segments of the piecewise, linear frontier technology constructed by the DEA. The final constraint imposes VRS(Note 4) on the problem.

Using the results from the linear programming problem above, which is solved once for each state/UT in the data, one can determine the technically efficient or the frontier production level of output for each state/UT, denoted by $\overline{u}$, as:

$$\underset{output}{Technically\ Efficient(\overline{u})} = \underset{output}{Observed} * \underset{score}{Techncial\ efficiency} = u\ \theta \qquad (2)$$

2.4.2 Capacity Output and Capacity Utilization Using DEA

Although DEA models were originally developed for estimating TE, Färe et al. (1989,1994), have proposed some modifications to the output-orientated TE measure proposed above, in order to use it to generate estimates of capacity output and capacity utilization consistent with the Johansen's (1968) definition.

$$
\begin{aligned}
& Max_{\phi,\lambda,z}\phi \\
& s.t.\ \phi u_{jm} \leq \sum_{j=1}^{J} z_j u_{jm}, \qquad m = 1,2....,M \\
& x_{jn} \geq \sum_{j=1}^{J} z_j x_{jn}, \quad \text{n } \varepsilon \ \alpha \qquad\qquad\qquad\qquad \text{(Problem 2)} \\
& \lambda_{jn} x_{jn} = \sum_{j=1}^{J} z_j x_{jn}, \quad \text{n } \varepsilon \ \widehat{\alpha} \\
& z_j \geq 0, \qquad\qquad j = 1,2,....,J \\
& \lambda_{\text{jn}} \geq 0\ , \qquad\qquad \text{n } \varepsilon \ \widehat{\alpha} \\
& \sum_{j=1}^{J} z_j = 1
\end{aligned}
$$

The only difference of the DEA linear programming problem (2) from the problem (1) is that the third constraint allows the variable inputs to vary and to be fully utilized so as not to constrain the model. Moreover, vector λ_{jn} is a measure of the ratio of the optimal use of the variable inputs to their current use which gives the capacity utilization rate of the n^{th} variable input for the j^{th} state/UT for $x_{jn} > 0$, $n \ \varepsilon \ \widehat{\alpha}$ (Färe et al., 1989, 1994). It indicates the proportion by how much the variable inputs need to vary to achieve full capacity (produce at the frontier).

The model is run once for each state/UT in the dataset and provides a scalar measure of the capacity score (ϕ) which measures the possible radial increase in output to fully utilize the existing capacity (or to reach the best-practice production frontier). Similar to the technically efficient level of output from equation (2) above, the capacity output $(\hat{u})$ for each state/UT is given by:

$$Capacity\ Output = \hat{u} = Observed\ \ output * Capacity\ score = u\ \phi \qquad (3)$$

Moreover, the unbiased measure of CU (CU-unbiased) for each state/UT is given by:

$$CU - unbiased = \frac{technically\ efficient\ output}{capacity\ output} = \frac{\theta\ u}{\phi\ u} = \frac{\theta}{\phi} \qquad (4)$$

The CU scores are less or equal to one, with 1 representing full capacity utilization, while a value of less than 1 indicating the presence of excess capacity. For example, if the measured CU is 0.57, then 43 percent of the capacity is deemed "excess", or idle relative to its optimal level, and capacity reduction of this amount would be required to reach full utilization.

3. Empirical Results and Discussions

3.1 Data Source and Descriptive Analysis

For each state/UT, the dataset provided in table 1 contains observations on multispecies aggregated output which is measured in terms of total weight in tons of fish catch per year; and the variable inputs (effort in kilowatt days and the number of vessels) which are obtained from Bhathal (2014). Moreover, the coastal length in kilometers and the number of fish landing centers which are considered as fixed inputs are obtained from CMFRI (2011).(Note 5)

Table 1. Output and Input Variables for 1990 – 2005 Period

State/UT	Catch (Tonnes)				Effort (KW days)				No of Vessels				Coastal length	Fishing facilities
	1990	1995	2000	2005	1990	1995	2000	2005	1990	1995	2000	2005		
Gujarat	337652	506365	698015	430310	78423484	159073487	213137572	232205546	16817	22663	28706	24152	1600	121
Daman & Diu	6778	14257	17391	17391	6652702	7330669	7683516	7683516	1090	1266	1407	1407	21	5
Goa	67835	31947	63104	83233	10765661	12664207	14826470	14990437	3201	3505	3938	4065	104	33
Maharashtra	352638	322791	375586	288023	95607953	105458283	110482397	110482397	14801	18212	19441	23508	720	152
Karnataka	186037	153060	187218	229380	44273575	56894181	76376394	84706532	16507	18595	22968	23179	300	96
Kerala	691522	546350	618328	548993	75034224	156777075	233449455	240308531	34792	48574	55148	55861	590	187
Lakshadweep Islands	7744	11166	10284	10284	1225771	2123124	2280300	2887303	935	1492	1490	2049	132	10
Tamil Nadu	316374	433593	402587	286637	57647875	129836764	149649359	149649359	44504	42732	52433	54420	1076	407
Puducherry	16190	13937	13017	11077	5382423	6888408	7449886	7449886	5195	7127	8362	4457	45	25
Andhra Pradesh	123339	152573	193989	163482	54770128	88088255	134607001	134607001	49410	59622	66659	66659	974	353
Orissa	67532	44300	86613	103919	12518428	22019864	20578937	20578937	15292	15493	14909	23740	480	73
West Bengal	51972	75184	72960	202129	15471059	20481705	32246923	32246923	6560	7368	9435	18646	158	59
Andaman and Nicobar Islands	20352	26642	30946	30946	657331	909326	1043935	1716978	1130	1570	1772	2783	1912	16

3.2 Technical Efficiency

The result of DEA estimations of the yearly TE scores of the 13 marine states/UTs of India for 1990, 1995, 2000 and 2005, based on DEA problem (1) is presented in table 2. An optimization package called General Algebraic Modeling System (GAMS) is used to run all the analysis.

The reported technical efficiency scores reveal that only four of the states: Daman & Diu, Kerala, Lakshadweep Islands and Andaman & Nicobar Islands have been consistently technically efficient and lie on the best practice production frontier during the study periods. Moreover, Gujarat, Goa, and Maharashtra have been technically efficient for all the years, except for 1990, 1995 and 2005 respectively. In addition to these, Puducherry, Orissa and West Bengal have also been technically efficient in 1990; 2000; and in 1995 and 2005 respectively, but they are inefficient in the remaining years of the study. Finally, Karnataka, Tamil Nadu, and Andhra Pradesh are the only states which have been consistently technically inefficient throughout the years.

Table 2. Technical Efficiency Score, Technically Efficient Output, and Excess Capacities

State/UT	Technical efficiency score (θ)				Technically efficient output				Excess capacity				Efficiency's potential increase (100%)			
	1990	1995	2000	2005	1990	1995	2000	2005	1990	1995	2000	2005	1990	1995	2000	2005
Gujarat	1.05	1.00	1.00	1.00	354535	506365	698015	430310	16883	0.00	0.00	0.00	0.05	0.00	0.00	0.00
Daman & Diu	1.00	1.00	1.00	1.00	6778	14257	17391	17391	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goa	1.00	1.24	1.00	1.00	67835	39614	63104	83233	0.00	7667	0.00	0.00	0.00	0.24	0.00	0.00
Maharashtra	1.00	1.00	1.00	1.09	352638	322791	375586	313945	0.00	0.00	0.00	25922	0.00	0.00	0.00	0.09
Karnataka	1.76	1.32	1.23	1.07	327425	202039	230278	245437	141388	48979	43060	160567	0.76	0.32	0.23	0.07
Kerala	1.00	1.00	1.00	1.00	691522	546350	618328	548993	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lakshadweep Islands	1.00	1.00	1.00	1.00	7744	11166	10284	10284	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tamil Nadu	1.69	1.05	1.24	1.29	534672	455273	499208	369762	218298	21680	96621	83125	0.69	0.05	0.24	0.29
Puducherry	1.00	1.14	1.55	3.48	16190	15888	20176	38548	0.00	1951	7159	27471	0.00	0.14	0.55	2.48
Andhra Pradesh	4.12	2.07	2.33	2.09	508157	315826	451994	341677	384818	163253	258005	178195	3.12	1.07	1.33	1.09
Orissa	1.71	1.89	1.00	1.46	115480	83727	86613	151722	47948	39427	0.00	47803	0.71	0.89	0.00	0.46
West Bengal	2.31	1.00	1.51	1.00	120055	75184	110170	202129	68083	0.00	37210	0.00	1.31	0.00	0.51	0.00
Andaman and Nicobar Islands	1.00	1.00	1.00	1.00	20352	26642	30946	30946	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The technically efficient level of output for each state/UT is obtained from a product of the technical efficiency score and the observed output (from table 1). We further use this result to compute the value of excess capacity as a difference between technically efficient output and observed output. Moreover, efficiency's potential increase (percentage of excess capacity) which determines the proportion by which output needs to increase to fully utilize the existing excess capacity, is estimated as the ratio of excess capacity to observed output. For example, at full efficiency, the total production of Andhra Pradesh in 1990 could have been 508,156.68 tons, i.e., 384,817.68 tons higher than the observed output (which corresponds to its excess capacity). The efficiency's potential increase is given by 312 percent which is the highest of all the states in that year. In 1995 and 2000, Andhra Pradesh also has the highest efficiency's potential increase of 107 percent and 133 percent respectively but overtook by Puducherry in 2005 at 248 percent. On the other hand, Gujarat in 1990 and Tamil Nadu in 1995 have the lowest efficiency's potential increase at 5 percent, as did Karnataka both in 2000 and 2005 at 23 percent and 7 percent respectively.

3.3 Capacity Output and Capacity Utilization

3.3.1 Capacity Output

In this section using the DEA problem (2), we have estimated the yearly capacity score (ϕ), capacity output and excess capacity of the India's 13 marine states/UTs marine fishery sectors, as presented in table 3. Based on the estimated values of capacity scores, it is revealed that Daman & Diu and Kerala are the only states which have been consistently efficient throughout the study period (with ϕ=1), while Gujarat has been efficient in 1995, 2000 and 2005 and West Bengal has been efficient only in 2005. The remaining states have been inefficient (with ϕ >1), implying that they have the capabilities to harvest considerably more than what they have actually been harvesting between 1990 and 2005. That is, their capacity outputs which are expressed as product of observed outputs and capacity scores, and which represent the output that could be produced if they would operate at their optimum efficiency, i.e., when the availability of the variable factors (effort and number of vessels) are unbounded (fully and efficiently utilized) but constrained by the fixed factors (number of fish landing facilities and coastal length) and the state of technology, is much higher than the observed outputs. The extra of capacity output above the observed output is called excess capacity, and the total productions of these inefficient states, need to increase by the ratio of excess capacity to the observed output which is called the capacity's potential increase (percent of excess capacity) so that to fully utilize these capacities. For example, in 1990, Gujarat which has been found to have the lowest value of capacity's potential increase has landed 337,652 tons of catch, but has it efficiently used its variable inputs, the catch could have been increased to 443,208.2 tons (capacity output) which is 105,556 tons in excess of the observed output, an approximately 31 percent increase in potential output. In that same year, Andhra Pradesh which has the highest value of capacity's potential increase (percent of excess capacity) has landed 123,339 tons of fish which is much less than its capacity output of 691,522 tons, corresponding to an excess capacity output of 568,183 tons, an approximately 461 percent increase in potential output. Similarly, Orissa has the highest potential increase in output of 451 percent in 1995, in addition to Lakshadweep Islands' of 354 percent in 2000 and Puducherry's of 349 percent in 2005 to fully utilize their existing capacities. On the contrary, to efficiently use their existing capacities, Tamil Nadu and Karnataka have required the lowest increase in potential output of 26 percent and 32 percent in 1995 and 2005 respectively; while Maharashtra has the lowest potential increase in output of 49 percent in 2000.

Table 3. Capacity Output and Excess Capacity of the India's Marine States/UTs during 1990-2005

	1990				1995				2000				2005			
State/UT	Capacity score (ϕ)	Capacity output	Excess capacity	Excess capacity (100%)	Capacity score (ϕ)	Capacity output	Excess capacity	Excess capacity (100%)	Capacity score (ϕ)	Capacity output	Excess capacity	Excess capacity (100%)	Capacity score (ϕ)	Capacity output	Excess capacity	Excess capacity (100%)
Gujarat	1.31	443208	105556	0.31	1.00	506365	0.00	0.00	1.00	698015	0.00	0.00	1.00	430310	0.00	0.00
Daman & Diu	1.00	6778	0.00	0.00	1.00	14257	0.00	0.00	1.00	17391	0.00	0.00	1.00	17391	0.00	0.00
Goa	1.57	106662	38827	0.57	2.88	91873	59926	1.88	1.66	105050	41946	0.66	1.36	113331	30098	0.36
Maharashtra	1.59	559840	207202	0.59	1.47	928284	605493	1.88	1.49	561344	185758	0.49	1.62	466258	178235	0.62
Karnataka	1.84	342531	156494	0.84	1.80	275160	122100	0.80	1.67	312051	124833	0.67	1.32	303230	73850	0.32
Kerala	1.00	691522	0.00	0.00	1.00	546350	0.00	0.00	1.00	618328	0.00	0.00	1.00	548993	0.00	0.00
Lakshadweep Islands	3.30	25590	17846	2.30	3.18	35469	24303	2.18	4.54	46728	36444	3.54	3.42	35189	24905	2.42
Tamil Nadu	2.19	691522	375148	1.19	1.26	546350	112757	0.26	1.63	656672	254085	0.63	1.92	548993	262356	0.92
Puducherry	2.20	35660	19470	1.20	2.63	36700	22763	1.63	3.28	42738	29721	2.28	4.49	49754	38677	3.49
Andhra Pradesh	5.61	691522	568183	4.61	3.58	546350	393777	2.58	3.34	648625	454636	2.34	3.36	548993	385511	2.36
Orissa	3.89	262616	195084	2.89	5.51	244050	199750	4.51	3.49	302207	215594	2.49	2.44	253477	149558	1.44
West Bengal	3.30	171646	119674	2.30	1.89	142371	67187	0.89	2.22	162081	89121	1.22	1.00	202129	0.00	0.00
Andaman and Nicobar Islands	2.37	48164	27812	1.37	2.29	60922	34280	1.29	2.65	81933	50987	1.65	1.83	56547	25601	0.83

3.3.2 Capacity Utilizations

The values of the unbiased capacity utilizations (CU-unbiased) which are corrected for technical efficiency for each state/UT are obtained from the ratio of technically efficient output to capacity output, and they are presented in table 4. States which have been operating at full capacity based on capacity and efficiency scores have also been found to be operating at full capacity based on unbiased CU measure (having CU-unbiased=1). It is also revealed that substantial proportion of the states (85 percent in 1990, 77 percent in 1995 and 2000, and 69 percent in 2005) have been operating below their full capacity (having CU-unbiased <1), meaning that they have not used their capacity to the fullest extent, and they have the potential to harvest more than what they have actually been harvesting through efficient utilization of the variable inputs, implying the presence of excess capacities in these inefficient states. We can also use these CU scores to estimate the proportion of capacity stock (variable inputs) that needs to be reduced to efficiently utilize the existing excess capacities of the inefficient states, which is given by (1-CU)100 percent. For example, Lakshadweep Islands has the lowest values of unbiased capacity utilization of 0.30, 0.31, 0.22 and 0.29 in 1990, 1995, 2000 and 2005 respectively; which indicate that 70 percent, 69 percent, 78 percent and 71 percent of the capacity (variable inputs) are deemed “excess” respectively, and an equivalent reduction in capacities is recommended in order to efficiently utilize the existing capacities, in each year. On the other hand, Karnataka has the highest values of unbiased CU of 96 percent and 81 percent, which correspond to the lowest value of excess capacities of 4 percent and 19 percent for 1990 and 2005 respectively. Similarly, Tamil Nadu has unbiased CU values of 84 percent and 76 percent which correspond to excess capacity of 16 percent and 24 percent during 1995 and 2000 respectively. Therefore, proportional capacity reductions are required for each state/UT on the specified years to efficiently utilize their excess capacities. On the average, the unbiased CU of the India’s marine states lie between 64 percent in 1995 to 75 percent in 2005 with a standard deviation of 0.23 and 0.22 respectively. The outcome of the study, based on unbiased CU suggests that the inefficient states could have increased their catch volume with a wider use of the variable inputs or the reported level of output could have produced by a smaller amount of the variable inputs. Therefore, we can conclude that India’s marine states have not utilized their capacity enough and the current inputs are in large excess of the endurance of the resources, implying that excess capacity in India’s marine states has been positive during the study periods.

Table 4. Unbiased Capacity Utilization of States/UTs for the Period 1990-2005

State/UT	1990	1995	2000	2005
Gujarat	0.80	1.00	1.00	1.00
Daman & Diu	1.00	1.00	1.00	1.00
Goa	0.64	0.43	0.60	0.73
Maharashtra	0.63	0.68	0.67	0.67
Karnataka	0.96	0.73	0.74	0.81
Kerala	1.00	1.00	1.00	1.00
Lakshadweep Islands	0.30	0.31	0.22	0.29
Tamil Nadu	0.77	0.84	0.76	0.67
Puducherry	0.45	0.43	0.47	0.77
Andhra Pradesh	0.74	0.58	0.70	0.62
Orissa	0.44	0.34	0.29	0.60
West Bengal	0.70	0.53	0.68	1.00
Andaman and Nicobar Islands	0.42	0.44	0.38	0.55
Average	0.68	0.64	0.65	0.75
Standard deviation	0.23	0.26	0.26	0.22

4. Concluding Remarks

Based on the results of our study, the current marine fishing practices of the India’s marine states/UTs shows clear symptoms of excess capacity which resulted into overfishing. As a result, our study recommends for the introduction of limited entry and effort reduction schemes through strong fisheries policies and their implementations, in a way that balances welfare concerns with sustainability. In addition to this, given that excess capacity is an ongoing and critical problem in many of the marine states, the study argues that the assignment of well specified and enforced property rights would play an important role in addressing this problem. Moreover, the success in demonstrating the existence of overcapacity in such an environment suggests that the methods used here could be successfully applied to other areas where information on stock status is lacking and total allowable catches (TACs)/quotas are not enforced.

It is also worth mentioning that the results of the study have some limitations. Usually, the estimates of capacity utilization and technical efficiency are affected by the quality of the data used. For that matter, the result of our study cannot be concluded without alluding to the fact of the difficulty in the reliability of the dataset used, because the aggregated yearly catch and effort data used are compiled from various published and unpublished sources, and sometimes through interpolation and extrapolation. Moreover, the empirical results of this study are not indicative of absolute (long-run) efficiency and capacity, because states/UTs face short-run constraints, such as the stock of capital or other fixed inputs, existing regulatory and resource conditions, the state of technology and others. Consequently, such analyses should complement rather than replacing the development of more detailed dynamic bioeconomic models to consider longer-term management strategies. A further weakness is that the efficiency and capacity scores cannot be ranked or compared directly to other analyses, as the scores are only relative to the best producers in the sample concerned. An additional shortcoming of the study is related to the deterministic nature of the DEA approach, which assumes that all the deviations from the frontier are caused by inefficient operations. Moreover, while DEA can be used to set targets for improvement of desired outputs, it does not give instructions on how to reach those targets.

Acknowledgements

This paper is a part of the doctoral dissertation of Ghirmai Tesfamariam Teame, which is in progress. The author is indebted to his PhD supervisor Prof. Kausik Gupta for his invaluable comments and suggestions. The author would also like to thank Dr. Brajgeet Bhathal from the University of British Columbia for giving the permission to use the state/union territories level multispecies aggregated catch and effort data. The author would also like to thank the two anonymous reviewers for their constrictive criticisms and suggestions. Finally, an earlier version of this article was presented in seminars held at the University of Kalyani and Vidyasagar University in 2017, and the author is very thankful to the participants of the seminars for their comments and suggestions.

References:

Avkiran, N. K. (2001). Investigating technical and scale efficiencies of Australian universities through data envelopment analysis. *Socio-Economic Planning Sciences*, *35*(1), 57-80. https://doi.org/10.1016/S0038-0121(00)00010-0

Bhathal, B. (2014). *Government-led development of India's marine fisheries since 1950: catch and effort trends, and bioeconomic models for exploring alternative policies* (Doctoral dissertation, University of British Columbia).

Bogetoft, P., & Otto, L. (2010). *Benchmarking with DEA, SFA, and R* (Vol. 157). Springer Science & Business Media.

Boopendranath, M. R. (2007). Fishing capacity management. *Integrated Fisheries Project Souvenir 2007*, 7-14.

Boussofiane, A., Dyson, R. G., & Thanassoulis, E. (1991). Applied data envelopment analysis. *European Journal of Operational Research*, *52*(1), 1-15. https://doi.org/10.1016/0377-2217(91)90331-O

CMFRI. (2011). *Marine fisheries census, India, 2010*. Cochin: Central Marine Fisheries Research Institute.

Coelli, T. J., Rao, D. P., O'Donnell, C. J., & Battese, G. E. (1998). *An introduction to productivity and efficiency analysis*. New York: Springer Science. https://doi.org/10.1007/978-1-4615-5493-6

Coelli, T., Grifell-Tatje, E., & Perelman, S. (2001). *Capacity utilization and short-run profit efficiency: A decomposition of short run profit efficiency* (CORE Discussion Papers; 2001/52). UCL-CORE - Center for Operations Research and Econometrics. Retrieved from http://hdl.handle.net/2078.1/4208

Dupont, D. P., Grafton, R. Q., Kirkley, J., & Squires, D. (2002). Capacity utilization measures and excess capacity in multi-product privatized fisheries. *Resource and Energy Economics*, *24*(3), 193-210. https://doi.org/10.1016/S0928-7655(01)00050-1

Dyson, R. G., Allen, R., Camanho, A. S., Podinovski, V. V., Sarrico, C. S., & Shale, E. A. (2001). Pitfalls and protocols in DEA. *European Journal of operational research*, *132*(2), 245-259. https://doi.org/10.1016/S0377-2217(00)00149-1

Esmaeili, A. (2006). Technical efficiency analysis for the Iranian fishery in the Persian Gulf. *ICES Journal of Marine Science: Journal du Conseil*, *63*(9), 1759-1764. https://doi.org/10.1016/j.icesjms.2006.06.012

FAO. (1998). Report of the technical working group on the management of fishing capacity. La Jolla, United States, 15-18 April 1998. *FAO Fisheries Report* No. 586. Rome: FAO.

Färe, R., Grosskopf, S., & Lovell, C. K. (1984). The structure of technical efficiency. In *Topics in Production Theory* (pp. 81-90). Palgrave Macmillan UK.

Färe, R., Grosskopf, S., & Kokkelenberg, E. C. (1989). Measuring plant capacity, utilization and technical change: A nonparametric approach. *International Economic Review*, *30*(3), 655-666. https://doi.org/10.2307/2526781

Färe, R., Grosskopf, S., & Lovell, C. K. (1994). *Production frontiers*. Cambridge University Press. https://doi.org/10.1007/978-1-349-07123-4_6

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society. Series A (General)*, *120*(3), 253-290. https://doi.org/10.2307/2343100

Felthoven, R. G., Horrace, W. C., & Schnier, K. E. (2009). Estimating heterogeneous capacity and capacity utilization in a multi-species fishery. *Journal of Productivity Analysis*, *32*(3), 173-189. https://doi.org/10.1007/s11123-009-0139-5

Fried, H. O., Lovell, C. K., & Schmidt, S. S. (Eds.). (2008). *The measurement of productive efficiency and productivity growth*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195183528.001.0001

Golany, B., & Roll, Y. (1989). An application procedure for DEA. *Omega*, *17*(3), 237-250. https://doi.org/10.1016/0305-0483(89)90029-7

Gordon, H. S. (1954). The economic theory of a common-property resource: the fishery. *Journal of political economy*, *62*(2), 124-142. https://doi.org/10.1016/0305-0483(89)90029-7

Johansen, L. (1968). Production functions and the concept of capacity. *Recherches récentes sur la fonction de production, Collection, Economie mathématique et économétrie*, *2*, 52.

Kirkley, J. E., & Squires, D. (1999). *Capacity and capacity utilization in fishing industries* (Discussion paper 99-16). Department of Economics, UCSD. Retrieved from https://escholarship.org/uc/item/6k91b50v

Kirkley, J., Paul, C. J. M., & Squires, D. (2004). Deterministic and stochastic capacity estimation for fishery capacity reduction. *Marine Resource Economics*, *19*(3), 271-294. https://doi.org/10.1086/mre.19.3.42629435

Mace, P. M. (1997). Developing and sustaining world fisheries resources-the state of the science and management. In *2nd World fisheries congress proceedings.* Brisbane: Commonwealth scientific and industrial research (CSIRO) publishing.

Morrison, C. J. (1985). Primal and dual capacity utilization: An application to productivity measurement in the US automobile industry. *Journal of Business & Economic Statistics*, *3*(4), 312-324. https://doi.org/10.1080/07350015.1985.10509463

Nelson, R. A. (1989). On the measurement of capacity utilization. *The Journal of Industrial Economics*, 273-286. https://doi.org/10.2307/2098615

Pascoe, S., Kirkley, J. E., Ward, J., & Greboval, D. F. (2003). *Measuring and assessing capacity in fisheries: Issues and methods*. Rome: Food & Agriculture Organization.

Pasiouras, F. (2008). Estimating the technical and scale efficiency of Greek commercial banks: The impact of credit risk, off-balance sheet activities, and international operations. *Research in International Business and Finance*, *22*(3), 301-318. https://doi.org/10.1016/j.ribaf.2007.09.002

Tingley, D., Pascoe, S., & Mardle, S. (2003). Estimating capacity utilization in multi-purpose, multi-metier fisheries. *Fisheries Research*, *63*(1), 121-134. https://doi.org/10.1016/S0165-7836(02)00283-7

Van Hoof, L., & De Wilde, J. W. (2005). Capacity assessment of the Dutch beam-trawler fleet using data envelopment analysis (DEA). *Marine Resource Economics*, *20*(4), 327-345. https://doi.org/10.1086/mre.20.4.42629481

Vestergaard, N., Hoff, A., Andersen, J., Lindebo, E., Grønbæk, L., Pascoe, S., ... & van Hoof, L. (2002). *Measuring capacity in fishing industries using the Data Envelopment Analysis (DEA) approach.* Institute of Environmental and Business Economics, University of Southern Denmark. Retrieved from http://www.sdu.dk/~/media/Files/Om_SDU/Institutter/Miljo/ime/report/measuring_capacity_dea_eureport_2002.pdf

Warming, J. (1911). On the rent of fishing grounds. *History of Political Economy*, *15*(3), 391-396.

Notes

Note 1. Interested readers can refer to Coelli et al. (2001) and Pascoe, Kirkley, Ward & Greboval (2003) for details on these.

Note 2. Capacity and efficiency are similar in concept, since they represent the degree to which DMUs are performing relative to other DMUs

Note 3. DEA does not require the researcher to arbitrarily choose a particular production functional form; rather it envelops the observed data points and reveals the technology as practiced in the industry, which allows greater flexibility in the estimation of the frontier. However, it is a non-statistical approach, and therefore, statistical tests of hypotheses about structure and significance of estimates cannot be easily carried out.

Note 4. For justification on selecting DEA techniques under VRS in fishery, refer to Tingley et al. (2003) and Van Hoof and De Wilde (2005)

Note 5. There are several rule of thumbs concerning the number of DMUs that must be included in DEA models to helps us get good discriminatory power and avoid loss of degrees of freedom. Our DEA models complies with the rule of thumbs provided by Boussofiane, Dyson & Thanassoulis (1991), Golany and Roll (1989) and Dyson et al. (2001)