Efficiency and Capacity Utilization of India’s Marine Fisheries

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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 fewer 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](image)

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

\[
\begin{align*}
\text{(a) for each } n, & \quad \sum_{j=1}^{J} x_{jn} > 0, \\
\text{(b) and for each } j, & \quad \sum_{n=1}^{N} x_{jn} > 0
\end{align*}
\]

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).

\[
\begin{align*}
\text{Max} & \quad \theta \\
\text{s.t.} & \quad \theta u_{jm} \leq \sum_{j=1}^{J} z_{j} u_{jm}, \quad m = 1, 2, ..., M \\
& \quad x_{jn} \geq \sum_{j=1}^{J} z_{j} x_{jn}, \quad n = 1, 2, ..., N \\
& \quad z_{j} \geq 0, \quad j = 1, 2, ..., J \\
& \quad \sum_{j=1}^{J} z_{j} = 1
\end{align*}
\]

Where the estimated parameter \( \theta \) (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 (\( \alpha \)) and variable (\( \bar{\alpha} \)) 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 \( u^* \), as:

\[
\text{Technically Efficient} (u^*) = \text{Observed} \ast \text{Technical efficiency} = u \ast \theta
\]

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.
\[
\begin{align*}
\text{Max}_{\phi, \lambda, \zeta} & \phi \\
\text{s.t. } & \phi u_{jm} \leq \sum_{j=1}^{J} z_j u_{jm}, \quad m = 1, 2, \ldots, M \\
x_{jn} & \geq \sum_{j=1}^{J} z_j x_{jn}, \quad n \in \alpha \\
\lambda_{jn} x_{jn} & = \sum_{j=1}^{J} z_j x_{jn}, \quad n \in \tilde{\alpha} \\
z_j & \geq 0, \quad j = 1, 2, \ldots, J \\
\lambda_{jn} & \geq 0 , \quad n \in \tilde{\alpha} \\
\sum_{j=1}^{J} z_j = 1 \\
\end{align*}
\]

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 \( \lambda_{jn} \) 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 \( x_{jn} > 0 \), \( n \in \tilde{\alpha} \) (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 \( \phi \) 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:

\[
Capacity \ Output = \hat{u} = \text{Observed output} \times \text{Capacity score} = u \phi
\]

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

\[
CU - \text{unbiased} = \frac{\text{technically efficient output}}{\text{capacity output}} = \frac{\theta u}{\phi u} = \frac{\theta}{\phi}
\]

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)
### 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 2005 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 (%) | Technically efficient output | Excess capacity | Efficiency's potential increase (100%) |
|-------------------|--------------------------------|------------------------------|-----------------|---------------------------------------|
| Gujarat           | 1.00                           | 0.00                         | 0.00            | 0.00                                  |
| Daman & Diu       | 1.00                           | 0.00                         | 0.00            | 0.00                                  |
| Goa               | 1.00                           | 0.00                         | 0.00            | 0.00                                  |
| Maharashtra       | 1.00                           | 0.00                         | 0.00            | 0.00                                  |
| Karnataka         | 1.00                           | 0.00                         | 0.00            | 0.00                                  |
| Kerala            | 1.00                           | 0.00                         | 0.00            | 0.00                                  |
| Lakshadweep Islands | 1.00                         | 0.00                         | 0.00            | 0.00                                  |
| Tamil Nadu        | 1.00                           | 0.00                         | 0.00            | 0.00                                  |
| Puducherry        | 1.00                           | 0.00                         | 0.00            | 0.00                                  |
| Andhra Pradesh    | 1.00                           | 0.00                         | 0.00            | 0.00                                  |
| Orissa            | 1.00                           | 0.00                         | 0.00            | 0.00                                  |
| West Bengal       | 1.00                           | 0.00                         | 0.00            | 0.00                                  |
| Andaman and Nicobar Islands | 1.00                    | 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 ($\phi$), 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 $\phi=1$), 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 $\phi >1$), 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匾 potential increase at 5 percent, as did Karnataka both in 2000 and 2005 at 23 percent and 7 percent respectively.

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

| State/UT     | 1990       | 1995       | 2000       | 2005       |
|--------------|------------|------------|------------|------------|
|              | Capacity score ($\phi$) | Capacity output | Excess capacity (100%) | Capacity score ($\phi$) | Capacity output | Excess capacity (100%) | Capacity score ($\phi$) | Capacity output | Excess capacity (100%) | Capacity score ($\phi$) | Capacity output | Excess capacity (100%) |
| Gujarat      | 1.31       | 443208    | 105556    | 0.31       | 1.00       | 506365    | 0.00                   | 1.00       | 690015    | 0.00                   | 1.00       | 430310    | 0.00                   |
| Daman & Diu  | 1.00       | 6778      | 0.00      | 0.00       | 0.00       | 14257     | 0.00                   | 1.00       | 17391     | 0.00                   | 1.00       | 17391     | 0.00                   |
| Goa          | 1.57       | 106662    | 38827     | 0.57       | 2.88       | 91873     | 59926      | 1.88                   | 1.66       | 105050    | 41946      | 0.66       | 113331    | 0.36                   |
| Mahasrashtra | 1.59       | 559840    | 207202    | 0.59       | 1.47       | 928284    | 605493     | 1.88                   | 1.49       | 561344    | 185758     | 0.49       | 646258    | 178235     | 0.62                   |
| Karnataka    | 1.84       | 342531    | 156494    | 0.84       | 1.80       | 275160    | 122100     | 0.80                   | 1.67       | 312051    | 124833     | 0.67       | 303230    | 73850      | 0.32                   |
| Kerala       | 1.00       | 691522    | 0.00      | 0.00       | 1.00       | 546350    | 0.00                   | 1.00       | 618328    | 0.00                   | 1.00       | 548993    | 0.00                   |
| Lakshadweep  |            |           |           |            |            |           |                       |            |           |                       |            |           |                       |
| Islands      | 3.30       | 255900    | 17846     | 2.30       | 3.18       | 35469     | 24303      | 2.18                   | 4.54       | 46728     | 36444      | 3.54       | 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       | 356600    | 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                   |
| 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 and 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.

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**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 help us get good discriminatory power and avoid loss of degrees of freedom. Our DEA models comply with the rule of thumbs provided by Boussofiane, Dyson & Thanassoulis (1991), Golany and Roll (1989) and Dyson et al. (2001).