WORKING PAPER 145/2016

CONTRIBUTION OF MANGROVES TO MARINE FISHERIES IN INDIA

Lavanya Ravikanth Anneboina
K. S. Kavi Kumar

Mentoring Excellence

MADRAS SCHOOL OF ECONOMICS
Gandhi Mandapam Road
Chennai 600 025
India

April 2016

Contribution of Mangroves to Marine Fisheries in India

Lavanya Ravikanth Anneboina
Research Consultant, Madras School of Economics
lavanya@mse.ac.in; lavi.anneboina@gmail.com

and

K. S. Kavi Kumar
Professor, Madras School of Economics
kavi@mse.ac.in; kavikumar@gmail.com

WORKING PAPER 145/2016

April 2016

Price : Rs. 35

MADRAS SCHOOL OF ECONOMICS
Gandhi Mandapam Road
Chennai 600 025
India

Phone: 2230 0304/2230 0307/2235 2157
Fax : 2235 4847/2235 2155
Email : info@mse.ac.in
Website: www.mse.ac.in

Contribution of Mangroves to Marine Fisheries in India

Lavanya Ravikanth Anneboina and K. S. Kavi Kumar

Abstract

Mangroves support and enhance fisheries by serving as a breeding ground and nursery habitat for marine life. The mangrove-fishery link has been well established in the ecological literature. This paper, however, employs an economic analysis to examine the role of mangroves in increasing marine fish output in India. In particular, the effectiveness of mangroves in increasing marine fish production is analysed using secondary data on marine fish production and fishing inputs. The results based on econometric analysis indicate that mangroves contribute significantly to the enhancement of fish production in the coastal states of India. Further, the paper also analyses the contribution of mangroves to commercial marine fisheries output in India and the same is estimated to be in the range of 23 – 34 percent, which in economic terms is valued between Rs. 1.46 – 2.15 lakhs per hectare in 2012-13 prices. The relative contribution of mangroves to total fish catch estimated in the Indian context is comparable to that estimated in other countries.

Keywords: *Marine fishery; Mangrove cover; Value of mangroves; Ecosystem services*

JEL Codes: *Q22; Q23; Q51; Q57*

ACKNOWLEDGEMENT

This work was undertaken as part of the project, 'Linking Coastal Zone Management to Ecosystem Services in India', funded by NCSCM, Chennai. The authors would like to thank Dr. Brinda Viswanathan, MSE for her valuable inputs. The authors would also like to thank Dr. L. Braat for comments on an earlier version of the paper. The authors acknowledge the useful comments provided by the review committee consisting of Prof. R. Ramesh, Prof. B. R. Subramanian, Prof. D. Chandramohan, Prof. R. Maria Saleth, Dr. Ahana Lakshmi, Dr. D. Asir Ramesh and Dr. Purvaja Ramachandran at the meeting held on 24th June 2015 at NCSCM, Chennai. The authors also gratefully acknowledge the support received from the partner institutions of the project – NCSCM and Goa University at various stages of the study.

Lavanya Ravikanth Anneboina
K. S. Kavi Kumar

INTRODUCTION

Marine fish production in India was 3,443 thousand tonnes in 2013-14, which accounted for 36 percent of total fish production in the country. West-coast regions produce a significantly higher proportion of total marine fish compared to their east-coast counterparts (i.e. 64 percent in 2012-13) and Gujarat and Kerala are the leading marine fish producers in the country, producing more than 500 thousand tonnes each in 2013-14 (DADF, 2014). Although inland fish production accounts for a higher proportion of total fish production in India, it is the preference for marine versus inland fish that determines consumption; inland fish is preferred in the eastern and central states whereas marine fish is preferred in the southern and western states of the country. Moreover, marine fish comprises of several commercially important fish species such as cuttlefish, squid, lobster, shrimp and certain types of finfish, which also make up the bulk of marine fish exports. Marine fish exports accounted for roughly 29 percent of total marine fish production in 2013-14 (DADF, 2014). Furthermore, a majority of commercially important marine fish species are mangrove-dependent.

Table 1 gives examples of commercially relevant fish species that are commonly found in mangroves in the coastal regions of India. These include crustaceans such as prawns and crabs, molluscs, and demersal finfish such as snappers, catfishes, pomfrets and croakers among others (Singh et al., 2012). It is important to note that it is the demersal, crustacean and mollusc fish species that are predominantly mangrove-dependent while pelagic fish species are less dependent on mangroves[1]. The table also provides information on fish catch within the mangrove-dependent demersal, crustacean and mollusc categories across coastal regions. It is interesting to note that mangrove-dependent fish catch as a

[1] Pelagic fishes including certain species of clupeids (hilsa shad), anchovies (setipinna), carangids and mullets have been documented to be found in the Indian mangrove waters (Singh et al., 2012), however they comprise of a small number of total pelagic fish species landed in India (CMFRI, 2015), the majority of which are not mangrove-dependent.

percentage of total marine fish catch (that includes all four fish categories) is significant in most of the coastal regions that also have significant mangrove cover. Since only the fringe area of mangrove forests typically serves as a breeding ground and nursery habitat for marine life, it is difficult to infer a correlation between overall mangrove area and the percentage of mangrove-dependent fish catch in each of the mangrove regions.

Mangrove forests in India are largely located in the deltas of the rivers Ganges, Mahanadi, Godavari, Krishna and Cauvery as well as on the Andaman and Nicobar group of islands. The extent of mangrove cover in India is 4,740 square kilometres, which accounts for 0.14 percent of the country’s total geographical area. As detailed in Table 1, West Bengal, Gujarat, Andaman and Nicobar Islands and Andhra Pradesh have the highest mangrove cover among all coastal regions accounting for 44, 23, 13 and 8 percent of the country’s total mangrove cover, respectively. Kerala, Karnataka, Daman and Diu and Pondicherry have the lowest extent of mangrove cover, i.e. less than 10 square kilometres each. Over the period 1987 to 2015, mangrove cover increased significantly in Gujarat (by 680 square kilometres) while it increased moderately in all other coastal regions except for Andhra Pradesh and Andaman and Nicobar Islands, in which mangrove cover declined over time (FSI, 2015).

Table 1: Details of Mangrove Area, Mangrove-Dependent Marine Fish Catch and Fish Species in the Coastal Regions of India

Coastal Regions of India	*Mangrove Area in 2015 (in Sq. Km.)[a]*	*Mangrove-Dependent Marine Fish Catch in 2014 (in '000 tonnes)[b]*			*Mangrove-Dependent Fish Catch as % of Total Marine Fish Catch in 2014[b]*	*Examples of Fish Species Found in Mangroves[c]*
		Demersals	*Crustaceans*	*Molluscs*		
Andhra Pradesh	367	71	35	3	32	Catfishes, snappers, tilapia, snails, crabs, prawns and molluscs.
Odisha	231	41	20	2	45	-
Tamil Nadu	47	179	44	22	37	Penaeid prawn species, catfishes, pomfrets, barramundi, mangrove red snapper, catfishes and perches.
West Bengal	2,106	26	16	0	56	Several penaeid and non-penaeid prawn and shrimp species.
Pondicherry	2	26	4	2	50	Mangrove red snapper, silverbellies, pomfrets, croakers, catfishes, rays, penaeid prawns, brachyuran crabs, bivalves and gastropods.
Goa	26	7	8	1	11	Sharks and several molluscs, crabs and prawns notably one armed fiddler crabs and horse shoe crabs.
Gujarat	1,107	206	156	57	59	-
Karnataka	3	102	29	27	33	-
Kerala	9	84	51	49	32	Rays.
Maharashtra	222	89	95	13	57	-
Daman & Diu	3	21	2	3	56	-
Andaman & Nicobar Is.	617	-	-	-	-	-

Note: Demersals include sharks, skates, rays, eels, catfishes, cods, snappers, breams, perches, goatfishes, threadfins, croakers, silverbellies, big-jawed jumper, pomfrets, halibut, flounders and soles; Crustaceans include penaeid and non-penaeid prawns, lobsters, crabs and stomatopods; Molluscs include mussels, oysters, clams, other bivalves, gastropods, squids, cuttlefish and octopus. Total marine fish catch includes demersals, crustaceans, molluscs and pelagic fish species. '-' indicates information could not be accessed from sources within the public domain.

Source: [a] FSI (2015); [b] CMFRI data - http://www.cmfri.org.in/fish-catch-estimates.html; [c] Singh et al. (2012).

The essential ecological support function that mangroves provide for commercial, recreational and subsistence fisheries, by serving as a breeding ground and nursery habitat for marine life, is well documented in the literature (Hutchison et al., 2014). Studies from across the world indicate that the relative contribution of mangrove-related fish species to total fisheries' catch is significant in most cases. The more recent studies (excluding the small-Island studies) estimate mangroves' contribution to fisheries in the range of 10 – 32 percent (Aburto-Oropeza et al., 2008; Ronnback, 1999). There are, however, hardly any studies that estimate the contribution of mangroves to fisheries in India. One exception is the study by Untawale (1986) that directly associates about 60 percent of commercially important coastal fish species to mangrove environments in India.

The aim of this paper is to examine whether, and to what extent, mangroves influence the production of commercially important marine fisheries in India using an econometric framework. In particular, the effectiveness of mangroves in increasing marine fish production is analysed through a stochastic frontier production function model, and is presented in the next section of the paper. The third and final section of the paper discusses the contribution of mangroves to marine fisheries output in India. Estimates of the percentage contribution of mangroves to fish output from around the world are compared to the estimate for India, which is assessed through the direct estimation of the marginal effect of mangroves on fish output. The section also provides conclusions.

EFFECTIVENESS OF MANGROVES IN INCREASING FISH PRODUCTION

Like any production activity, fish output is likely to be influenced by key inputs such as the capital expenditure incurred in undertaking fishing activity, the 'labour' employed in fish production, which in this case would include the number and type of fishing vessels engaged in fish production, as well as other inputs directly affecting output. However, other than the inputs that directly affect fish output, there are likely to be other factors that indirectly affect fish production through their impact on the effectiveness with which fish is produced, like mangrove area. It is well established in the literature that mangroves serve as a nursery habitat and a breeding ground for several species of fish, thus mangroves have the capacity for enhancing the productivity of fisheries. While not directly influencing fish production, mangroves can affect the Technical Efficiency[2] of fish production by providing an enabling environment for the growth of fish stocks, which in turn can influence the quantity of fish produced. In other words, an increase in fish production can come from an increase in production efficiency that may be positively influenced by the presence of mangroves. Therefore, it is important to assess whether mangroves act as enabling factor in improving the technical efficiency of production units that are engaged in fish production.

Methodology

Measures of efficiency are usually computed by comparing observed performance with some standard specified notion of performance. The 'production frontier' serves as one such standard in the case of technical

[2] Technical Efficiency is the standard terminology used in the economics literature to describe the effectiveness with which a given set of inputs are used by a production unit to produce an output. Compared to the maximum amount of output that can potentially be achieved with given inputs and technology, most production units may end-up producing a lower level of output, which is reflected by their technical inefficiency. Enabling factors, such as mangroves (as discussed here), are hypothesized to contribute towards enhancing the technical efficiency of production thereby enabling production units to move closer towards achieving their potential level of output.

efficiency. The frontier production function may be defined as the maximum feasible or potential output that can be produced by a production unit such as a coastal state, at a particular point in time, given a certain level of inputs and technology. Technical efficiency may be defined as the effectiveness with which a given set of inputs is used to produce an output. A production unit is said to be technically efficient if it produces the maximum possible output with a specified endowment of inputs (represented by a frontier production function), given the prevailing technology and environmental conditions. A key aspect of stochastic frontier analysis is that in reality each production unit produces potentially less than it might due to a degree of inefficiency in the production process. If the production unit is inefficient, its actual output is less than its potential output. Thus, the ratio of the actual output and the potential output gives a measure of the technical efficiency of the production unit. More formally, suppose a coastal state has a production plan $(y, \mathbf{x})$, where the first argument is an output and the second represents a set of inputs. Given a production function f(.), the state is technically efficient if $y = f(\mathbf{x})$, and technically inefficient if $y < f(\mathbf{x})$. Therefore, technical efficiency can be measured by the ratio $0 \leq y/f(\mathbf{x}) \leq 1$ (see Shanmugam and Venkataramani (2006), who also use an administrative division, i.e. a district, as the unit of analysis in their production frontier model).

A stochastic frontier production function model is used to predict technical efficiency of fish production. The main feature of this model is that observed deviations in y from the production function $f(\mathbf{x})$, i.e. the theoretical ideal frontier of efficient production, could arise from two sources: i) productive inefficiency as mentioned above, and ii) idiosyncratic effects that are specific to the production unit or coastal state (Aigner et al., 1977). In econometric parlance what this means is that the disturbance term is assumed to have two components; one having a strictly nonnegative distribution (i.e. the inefficiency term) and the other having a symmetric distribution (i.e. the idiosyncratic error term), hence the name 'stochastic frontier' (Greene, 2012). Moreover, since panel data are used to estimate the model, two specifications of the inefficiency term are possible; one in which the inefficiency term does not vary with time and the other in which it does. The time-varying model specification includes a decay parameter that indicates how inefficiency changes over time: when the decay parameter is equal to 0 the time-varying model reduces to the time-invariant model; when it is greater than 0 the degree of inefficiency decreases over time; and, when it is less than 0 the degree of inefficiency increases over time (Battese and Coelli, 1992). The time-varying model specification is used in this exercise since it correctly fits the data. For a more formal description of the model see Appendix A.

Once the stochastic frontier production function model is estimated and the technical efficiency of fish production is predicted, the predicted technical efficiency is then regressed on mangrove area (and other control variables) to judge if mangrove area influences the technical efficiency of fish production. The empirical strategy is detailed in the next section.

Data and Empirical Strategy

Annual state-level data, compiled from various secondary sources, covering the period 1985 – 2011 is used in the analysis. Total marine fish production (in tonnes) includes pelagic, demersal, crustacean and mollusc fish species, and measures the aggregate total output variable (Q_{it}) in the study. Data on marine fish production comes from the Central Marine Fisheries Research Institute[3]. Since data on marine fish output is available for the major Indian coastal states and one coastal union territory (Pondicherry), only these coastal regions are considered for the analysis. The input variables (x_{it}) used in the analysis to explain fish output include: i) the plan outlay on fisheries development under state

[3] See http://www.cmfri.org.in/annual-data.html

sector schemes (in Rupees), data for which is sourced from the Planning Commission's Annual Plan documents[4], and ii) the total number of marine fishing vessels including mechanised boats, motorised crafts and traditional (non-motorised) crafts (in number), data for which is sourced from three census of marine fishermen, craft and gear conducted in 1980, 2005, 2010 (CMFRI, 1981; DADF and CMFRI, 2005, 2010). Using information for these three time-periods, data was interpolated for the remaining years over the period 1985 – 2011. Table 2 presents the average values of the variables entering the production function.

Table 2: Mean Values of Marine Fish Production, Fisheries Outlay and Marine Fishing Vessels (over the period 1985 – 2011)

Coastal Region	*Marine Fish Production (Tonnes)*	*Fisheries Plan Outlay (Rs. Lakhs)*	*Marine Fishing Vessels (No.)*
Kerala	5,59,072	3,230	27,396
Karnataka	2,12,325	2,420	12,664
Goa	74,242	502	2,752
Maharashtra	3,40,430	2,100	16,901
Gujarat	4,77,678	1,740	17,997
West Bengal	1,30,889	3,570	12,569
Odisha	95,134	1,170	16,432
Andhra Pradesh	1,77,566	767	38,107
Tamil Nadu	3,80,806	3,300	50,377
Pondicherry	13,882	882	3,219

Over the period 1985 to 2011, Kerala had the highest average marine fish production, followed by Gujarat and Tamil Nadu. Mean plan outlay on fisheries was the highest in West Bengal, followed by Kerala and Tamil Nadu over the same period. Note that the plan outlay on fisheries includes funds allocated for the development of both marine and inland fisheries. The mean total number of marine fishing vessels was the highest in Tamil Nadu, followed by Andhra Pradesh and Kerala over the period 1985 to 2011.

[4] See http://planningcommission.gov.in/plans/annualplan/index.php?state=aplsbody.htm

The empirical strategy followed in this analysis consists of two stages. In the first stage, the stochastic frontier production function is estimated, and the technical efficiency values for fish production are derived using the model estimates. The type of functional form employed for the production function is the Cobb-Douglas function since it provides the best fit for the model. Therefore, the stochastic frontier production function is given by

$$\ln(Q_{it}) = \beta_0 + \beta_1 \ln(x_{1it}) + \beta_2 \ln(x_{2it}) + v_{it} - u_{it} \tag{1}$$

where, β_is are the parameters to be estimated and x_1 and x_2 refer to the two inputs namely fisheries outlay and fishing vessels, respectively. Q is marine fish output, and *i* and *t* refer to the coastal state and the year in question, respectively, as defined above. The maximum likelihood estimation technique is used to estimate (1). The values of technical efficiency are obtained from the model estimates of (1).

In the second stage of the analysis, the influence of mangroves on technical efficiency is ascertained. In order to do this, the technical efficiency values are regressed on mangrove area and other control variables (state dummy variables). Since the estimated technical efficiency values are bound between 0 and 1, they are normalised before the regression analysis is undertaken. The specification of the second-stage panel (fixed effects) regression model is thus

$$\ln[TE_{it}/(1 - TE_{it})] = \alpha_0 + \alpha_1 MS_{it} + \Sigma_{i=1}^{n-1} \beta_i SD_i + e_{it} \tag{2}$$

where, TE is technical efficiency, MS is mangrove stretch, which is defined as the square root of mangrove area[5] and SD represents the state dummy variables that control for unobserved state fixed effects.

[5] Following Aburto-Oropeza et al. (2008), the square root of mangrove area rather than mangrove area itself is used in the regression model since the nursing ground role of mangroves is better captured by the former. Further, it also provides a better model fit than the latter. Having said that, the results are also robust when mangrove area is used as the explanatory variable (see the results section for further discussion on this).

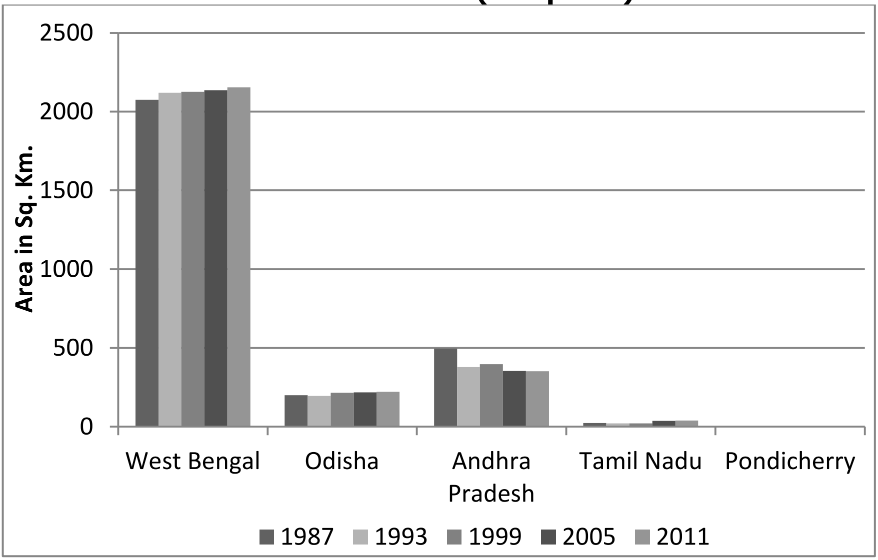
The α_is and β_is are the parameters to be estimated and e is the error term.

In order to estimate (2), data on the area under mangrove cover (in square kilometres) is used, and this information is sourced from the India State of Forest Reports, published by the Forest Survey of India (FSI, 1987 – 2011). Note that the forest surveys were conducted every once in two years starting from the year 1987, and thus data on mangrove area is only available for 12 years within the time period 1985 – 2011[6]. Therefore, years for which mangrove data are not available are eliminated and thus, (2) is estimated with a smaller sample size compared to (1).

Figure 1 (below) presents the area under mangrove cover over the period 1987 to 2011 for the east-coast states. West Bengal has the highest mangrove cover among all coastal states (both east and west), and mangrove cover has increased in the state by about 4 percent over the period 1987 to 2011. Among the east-coast states, Andhra Pradesh has the second highest area under mangrove cover however mangrove cover in this state has declined by roughly 29 percent between 1987 and 2011. In fact, Andhra Pradesh is the only state that records a decline in mangrove cover over time among all coastal regions in the country. Odisha and Tamil Nadu have the third and fourth highest mangrove cover among the east-coast states and the same has increased by approximately 12 and 70 percent respectively, over the period 1987 to 2011. Pondicherry hardly has any mangrove cover at all (about 1 sq. km. in 2011).

[6] There should actually be 13 data points between 1987 and 2011, however the forest survey was not conducted in the year 2007 and so data is missing for this year.

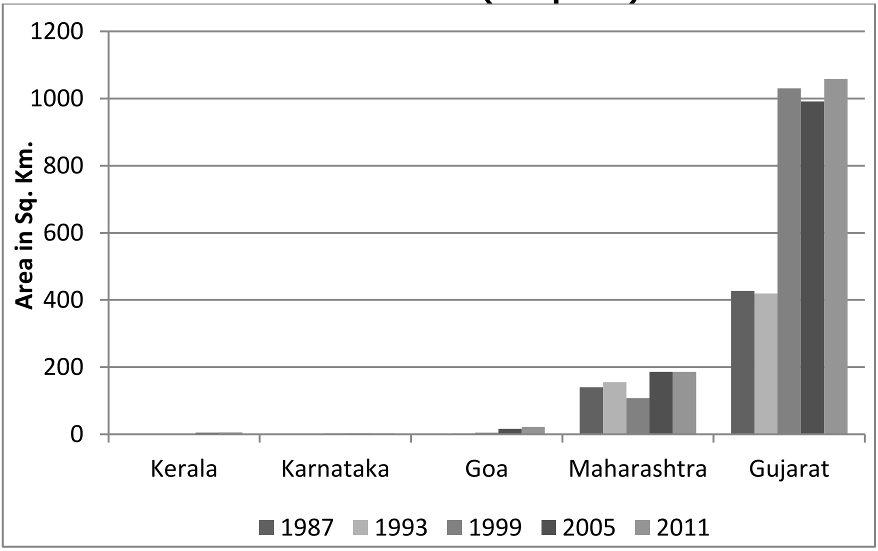
Figure 1: Area under Mangrove Cover from 1987 to 2011 for East-Coast States (in Sq. Km.)



Source: FSI (1987-2011).

Among the west-coast states (see Figure 2), Kerala and Karnataka had less than 10 sq. km. of mangrove cover, and Goa had about 22 sq. km. of mangrove cover in 2011. Gujarat has the highest area under mangrove cover, and it has witnessed a significant increase in mangrove cover over the period 1987 to 2011 by about 148 percent. The sharp increase in mangrove cover was witnessed in Gujarat post-1993. Maharashtra has the second highest mangrove cover among the west-coast states, and the same has increased by about 33 percent during 1987 to 2011. Comparing mangrove cover across the east- and west-coast states, it is evident that the east-coast has a higher total mangrove cover compared to its western counterpart.

Figure 2: Area under Mangrove Cover from 1987 to 2011 for West-Coast States (in Sq. Km.)



Source: FSI (1987-2011).

Results

Estimates of the Stochastic Frontier Production Function

The estimates of the stochastic frontier production function (time-varying) model are presented in Table 3. The estimated parameters of the two input variables are positive, as expected, and may be interpreted as output elasticities. Note that the parameter estimate for marine fishing vessels is highly significant at the 1 percent level, however the parameter estimate for fisheries plan outlay is significant only at the 10 percent level.

Since the estimated decay parameter η is greater than 0 and the coefficient is highly significant at the 1 percent level, this implies that the time-varying model is the correct model specification and that the degree of inefficiency in production decreases over time. The estimated values of the variance of the inefficiency term σ_u^2 and the variance of the error term σ_v^2 are 0.758 and 0.122 respectively. These values indicate that the differences between the observed (actual) and frontier (potential) output are due to inefficiency and not chance alone. The estimate of γ (the ratio of the variance of state-specific technical efficiency to the total variance of output) is 0.86, indicating that 86 percent of the difference between the observed and frontier output is primarily due to factors which are under the control of states.

Table 3: Estimates of the Stochastic Frontier Production Function (Time-Varying) Model

Variables	***Parameter Estimates***
Constant	5.523*** (5.50)
ln (Fisheries Plan Outlay)	0.043* (1.66)
ln (Marine Fishing Vessels)	0.697*** (7.29)
μ	0.372 (0.39)
η	0.014*** (5.58)
ln $(\sigma_v^2 + \sigma_u^2)$	-0.128 (-0.14)
exp (γ) / (1 + exp (γ))	1.824* (1.70)
$\sigma_v^2 + \sigma_u^2$	0.880
γ	0.861
σ_u^2	0.758
σ_v^2	0.122
Log-Likelihood	-122.075
Number of Iterations	7
Number of Observations	270
Wald $\chi^2(2)$ Value	62.20

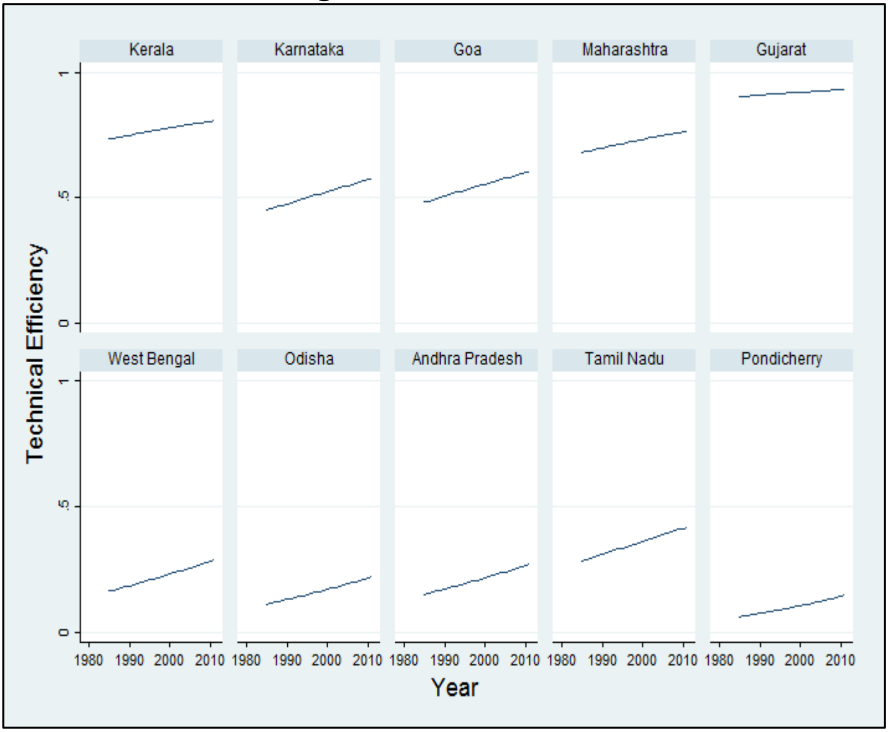
Notes: Dependent variable is ln (Marine Fish Production); μ is the estimated mean value of the inefficiency term; $\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$; ***, **, * imply level of significance at 1 percent, 5 percent and 10 percent respectively; figures in parentheses are asymptotic t values (or z values).

Estimates of Technical Efficiency

The mean value of technical efficiency for the sample is estimated to be about 45 percent, which implies that states on average could increase their marine fish output by 55 percent without any additional resources but through more efficient use of existing inputs and technology.

Figure 3 plots the estimated values of technical efficiency for each coastal region over the time period 1985 to 2011. In general, technical efficiency is higher among the west-coast states compared to that of the east-coast states. Technical efficiency increases over time across all coastal states (in line with the observation made above that the degree of inefficiency decreases over time). Among the west-coast states (top panels), Gujarat has the highest level of technical efficiency (close to 100 percent), followed by Kerala and Maharashtra, and Karnataka has the lowest (which is almost at the same level as Goa, i.e. around 50 percent). Among the east-coast states (bottom panels), Tamil Nadu has the highest level of technical efficiency (with a mean of roughly 40 percent over time), West Bengal, Andhra Pradesh and Odisha all have similar levels of technical efficiency (about 20 percent), and Pondicherry has the lowest level.

Figure 3: Estimated Values of Technical Efficiency across Coastal Regions and over Time



Estimates of the Influence of Mangroves on Technical Efficiency

The regression estimates for model (2) are presented in Table 4. The coefficient on mangrove stretch is positive and significant at the 1 percent level[7]. This implies that mangroves do in fact improve the efficiency of fish production after controlling for state fixed effects. The coefficients of the state fixed effects variables are all positive and significant at the 1 percent level, except for the West Bengal, Odisha and Andhra Pradesh fixed effect coefficients which are insignificant. The significant state fixed effect coefficients tell us the extent to which

[7] Note that the results are robust even when mangrove area is used as the explanatory variable. The estimated coefficient is 0.000383, which is significant at the 5 percent level.

technical efficiency is higher in the state in question compared to the reference coastal region (Pondicherry). This implies that barring Tamil Nadu, the technical efficiency in fish production in the other east-coast regions is not significantly different to that of Pondicherry, which is corroborated by Figure 3.

Table 4: Estimates of the Influence of Mangroves on Technical Efficiency

Variables	***Parameter Estimates***
Constant	-2.211*** (-43.23)
Mangrove Stretch	**0.031*** (3.48)**
Kerala fixed effect	3.412*** (47.17)
Karnataka fixed effect	2.240*** (30.89)
Goa fixed effect	2.317*** (30.98)
Maharashtra fixed effect	2.819*** (22.43)
Gujarat fixed effect	3.793*** (15.31)
West Bengal fixed effect	-0.453 (-1.11)
Odisha fixed effect	0.129 (0.90)
Andhra Pradesh fixed effect	0.278 (1.52)
Tamil Nadu fixed effect	1.434*** (16.79)
Adjusted R^2	0.984
Number of Observations	120

Notes: Dependent variable is the natural log of normalised technical efficiency, i.e. $\ln[TE_{it}/(1-TE_{it})]$; ***, **, * imply level of significance at 1 percent, 5 percent and 10 percent respectively; figures in parentheses are absolute t values.

DISCUSSION AND CONCLUSIONS

The aim of this paper was to examine whether mangroves influence the production of commercially important marine fisheries in India. In particular, the paper analysed whether mangroves affect the technical efficiency of fish production using a two-stage econometric approach. In the first stage, a stochastic frontier production function approach was used to estimate technical efficiency, and in the second stage, the influence of mangroves on technical efficiency was ascertained via fixed effects regression analysis. The results of the analysis indicate that mangroves do have a positive impact on fish production, which is evidenced through their influence on the technical efficiency of fish production. Thus, mangroves are important for the efficiency improvement of fish production in India.

Given that mangroves influence marine fish production, a distinct but related question that warrants analysis and discussion is the extent to which mangroves increase marine fish production in India or in other words, the contribution of mangroves to marine fish production in India. One way in which this may be analysed is by examining changes in fish production over time in two regions that are seemingly similar in every way excepting that one region has implemented a mangrove rejuvenation programme while the other has not. By doing so one can estimate the extent to which fish production has increased as a result of the change in mangrove area over time in the region that has undertaken the said intervention, after controlling for all other factors affecting fish production in that region. This is essentially what the difference-in-difference (DID) estimation technique does, and it has been used in several exercises concerned with program/project evaluation (See for example, Card and Krueger, 1994 and Meyer, 1995). The DID approach separates out the effect of the programme on the region with the intervention and treats the trend in the region without the intervention as the counterfactual. On the basis of FSI data, Sahu et al. (2015) note that during the period 1987 to 2013, Gujarat recorded the maximum net increase (676 km^2) and the maximum mean annual increment (28.16 ± 50.58 km^2) in mangrove area in the country. Figure 2 shows a significant improvement in mangrove cover in Gujarat post-1993. This is a result of the mangrove plantation/ regeneration activities that were planned and initiated in 1993 by the state government of Gujarat and carried out ever since, which have proved to be remarkably successful over time (FSI, 2011)[8]. Figures 1 and 2 reveal that no other coastal region records a significant change in mangrove cover over time. Thus, the changes in fish production due to the changes in mangrove cover may be estimated, using the DID methodology, by taking the case of Gujarat in comparison to other coastal regions of India. There is some emerging analysis in this context under the TEEB-India initiative. The results of the DID estimation may be then used to derive the marginal effect of mangroves on fish production, i.e. the contribution of a hectare of mangrove area to marine fish output.

Alternatively, the marginal effect of mangroves on fish production can also be estimated by using a panel fixed effects model, in which total marine fish production is directly regressed on mangrove stretch (i.e. the square root of mangrove area, as defined earlier) and other control variables such as fishery plan outlay (in Rupees), number of fishing vessels, time trend (for the period 1987 to 2011), a control variable for Gujarat mangroves[9] (owing to their significant increase over time) and the state-specific fixed effects (with Pondicherry as the reference category). The results are presented in Table 5.

The mangrove stretch coefficient in the OLS regression estimation is positive and highly significant at the 1 percent level, implying that a 1 square kilometre increase in mangrove area leads to a

[8] See also http://www.gsbb.in/pdf/mangrove-conservation.pdf and https://forests.gujarat.gov.in/mangrove-conserv.htm

[9] This is the Gujarat fixed effects variable combined with Gujarat mangrove area.

275.88 tonne increase in total marine fish production per annum[10]. The annual per hectare contribution of mangroves to total marine fish production is therefore 2.76 tonnes. The mangrove stretch coefficient is significant despite controlling for the effect of the Gujarat mangroves on total marine fish production, the coefficient for which is also positive and significant at the 5 percent level. Fishery outlay, despite being highly significant, seems to have a negligible positive impact on fish catch. The time trend coefficient is also highly significant indicating the yearly increase in fish catch over time.

Table 5: Estimates of the Marginal Effect of Mangroves on Fish Output

Key Variables	***Parameter Estimates***
Fisheries Plan Outlay	0.000085***
	(4.56)
Marine Fishing Vessels	-1.72
	(-1.10)
Mangrove Stretch	**10593.68*** **
	(3.71)
Time Trend	2023.09***
	(2.76)
Gujarat Mangroves Control	238.45**
	(2.45)
Adjusted R^2	0.895
Number of Observations	250

Notes: Dependent variable is total marine fish production; mangrove area has been interpolated for years within the time period 1987 to 2011 for which mangrove area data are not available; mean mangrove area for the entire sample is 368.63 km^2; ***, **, * imply level of significance at 1 percent, 5 percent and 10 percent respectively; figures in parentheses are absolute t values.

A similar regression model was estimated with the dependent variable being the total mangrove-dependent marine fish production,

---

10 Note that the result is robust even when mangrove area (rather than mangrove stretch) is used as the explanatory variable, and in that case the estimated coefficient is 279.16, which is also significant at the 1 percent level. However, mangrove stretch provides an overall better fit to the model.

which includes demersal, crustacean and mollusc fish catch and excludes pelagic fish catch. The mangrove stretch coefficient in this model was also found to be positive and highly significant at the 1 percent level[11]. The estimated annual per hectare contribution of mangroves to total mangrove-dependent fish production is 1.84 tonnes.

Following Salem and Mercer (2012) and Brander et al. (2006), and assuming that the marginal value of the productivity of mangroves is equal to its average value (i.e. that mangrove contributions exhibit constant returns to scale), the marginal values of mangroves' contribution to marine fish production derived in the above regressions (i.e. 2.76 and 1.84 tonnes per hectare per year for total and mangrove-dependent fish catch, respectively) may be used to calculate the percentage contribution of mangroves to marine fish production in India[12], as follows:

As of 2011, the total mangrove area in India was 4,66,256 hectares (FSI, 2011). Therefore, the fish contribution of total mangroves in India in 2011 may be calculated by multiplying the annual per hectare fish contribution values estimated for India by the total mangrove area for India in 2011. This gives the total fish contribution from mangroves in India as 12,86,867 tonnes, and the mangrove-dependent fish contribution from mangroves in India as 8,57,911 tonnes in 2011. Total marine fish production in India was 37,76,116 tonnes in 2011 (CMFRI estimates). Hence, the proportion of fish catch that may be attributed to mangroves in India in 2011 is 34 percent, when total fish production is used to estimate the marginal effect, and 23 percent, when mangrove-dependent fish production is used to estimate the marginal effect. These values are summarised in Table 6.

---

[11] In addition, fish outlay and fishing vessels are both positive and significant at the 5 percent level.

[12] It is important to note, however, that "Costanza et al. (1989) assert that average productivity is more appropriate for the evaluation of large areas, while marginal values should be used in assessing small area values" (cited in Salem and Mercer, 2012; pp. 367).

Table 6: Contribution of Mangroves to Marine Fish Production in India in 2011

Marine Fish Production	***Annual Per Hectare Contribution of Mangroves to Marine Fish Production in India (t/ha/yr)***	***Total Mangrove Area in India in 2011 (ha)***	***Contribution of Mangroves to Marine Fish Production in India in 2011 (t)***	***Total Marine Fish Production in India in 2011 (t)***	***Percentage Contribution of Mangroves to Total Marine Fish Production in India in 2011 (%)***
Total Fish Catch	2.76	4,66,256	12,86,867	37,76,116	34
Mangrove-Dependent Fish Catch	1.84	4,66,256	8,57,911	37,76,116	23

Note: Total fish catch includes landings of pelagic, demersal, crustacean and mollusc fish species, whereas mangrove-dependent fish catch includes landings of demersal, crustacean and mollusc fish species only.

The contribution of mangroves to total marine fish production in India, as per the estimates in this study, may be taken to be in the range of 23 – 34 percent. In reality, the contribution of mangroves to fisheries is likely to be somewhat lower than these values. This is because, the marginal effects estimates, from which the percentage contribution of mangroves to fisheries is estimated, are likely to be higher than the average effects. Therefore, the estimates of the contribution of mangroves to fisheries should be taken as indicative only as it is not easy to eliminate the role of confounding factors.

A global overview of estimates of mangroves' contribution to fisheries is presented in Table 7. Studies from across the world indicate that the relative contribution of mangrove-related species to total fisheries catch is significant in most cases. Looking at the more recent studies (and excluding the small-Island studies), the estimates of mangroves' contribution to fisheries are in the range of 10 – 32 percent. The present study estimates the contribution of mangroves to marine fisheries in India in the range of 23 – 34 percent, which is within, but leaning towards the higher end of the range of the country-wide estimates. The most recent and the most empirically rigorous study among those listed in Table 7 is the one undertaken by Aburto-Oropeza et al. (2008) in the Gulf of California, Mexico. This study combined fish landing data and satellite imagery of mangroves into scaling models to explore how the relationship between mangrove area and fisheries changes as the size of the mangrove habitat increases. The study found that (fringe) mangrove-related fish and crab species accounted for 32 percent of the small-scale fisheries landings in the region. This estimate is within the higher end of the range of values of the contribution of mangroves to marine fisheries in India that were estimated in the present study.

Table 7: Mangroves' Contribution to Fisheries at Different Locations

S. No.	***Study***	***Year***	***Country***	***Mangrove Contribution to Fishery (%)***
1.	Aburto-Oropeza et al.	2008	Mexico	32[a]
2.	Naylor and Drew	1998	Micronesia	90[b]
3.	Singh et al.	1994	ASEAN	30[c]
4.	Bennett and Reynolds	1993	Malaysia	10 – 20[b]
5.	Lal	1990	Fiji	56[b]
6.	Hamilton and Snedaker	1984	Australia	67[c]
7.	Macintosh	1982	Malacca Strait	49[d]

Notes: [a] Mangrove fringe contribution to small-scale fishery; [b] Contribution of subsistence fisheries to total catch supported by mangroves; [c] Contribution of mangrove-related species to total fisheries/commercial catch; [d] Contribution of mangrove-related species to demersal fish catch.

Source: Modified from Ronnback (1999). For references of studies in the table (except Aburto-Oropeza et al., 2008) see source document.

A recent report on the economic valuation of coastal and marine ecosystem services in India (Kavi Kumar et al., 2016) estimated, using the direct market valuation approach, the total value of marine fisheries as a provisioning service as approximately Rs. 295 billion (in 2012-13 prices). Applying to this value, the percentage contribution of mangroves to marine fisheries estimated in this paper (i.e. 23 – 34 percent) gives the rupee value of mangroves' contribution to marine fisheries in the range of Rs. 68 – 100 billion in India in 2012-13. On a per hectare basis, the economic value of mangroves' contribution to marine fisheries in India translates into Rs. 1.46 – 2.15 lakhs per hectare in 2012-13 prices.

In addition to their contribution to marine fisheries[13], mangroves also provide raw materials such as wood, and a host of other ecosystem services including 'regulating services' such as coastal protection, carbon sequestration, erosion control and water purification, and 'cultural services' such as tourism, recreation, education and research (Barbier et al., 2011; Braat and de Groot, 2012). While economic values are not available for all services provided by mangroves in India, Kavi Kumar et al. (2016) estimate the values of two regulating services provided by mangroves in India, namely coastal protection and carbon sequestration. The benefit transfer approach is used to value the coastal protection service of mangroves in India and the same is estimated in the range of Rs. 560 – 754 billion in 2012-13 prices. The direct market valuation approach is used to value the carbon sequestration service of mangroves in India and the same is estimated in the range of Rs. 0.76 – 1.65 billion in 2012-13 prices. Although the average coastal protection value of mangroves is almost eight times higher than the mean value of mangroves' contribution to marine fisheries, the latter is still significant and implies that mangrove ecosystems play an important role in enhancing the production and value of marine fisheries in India. The mangrove-fishery linkage acquires further significance on account of the fact that fisheries are an important source of livelihood for a large number of people in India.

[13] Note that in the classification of ecosystem services (de Groot et al., 2012), the provision of a breeding ground and nursery habitat by a particular ecosystem is classified as a 'habitat service'. However, by providing a nursery service for fish, mangroves contribute to the enhancement of marine fisheries, or to the provision of food (fish), which is classified as a 'provisioning service'. In this paper, the economic value of the habitat service of mangroves is estimated in terms of the economic value of mangroves' contribution to marine fisheries and as such may be viewed as an estimate for either the provision of food or the provision of habitat.

APPENDIX A: THE STOCHASTIC FRONTIER PRODUCTION FUNCTION MODEL FOR PANEL DATA

The frontier production function may be defined as the maximum feasible or potential output that can be produced by a production unit such as a coastal state, at a particular point in time, given a certain level of inputs and technology. More formally (see Aigner et al., 1977; Meeusen and van den Broeck, 1977; Kumbhakar and Lovell, 2000), suppose the producer has a production function $f(\mathbf{X}_{it}, \boldsymbol{\beta})$, in a world without error or inefficiency, in time *t*, the *i*th production unit (coastal state) would produce

$$Q_{it} = f(\mathbf{X}_{it}, \boldsymbol{\beta}) \tag{A.1}$$

where, Q_{it} represents the potential output, $\mathbf{X}_{it}$ is a vector of inputs, and $\boldsymbol{\beta}$ is a vector of parameters that describe the transformation process.

A key aspect of stochastic frontier analysis is that in reality each production unit produces potentially less than it might due to a degree of inefficiency in the production process. Specifically, the actual production function (corresponding to the production unit's actual output) can be written as

$$Q_{it} = f(\mathbf{X}_{it}, \boldsymbol{\beta})\, \xi_{it} \tag{A.2}$$

where, ξ_{it} is the level of efficiency for production unit *i* at time *t*; ξ_{it} must be in the interval [0; 1]. If $\xi_{it} = 1$, the production unit is achieving the optimal output, however, when $\xi_{it} < 1$, the production unit is inefficient, i.e. its actual output is less than its potential output. Thus, the ratio of the actual output Q_{it} and the potential output $f(\mathbf{X}_{it}, \boldsymbol{\beta})$ gives a measure of the technical efficiency of the production unit. Using equation (A.2) above, we may define this measure as

Technical Efficiency = Q_{it} / $f(\mathbf{X}_{it}, \boldsymbol{\beta}) = \xi_{it}$ (A.3)

Since the output is assumed to be strictly positive (i.e. $Q_{it} > 0$), the degree of technical efficiency is assumed to be strictly positive (i.e. $\xi_{it} > 0$). Output is also assumed to be subject to random shocks, implying that

$$Q_{it} = f(\mathbf{X}_{it}, \boldsymbol{\beta})\, \xi_{it} \exp(v_{it}) \quad (A.4)$$

where, v_{it} is the idiosyncratic error variable, which captures the effect of the other omitted variables that may influence output.

Taking the natural logs on both sides of equation (A.4), assuming there are *k* inputs, that the production function is linear in logs, and defining $u_{it} = -\ln(\xi_{it})$ yields

$$\ln(Q_{it}) = \beta_0 + \Sigma_{j=1}^{k} \beta_j \ln(x_{jit}) + v_{it} - u_{it} \quad (A.5)$$

Since u_{it} is subtracted from $\ln(Q_{it})$, restricting $u_{it} \geq 0$ implies that $0 < \xi_{it} \leq 1$, as specified above. The new function described in equation (A.5) is known as the stochastic production frontier model for panel data. The key feature of this model is that the disturbance term is assumed to have two components. One component is assumed to have a strictly nonnegative distribution, and the other component is assumed to have a symmetric distribution. In the econometrics literature, the nonnegative component is often referred to as the inefficiency term (u_{it}), and the component with the symmetric distribution as the idiosyncratic error (v_{it}). Two specifications of the u_{it} term (in equation (A.5)) are possible; one in which u_{it} is a time-invariant random variable and the other in which it is a time-varying random variable. In the time-invariant model, $u_{it} = u_i$, u_i is an independently and identically distributed truncated-normal (truncated at zero) with mean μ and variance σ_u^2, v_{it} is an independently and identically distributed normal with mean 0 and variance σ_v^2, and u_i and v_{it}

are distributed independently of each other and the covariates in the model.
However, in the time-varying decay specification (Battese and Coelli, 1992),

$$u_{it} = \exp\{-\eta(t - T_i)\}u_i \tag{A.6}$$

where, T_i is the last period in the *i*th panel, η is the decay parameter, u_i is an independently and identically distributed truncated-normal (truncated at zero) with mean μ and variance σ_u^2, v_{it} is an independently and identically distributed normal with mean 0 and variance σ_v^2, and u_i and v_{it} are distributed independently of each other and the covariates in the model. Note that when $\eta > 0$, the degree of inefficiency decreases over time; when $\eta < 0$, the degree of inefficiency increases over time. Since $t = T_i$ in the last period, the last period for the production unit *i* contains the base level of inefficiency for that production unit. If $\eta > 0$, the level of inefficiency decays toward the base level. If $\eta < 0$, the level of inefficiency increases to the base level.

Whether the model specification is time-invariant or time-varying, the stochastic production frontier model's (as described in equation (A.5)) coefficients are estimated by maximising its log likelihood function. The time-specific technical efficiency is obtained from the conditional mean of exp ($-u_{it}$), given the distribution of the composite error term, ε_{it}.

REFERENCES

Aburto-Oropeza, O., E. Ezcurra, G. Danemann, V. Valdez, J. Murray and E. Sala (2008), "Mangroves in the Gulf of California Increase Fishery Yields", *PNAS*, 150 (30), 10456 – 10459.

Aigner, D. J., C. A. K. Lovell and P. Schmidt (1977), "Formulation and Estimation of Stochastic Frontier Production Function Models", *Journal of Econometrics*, 6, 21–37.

Barbier, E. B., S. D. Hacker, C. Kennedy, E. W. Koch, A. C. Stier and B. R. Silliman (2011),"The Value of Estuarine and Coastal Ecosystem Services", *Ecological Monographs*, 81 (2), 169-193.

Battese, G. E. and T. J. Coelli (1992), "Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India", *Journal of Productivity Analysis*, 3, 153–169.

Braat, L. C. and R. de Groot (2012), "The Ecosystem Services Agenda: Bridging the Worlds of Natural Science and Economics, Conservation and Development, and Public and Private Policy", *Ecosystem Services*, 1, 4-15.

Brander, L. M., R. J. G. M. Florax and J. E. Vermaat (2006), "The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature", *Environmental and Resource Economics*, 33(2), 223–250.

Card, D. and A. B. Krueger (1994), "Minimum Wages and Employment: A Case Study of the Fast-Food Industry in New Jersey and Pennsylvania", *American Economic Review*, 84(4), 772-793.

CMFRI (1981), *All India Census of Marine Fisherman, Craft and Gear: 1980*, Central Marine Fisheries Research Institute, Cochin, India.

CMFRI (2015), *Annual Report 2014-15*, Central Marine Fisheries Research Institute, Cochin.

Costanza, R., S. C. Farber and J. Maxwell (1989), "Valuation and Management of Wetland Ecosystems", *Ecological Economics*, 1(4), 335–361.

DADF (2014), *Handbook on Fisheries Statistics*, Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India, New Delhi.

DADF and CMFRI (2005, 2010), *Marine Fisheries Census*, Department of Animal Husbandry Dairying and Fisheries, Ministry of Agriculture, New Delhi and Central Marine Fisheries Research Institute, Kochi, Indian Council of Agricultural Research, New Delhi.

de Groot, R., L. Brander, S. van der Ploeg, R. Costanza, F. Bernard, L. Braat, M. Christie, N. Crossman, A. Ghermandi, L. Hein, S. Hussain, P. Kumar, A. McVittie, R. Portela, L.C. Rodriguez, P. ten Brink, and P. van Beukering (2012), "Global Estimates of the Value of Ecosystems and their Services in Monetary Units", *Ecosystem Services*, 1, 50-61.

FSI (1987 – 2011, 2015), *India State of Forest Report*, Forest Survey of India, Ministry of Environment and Forests, Government of India.

Greene, W. H. (2012), *Econometric Analysis*, Seventh Edition, Prentice Hall, NJ.

Hutchison, J., M. Spalding and P. zu Ermgassen (2014), "The Role of Mangroves in Fisheries Enhancement", The Nature Conservancy and Wetlands International.

Kavi Kumar, K. S., L. R. Anneboina, R. Bhatta, P. Naren, M. Nath, A. Sharan, P. Mukhopadhyay, S. Ghosh, V. da Costa and S. Pednekar (2016), "Valuation of Coastal and Marine Ecosystem Services in India: Macro Assessment", Monograph 35, Madras School of Economics, Chennai.

Kumbhakar, S. C. and C. A. K. Lovell (2000), *Stochastic Frontier Analysis*, Cambridge: Cambridge University Press.

Meeusen, W. and J. van den Broeck (1977), "Efficiency Estimation from Cobb–Douglas Production Functions with Composed Error", *International Economic Review*, 18, 435–444.

Meyer, B. D. (1995), "Natural and Quasi-Experiments in Economics", *Journal of Business and Economic Statistics*, 13(2), 151 – 161.

Ronnback, P. (1999), "The Ecological Basis for Economic Value of Seafood Production Supported by Mangrove Ecosystems", *Ecological Economics*, 29, 235 – 252.

Sahu, S. C., H. S. Suresh, I. K. Murthy and N. H. Ravindranath (2015), "Mangrove Area Assessment in India: Implications of Loss of Mangroves", *Journal of Earth Science and Climate Change*, 6(5), 280.

Salem, M. E. and D. E. Mercer (2012), "The Economic Value of Mangroves: A Meta-Analysis", *Sustainability*, 4, 359-383.

Shanmugam, K. R. and A. Venkataramani (2006), "Technical Efficiency in Agricultural Production and Its Determinants: An Exploratory Study at the District Level", Working Paper 10, Madras School of Economics, Chennai.

Singh, A. K., A. Ansari, D. Kumar and U. K. Sarkar (2012), "Status, Biodiversity and Distribution of Mangroves in India: An overview", In: Proceedings of National Conference on Marine Biodiversity, Lucknow, 22 May 2012, Uttar Pradesh State Biodiversity Board, Lucknow.

Untawale, A. G. (1986), "Asia country reports: India", In: Mangroves of Asia and the Pacific: Status and Management, Technical Report of the UNDP: UNESCO Research and Training Pilot Programme on Mangrove Ecosystems in Asia and the Pacific.

MSE Monographs

* Monograph 23/2012
  Green Economy – Indian Perspective
  K.S. Kavikumar, Ramprasad Sengupta, Maria Saleth, K.R.Ashok and R.Balasubramanian
* Monograph 24/2013
  Estimation and Forecast of Wood Demand and Supply in Tamilandu
  K.S. Kavi Kumar, Brinda Viswanathan and Zareena Begum I
* Monograph 25/2013
  Enumeration of Crafts Persons in India
  Brinda Viswanathan
* Monograph 26/2013
  Medical Tourism in India: Progress, Opportunities and Challenges
  K.R.Shanmugam
* Monograph 27/2014
  Appraisal of Priority Sector Lending by Commercial Banks in India
  C. Bhujanga Rao
* Monograph 28/2014
  Fiscal Instruments for Climate Friendly Industrial Development in Tamil Nadu
  D.K. Srivastava, K.R. Shanmugam, K.S. Kavi Kumar and Madhuri Saripalle
* Monograph 29/2014
  Prevalence of Undernutrition and Evidence on Interventions: Challenges for India
  Brinda Viswanathan.
* Monograph 30/2014
  Counting The Poor: Measurement And Other Issues
  C. Rangarajan and S. Mahendra Dev
* Monograph 31/2015
  Technology and Economy for National Development: Technology Leads to Nonlinear Growth
  Dr. A. P. J. Abdul Kalam, Former President of India
* Monograph 32/2015
  India and the International Financial System
  Raghuram Rajan
* Mongraph 33/2015
  Fourteenth Finance Commission: Continuity, Change and Way Forward
  Y.V. Reddy
* Mongraph 34/2015
  Farm Production Diversity, Household Dietary Diversity and Women's BMI: A Study of Rural Indian Farm Households
  Brinda Viswanathan

MSE Working Papers

Recent Issues

* Working Paper 134/2015
  Inflation and the Dispersion of Relative Prices: A Case For Four Percent Solution
  Sartaj Rasool Rather, S Raja Sethu Durai and M Ramachandran

* Working Paper 135/2015
  Does Corporate Governance Matter in Determinants and Use of Cash: Evidence from India
  Saumitra Bhaduri and Ekta Selarka

* Working Paper 136/2015
  Determinants of Child Health: An Empirical Analysis
  Sowmya Dhanaraj

* Working Paper 137/2015
  Consumer's Acceptance Towards Genetically Modified Crops and Growth of the Economy: A Theoretical Approach
  Amrita Chatterjee and Arpita Ghose

* Working Paper 138/2016
  Kerosene Consumption in India: Welfare and Environmental Issues
  K.S. Kavi Kumar and Brinda Viswanathan

* Working Paper 139/2016
  Covariate and idiosyncratic shocks and coping strategies for poor and non-poor rural households in india
  Kailash Chandra Pradhan and Shrabani Mukherjee

* Working Paper 140/2016
  Economic Incentives for the Conservation of Bharathapuzha River: Focus on Sand Mining
  Lakshmi Sreedhar and Zareena Begum Irfan

* Working Paper 141/2016
  Does Carbon Tax Makes Sense? Assessing Global Scenario and Addressing Indian Perspective
  Mohana Mondal, Zareena Begum Irfan and Sunder Ramaswamy

* Working Paper 142/2016
  Game Theoretical Approach to Regulate the Public-Owned River Water Utilities:
  A case study of Cauvery River
  Zareena Begum Irfan and Jeeva Mary Jacob

* Working Paper 143/2016
  Revisiting the Determinants of Child Anthropometric Indicators in India Using Seemingly Unrelated Regressions Model
  G. Naline and Brinda Viswanathan

* Working paper 144/2016
  The Tradeoffs Between Ghgs Emissions, Income Inequality And Productivity
  Unmesh Patnaik and Santosh K. Sahu

---

* Working papers are downloadable from MSE website http://www.mse.ac.in

$ Restricted circulation