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Technical efficiency in the Malaysian gill net artisanal fishery

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ABSTRACT. Artisanal fishing communities include some of the ‘poorest of the poor’. Using data from gill net fishers in Malaysia, the paper presents the first technical efficiency study of an artisanal fishery and finds that artisanal fishers are poor, but enjoy a high level of technical efficiency. If the relatively high levels of technical efficiency found in the Malaysian gill net fishery existed in other artisanal fisheries, it suggests that targeted development assistance that has traditionally been focussed on the harvesting sector may be better directed to other priorities in artisanal fishing communities.

1. Introduction

> *there is little doubt that the problems facing small-scale fishermen in developing countries are among the most intractable ones in the field of development assistance …*
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> (Francis T. Christy, 1986, p. 121)

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Where the land meets the sea, over 200 million artisanal fishers worldwide live and exploit a complex and varied ecosystem.[1] Dispersed and isolated by geography, artisanal fishing communities are socially, politically, and culturally marginal to their society.[2] Indeed, artisanal fishers and their families form some of the 'poorest of the poor'. Many face difficult conditions for economic growth and development due to their isolation and poor infrastructure and limited access to public health, education, and other such services.

In contrast to large-scale commercial fisheries, artisanal fisheries are owner-operated and labor-intensive, employing rudimentary technologies. Artisanal fishers harvest the sea from comparatively small vessels, powered by sail, paddles, or outboard motors of limited power, have limited fishing range, and generally deploy passive fishing gears that are set and later retrieved. As with large-scale fisheries, the resources and ecosystems utilized by artisanal fishers are increasingly overexploited and degraded from destructive fishing practices, pollution, and changes in land use.[3] Artisanal fisheries are often overcapitalised, and fishing capacity is far in excess of that required to take the maximum sustainable yield, and even further in excess of that required for economic efficiency. These problems are compounded by incomplete property rights and conflicts with large-scale, industrial vessels.[4]

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[1] Some 200 million people worldwide depend on fishing and fish-related industries for their livelihood. Artisanal fisheries employ about 24 times as many people as large-scale commercial fisheries and generate almost 50 per cent of total world landings for human consumption (Pauly, 1997). Artisanal fisheries are often the main if not sole provider of fish for the domestic market (Lawson, 1984).

[2] Immobility of artisanal fisheries labor arises for several reasons. The fundamental reason is the profound geographical, social, and cultural isolation and consequent marginalization to society. Their specialized way of life, evolved to adapt and exploit their unique ecosystem, and job skills further contribute. The geographical isolation limits educational opportunities, knowledge of opportunities elsewhere, and kinship ties in cities and towns which would help emigration.

[3] Destructive fishing practices include the use of dynamite and cyanide poison to stun or kill fish, and coral mining. Estuaries, coastal wetlands, bays, and nearshore areas of the sea form breeding grounds and nurseries for juvenile fish and prawns. Over 30 per cent of marine productivity occurs in these marginal areas and yet they comprise only 1 per cent of the total marine volume (Agardy, 1997). Destruction of these habitats and coral reefs lowers the environmental carrying capacity and the ultimate size of the fish stocks that can be sustainably harvested. Mangrove swamps have some of the highest levels of primary biological productivity of any ecosystem, but are harvested for wood chips and cleared for aquaculture sites. Coral reefs are killed by cyanide, dynamite, or pollution. Over one-half of the world's salt marshes and mangrove swamps have been cleared or drained for development and 10 per cent of the world's coral reefs have been eliminated by human activity (Agardy, 1997).

[4] The conflicts arise from the harvesting of fish which, in tropical waters, tend to be concentrated in coastal areas and shallow, inshore waters. Moreover, in overfished tropical waters, only the youngest age classes remain, which are located in nearshore waters. These waters are fished by both artisanal and large-scale vessels, which leads to conflicts. In many instances, artisanal and large-scale com-

The earliest fisheries development strategies focused almost exclusively on large-scale fisheries, presumably in the belief that artisanal fisheries would expand their scale of production and adopt the technologies of large-scale fisheries and fish further offshore or otherwise provide labor to the operation of large-scale fisheries (Panayotou, 1982; Platteau, 1989). Artisanal fishers were expected to move from their isolated coastal villages and hamlets to find employment inland and in cities, and little attention was given to the growing environmental and resource problems associated with fishing.

Since the mid 1980s, fisheries development strategies began to focus on artisanal fishers. Assistance directed to the harvesting sector aimed to increase the efficiency of traditional fishing methods, and included aid to introduce or upgrade the motors for traditional craft and to use monofilament nylon in place of traditional fishing gear (Lawson, 1984; Ishak, 1994; Vincent, Rozali, and Jahara, 1997). This approach often involved credit assistance, subsidies for vessels, motors, and gear, and aid in marketing fish. Despite some successes, a focus on the harvesting sector helped to create a dependency on the state (Lawson, 1984; Ishak, 1994), contributed to overexploitation of certain fish stocks, and largely failed to solve the problems of endemic poverty and poor infrastructure in fishing communities (Panayotou, 1982).

Given the lessons from the past, what is the preferred approach to promote the development of artisanal fishing communities?[5] Should the current focus on the harvesting sector be continued or a strategy for the future be recast? The answer, in part, hinges upon whether artisanal fishers are technically efficient. In this paper, we use vessel data from the

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mercial fishers are from different ethnic groups, exacerbating the conflicts. In addition, larger vessels home port in larger urban areas rather than in the traditional fishing villages and hamlets strung along the coast. This poses another source of conflict as almost all of the employment gains associated with large-scale fishing and from modernization of fishing fleets are concentrated in towns and cities and not in artisanal fishing communities (IPFC, 1994). Large-scale fishers concentrate on production for urban and export markets (especially prawns for export) while artisanal fishers concentrate on own consumption and local markets, with only a limited export orientation.

[5] Several lessons can be learned from past experiences. First, artisanal fishers are unlikely to transform their fisheries into large-scale, fully commercialized operations. Second, the gains from introducing motors and upgrading gear are already largely realized. Third, artisanal fishers and their families are unlikely to depart in mass from their narrow strip of land and sea to find employment elsewhere inland. Fourth, most fish stocks are fully or overexploited, which precludes the introduction of larger-scale production technologies, such as trawl or purse seine nets. Fifth, policies should be predicated on full and sustainable utilization of the largely renewable resources of the complex and varied ecosystem in the coastal littoral and nearby fishing grounds. Sixth, sustainable fishery development is often limited by a yield fundamentally fixed by nature. Seventh, halting or even reversing the extensive ongoing degradation of the ecosystem is required to maintain the renewable resources upon which artisanal fishing communities survive.

Malaysian gillnet fishery to estimate individual measures of technical efficiency. These measures are then regressed on vessel and skipper characteristics to determine what factors may be contributing to efficiencies in the fishery. The results suggest that fishers are largely technically efficient and that development assistance for artisanal fishing communities focussed on the harvesting sector may be better directed to other priorities.

2. The Malaysian gill net fishery

The fisheries of Malaysia are highly diverse, comprising a multiplicity of species and gear types. The most important industrial gear types are trawl (*pukat tunda*) and purse seine (*pukat jerut*) nets, where trawl gear harvest demersal (bottom-dwelling) species and purse seines harvest pelagic (surface-dwelling) species (Ishak, 1994). Demersal fish account for about 30 per cent of the total fish harvested in Peninsular Malaysia (Kuperan *et al.*, 2002). Trawlers and purse seiners together contributed 81 per cent of total fish landings and 77 per cent of total wholesale value in Peninsular Malaysia in 1996.

The Peninsular Malaysian fishing industry provides a significant source of animal protein, employment, and to a lesser extent, foreign exchange (Ishak, 1994). The west coast fishing grounds lie largely in Malaysia's Extended Economic Zone in the Straights of Malacca and the Southern Indian Ocean. The west coast's stocks of shrimp and demersal fish provide the chief attraction for commercial vessels, and west coast issues have been the principal driving force for Peninsular Malaysian fishing policy during the last 30 years. The concentration of fishing in inshore waters led to overfishing off the west coast, beginning in the late 1960s and early 1970s, fuelled by the introduction of trawling to harvest shrimp for lucrative export markets (Ooi, 1990; Ishak, 1994). Landings are increasingly comprised of lower-valued species, especially 'trash fish', which are often discarded at sea with high mortality. Most of the untapped fishery resources are pelagic and lie offshore.

Due to open access and a fisheries development policy promoting expansion of fishing capacity, excess capacity and overfishing have developed in inshore fishing grounds, yielding conflicts between large- and small-scale fisheries (Jahara, 1988; Ooi, 1990; Ishak, 1994). Both large-scale, industrial fisheries, using trawl or purse seine gear and with a clear commercial orientation, and small-scale (artisanal) fisheries, using traditional gear and with more of a subsistence orientation, built up a large portion of their fishing capacity to harvest the same resource stocks. In tropical waters, these resource stocks tend to be concentrated in the shallow, nutrient-rich, readily accessible inshore waters, and include rich beds of commercially valuable shrimp, which are harvested largely for export. The large numbers of small-scale fishers are generally confined to inshore operations by their small vessels, low engine power, and traditional fishing gear. In contrast, the more limited number of large-scale fishers, with their larger vessels, are often free to fish both in inshore and offshore waters.

2.1. Artisanal fishing practices

The artisanal fishing communities examined in this paper are the gill net (*pukat hanyut*, *pukat hijau*, *pukat tansi*) fisheries on the west and east coasts of the Malaysian peninsula. The gear type employed in these fisheries is common in Southeast Asia and accounts for over half of all the gear used in all fisheries in Malaysia (Alam, 1991). Throughout Southeast Asia, gill net fishers employ small boats, often of wood construction, powered by comparatively small motors, usually outboard, deploy nets usually made of monofilament nylon, and catch a wide variety of species.

Typically in these fisheries, and elsewhere in Southeast Asia, gill net vessels set out from the port, village, or hamlet on what are generally day fishing trips with a limited operating radius. A captain (*Taikong*) commands the vessel during the fishing trip and is most often the vessel's owner. The captain remains in charge of the fishing vessel, selects, organizes and manages the crew, is responsible for the security and maintenance of all fishing equipment, provides overall leadership (Firth, 1975; Alam, 1991) and is often the most knowledgeable and experienced person on board.

Fishers employ surface, mid-water and bottom gill nets, depending on the species they are seeking.[6] Gill nets are set around coastal areas, river mouths or traditional resource-rich fishing grounds and 'soak' for some time, during which fish or shrimp swim or are carried by tides and currents into the net where they become entangled. After 'soaking', the nets are retrieved and the fish entangled in the mesh are extracted and hauled on board.

There are various kinds of drift gill nets in use, with mesh sizes ranging from 2.5 to 4 inches (Bailey, 1983). Mesh size varies by net type and can vary within a net because different mesh sizes can catch different species according to their seasonal variability. The *pukat hanyut* hangs from the surface by floats. The *pukat hijau* has a larger mesh size, is heavier, and is more suitable for the relatively heavy seas during and immediately after the monsoon period. Both the *pukat hanyut* and *pukat hijau* are used at night, except during the bright phase of the moon when the fish can see the shadow of the net and avoid it or sharks and dolphins can eat the trapped fish. Hence, fishing stops or slows during full moons or adverse weather.

The gill net is let off the stern as the vessel moves slowly away from the coast. The prevailing currents move up and down the coast, depending on the tides, and so the fish, which generally swim against the current, become trapped in the nets which run perpendicular to the coast. A small lantern is placed on a wooden floating platform attached to one end of the net and another placed on the vessel itself to mark the location of the net.

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[6] The species of fish commercially exploited, while generally not migratory, are sensitive to major seasonal variations (Bailey, 1983). On the east coast, during and immediately after the northeast monsoon, these species congregate close to the shoreline, where food is concentrated, and are normally found within five miles of the coast, but when the seas enter the prolonged calm, coinciding with decreased river discharge and hence lower nutrient inflow and plankton growth, the fish tend to disperse over a wider area to forage. In the season of clear water, the decline in water turbidity signifies lower organic water content and reduced marine life.

The net is attached by nylon rope to a string of plastic floats which allow the net to hang about 3 feet below the surface, with the netting running about 30 feet deep and of variable length.

Pukat tansi is a bottom-set gill net used during the day and cast and retrieved many more times during the day than *pukat hanyut*, and is used more during the monsoon season since day fishing is then safer. *Pukat hanyut* crews tend to be smaller than *pukat tansi* crews, but all crews are often larger than technically required, reflecting the large number of available fishers, many of whom can call upon ties of kinship or friendship to secure a place.

Upon arrival on shore, the fish and shrimp are sold fresh to a variety of local outlets, such as petty traders, beach markets, and local 'open-air' markets; state-sponsored buyers and cooperatives; and middlemen or brokers. Some fish are retained for home consumption and others may be dried and subsequently sold.

2.2. Fishing grounds

Much of the sea off the west coast is comparatively shallow with a muddy and flat sea floor and is fringed by mangrove swamps and estuaries. The fishing grounds are bounded by the island of Sumatra on the opposite side of the Straits, and have been subject to biological and economic overfishing (Ishak, 1994; Vincent, Rozali, and Jahara, 1997). The east coast fishing grounds along the South China Sea are larger in area, face a more severe monsoon, have deeper and rougher waters, more reefs, fewer shrimp, and a coastline more fringed by sandy beaches and coconut palms than the west coast. West coast fishers exploit the pelagic (migratory), demersal (bottom-dwelling), and shrimp resources while east coast fishers are more likely to harvest pelagic fish (Ooi, 1990).

Social and economic conditions and traditions vary substantially between the east and west coasts of Peninsular Malaysia. The majority of the manufacturing industries, plantations, tin reserves, and population are concentrated in the west. By contrast, the east coast states are more sparsely populated and relatively underdeveloped. On both coasts, the widely dispersed fishing villages are typically located along rivers, estuaries, or at river mouths, which can be isolated and lack physical, social, and public amenities and infrastructure. Some fishing communities earn almost all of their income from marine fishing, while others make their livelihood by combining fishing, farming, aquaculture, gathering from mangrove forests and coral reefs, and working on plantations or rice farms.

3. Model and data

To better understand the value of development policies in artisanal fishing communities, we use a data set of individual landings, crew, and vessel characteristics in the Malaysian gill net fishery to assess the constraints facing fishers and to estimate measures of technical efficiency. For each vessel, its efficiency is measured relative to its ability to produce on the fleet's best-practice frontier, the maximum output possible from a given set of inputs and production technology (Aigner, Lovell, and Schmidt, 1977; Kumbhakar and Lovell, 2000).

The approach used to obtain measures of technical efficiency is to estimate a stochastic frontier (Kumbhakar and Lovell, 2000), where technical inefficiency is measured as the deviation of an individual vessel's production from the best-practice production frontier. In this approach, production is assumed to be stochastic because fishing is sensitive to random factors such as weather, resource availability, and environmental influences.

Due to differences in resource abundance and availability, species composition, ecosystems, weather, and socioeconomic conditions between the two coasts in the Malaysian gillnet fishery, two separate stochastic production frontiers with a translog functional form are specified, one for each coast[7]

$$\begin{aligned}\ln Y_i = {} & \alpha_0 + \alpha_1 \ln K_i + \alpha_2 \ln L_i + \alpha_3 \ln T_i + \alpha_4 \ln N_i + \alpha_5 \ln OD_i + \alpha_6 \ln K_i^2 + \\ & \alpha_7 \ln L_i^2 + \alpha_8 \ln T_i^2 + \alpha_9 \ln N_i^2 + \alpha_{10} \ln K_i \ln L_i + \alpha_{11} \ln K_i \ln T_i + \alpha_{12} \ln K_i \\ & \ln N_i + \alpha_{13} \ln L_i \ln T_i + \alpha_{14} \ln L_i \ln N_i + \alpha_{15} \ln T_i \ln N_i + \epsilon_{\mathrm{i}} \qquad (1)\end{aligned}$$

for vessel (firm) *I* and where symmetry has been imposed by $\alpha_{jk} = \alpha_{kj}$ and $j,k = K,L,N,T$. Total output (catch) in kilograms is denoted by Y_i and is the geometric mean of 15 species of fish plus shrimp (where revenue shares serve as weights). The inputs are specified as service flows by multiplying the stocks of capital and labor by days at sea.[8] The vessel capital stock (K_i) is a volumetric measure given by vessel gross registered tons (GRT); labor (L_i) is the number of crew employed per vessel for the month, including the captain; and the gill net capital stock (N_i) is measured by its length in meters multiplied by the number of hauls of the gill net per day.[9] The

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[7] The translog functional form – a flexible functional form – can be interpreted as either a linear-in-parameters, second-order approximation to an unknown, unspecified, arbitrary, twice-differentiable underlying functional form or as a true or exact production function. As a flexible functional form, the translog does not *a priori* restrict the value of factor substitution elasticities. We interpret the translog as a second-order approximation and subsequent tests of separability to distinguish the translog from the Cobb–Douglas functional form in order to impose fewer restrictions on the form of aggregator functions of aggregate inputs or outputs (Blackorby, Primont, and Russell, 1978).

[8] Campbell and Hand (1998) discuss the importance of specifying these variables as service flows rather than assuming that the stocks are in full static equilibrium with proportional service flows. A flow specification increases the possibility of multicollinearity for the stochastic production frontier. However, this study is concerned with estimates of technical efficiency, using predictions of output. Hence, multicollinearity does not raise the same problem as it would if the study focused on individual parameter estimates, or combinations of them, as for example in an evaluation of input substitution possibilities.

[9] Net length was chosen over mesh size as a more accurate measure of the volume of water swept by the fishing gear. Specifying mesh size as an additional variable would have increased multicollinearity. Also, GRT-days is scaled by 10 and net-haul-days is scaled by 100 to keep the magnitude roughly comparable to labor-days, number of trips, and operating distance from shore.

number of trips per month (T_i) represents variable input usage (e.g., diesel and/or gasoline, lubricant and/or oil, ice, container/polythene, and miscellaneous variable inputs).

Distance from shore to the fishing ground is specified in nautical miles (OD_i) and is intended to capture environmental effects, providing for differences in resource conditions that vary by distance from shore and by water depth.[10] The effects of *OD* on the level of catch can be expected to vary by coast, depending on the topography of the ocean bottom, currents, demographic structure of the population, species of fish, and extent of depletion of inshore waters. In addition, shrimp, which are a more valuable component of catch on the west coast than on the east coast, are found close to shore.

The error term, ϵ_i in equation (1) is defined as $\epsilon_i = V_i - U_i$, where U_i, and V_i are distributed independently of both each other and the regressors in equation (1). The two-sided error term V_i captures exogenous stochastic shocks and is assumed to be symmetrical and independently and identically distributed as $N(0, \sigma_V^2)$. The non-negative error term U_i captures differences in technical inefficiency and is assumed to be an independently distributed non-negative random variable, such that U_i is the truncation of a normal distribution at 0, with mean $\mu_i = Z_i\delta$ and variance σ_U^2, $N(Z_i\delta,\sigma_U^2)$. The one-sided non-negative random variable, U_i, representing technical inefficiency, must be non-negative so that no firm can perform better than the best-practice frontier. The independent distribution of V_i and U_i allows for the separation of noise and technical inefficiency. Z_i defines a $(1 \times M)$ vector of explanatory variables associated with the technical inefficiency function and δ is an $(M \times 1)$ vector of unknown parameters to be estimated (Battese and Coelli, 1995).

The technical inefficiency calculated from the stochastic production frontier, equation (1), may be a function of explanatory variables and regressed against these variables in a separate and subsequent regression. However, Kumbhakar, Ghosh, and McGuckin (1991) and Reifschneider and Stevenson (1991) first noted the inconsistency between inefficiency effects when two independent and separate regressions are performed. In the first stage of a two-step estimation, the error is assumed to be independently and identically distributed, but the predicted inefficiency effects in the second stage are specified as a function of a number of firm-specific factors implying the errors are not identically distributed. For this reason,

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[10] Because distance from the fishing ground represents an environmental parameter, it is specified as a single-order term in the stochastic frontier. An anonymous reviewer noted that this distance variable, *OD*, is positively correlated with the measure of vessel size, GRT, on the east coast, suggesting that larger vessels tend to operate further from shore. This correlation raises the possibility of the east coast results being affected by multicollinearity. Due to data limitations, the location or state of the vessel was not recorded and thus area dummy variables, which would otherwise capture spatial differences in resource abundance, fishing practices, and socio-economic conditions, are not included in the model. Data limitations also precluded accounting for the type of gill net used.

and as described in detail in Coelli, Rao, and Battese (1998), we estimate both (1) and (2) jointly, using the maximum likelihood estimation.

Technical inefficiency for each firm i, U_i, is defined as the ratio of actual output to the potential frontier output. U_i is not directly observable, but Jondrow *et al*. (1982) found its expected value of U_i conditional on the value of $\epsilon_i = V_i - U_i$, i.e., $E[U_i \mid \epsilon_i]$. Technical efficiency for each firm is defined as $TE_i = \exp(-U_i) = \exp(-Z_i\delta - W_i)$, where exp is the exponential operator (Battese and Coelli, 1988). The range of technical efficiency for firm $i(TE_i)$ is $0 \leqslant TE_i \leqslant 1$, where $TE_i = 1$ represents the achievement of maximum output (adjusted for random fluctuations) for the given inputs, or 100 per cent efficiency.

The technical inefficiency function, comprised of the vector of variables Z which are hypothesized to affect the technical efficiency of vessels, is specified by

$$U_i = \delta_0 + \delta_1 EXLIH + \delta_2 EXLIE + \delta_3 EXLIN + \delta_4 FEXP + \delta_5 MESH + \delta_6 FSIZE + \delta_7 D_{\mathrm{CH}} + \delta_8 D_{\mathrm{CT}} + \delta_9 D_{\mathrm{NOP}} + \delta_{10} D_{\mathrm{SM}} + \delta_{11} D_{\mathrm{P}} + \delta_{12} D_{\mathrm{S}} + \delta_{13} D_{\mathrm{B}} \quad (2)$$

U_i is the vessel-level technical inefficiency measure; *EXLIH*, *EXLIE*, and *EXLIN* are the remaining economic life, in years, of the vessel hull, engine, and gill net as estimated by respondents; *FEXP* is years of fishing experience for the captain; *MESH* is mesh size in meters; and *FSIZE* is the family size of the captain. The seven D terms are dummy variables and are equal to one when: the vessel has a Chinese captain (CH); the captain has participated in a Malaysian fisher training program (CT); the captain is not the owner of the vessel (NOP); the vessel is small (SM) – defined as less than 5 and 10 GRT, respectively, for the west and east coasts; the captain has a primary education (P); the captain has a secondary education (S) (none of the captains of the east coast vessels received a secondary education); and on the west coast, if the engine brand is any other than Yanmar (B).[11] The intercept δ_0 captures the case of a Malay captain, who owns and operates the vessel, did not participate in the training program, does not have a formal education, and has a Yanmar engine.[12] A random error term was

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[11] This gives 11 and 13 explanatory variables for east and west coast variables. In addition, all engine brands are Cumins on the east coast. On the west coast, 31 vessels had Yanmar engines, 1 had Cumins, and the remaining 8 used different (and unspecified) makes. For the west coast, the mean horsepower of Yanmar (non-Yanmar) engines is 18.15 (11.56) with a standard deviation of 6.92 (7.89) and the minimum is 4 (4) and the maximum is 24 (33). The distributions indicate that the engine brand dummy variable for non-Yanmar engines is capturing performance capabilities other than solely a smaller mean horsepower.

[12] Other variables, such as kinship ties between the captain and boat owner, could also be included in the inefficiency function but were excluded because of missing observations. The captain is the primary decision maker on the vessel (Alam, 1991; Firth, 1975). One way to introduce managerial ability or skipper skill is through fixed or random effects but this requires panel data and we are confined to cross-sectional data. Instead, we introduce skipper skill through the technical efficiency measure. Hence, the captain's human capital variables are assumed to affect production through the technical inefficiency. In the output-oriented technical efficiency approach, this corresponds to the ability to locate and catch fish (output) given the input bundle. This approach disembodies the

added to equation (2) for estimation, and both (1) and (2) were jointly estimated by maximum likelihood using frontier 4.1 (Coelli, 1996), under the behavioral hypothesis that fishers maximize expected profits (Zellner, Kmenta, and Dreze, 1966), as described in Coelli, Rao, and Battese (1998: 207–208).

The specification of technical inefficiency as unexpected and unknown, or as expected and foreseen, when the firm chooses its inputs affects the specification and estimation of the production function (Kumbhakar, 1987). Given the overwhelming importance of 'captain's skill' in locating and catching fish and the inherent stochastic effects from weather, temperature, and biological variations in fishing (Campbell, 1991), it is likely that technical inefficiency that is unforeseen is more important than the foreseen. The point is that technical inefficiency is likely to be never entirely foreseen or unforeseen, but, in fishing, technical inefficiency is more likely to be unexpected and unknown. Thus we specify the technical inefficiency as unexpected or unforeseen. Given unknown and unexpected technical inefficiency, the argument of expected profit maximization (Zellner, Kmenta, and Dreze, 1966) can be used to treat inputs as exogenous (Kumbhakar, 1987: 336). If technical inefficiency is known to the firm, estimates of the production function parameters obtained directly from the profit function will be inconsistent.

Several hypotheses about the model can be tested using generalized likelihood ratio tests. The first null hypothesis is whether or not technical inefficiency effects are absent ($\sigma_U^2 = 0$). This test is performed against the full translog stochastic frontier given in equation (1). This null hypothesis is specified as $\gamma = 0$, where $\gamma = \sigma_U^2/(\sigma_V^2 + \sigma_U^2)$ and lies between 0 and 1. If we fail to reject the null hypothesis, H_0: $\gamma = 0$, then the U_i term should be removed from the model (Battese and Coelli, 1995) and the stochastic production frontier is rejected in favor of ordinary least squares estimation of the average production function in which the explanatory variables in technical inefficiency function (Z_i) are included in the production function.[13]

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managerial input or 'skipper skill' from the skipper's own contribution to labor power (captured in crew size). To account for inter-vessel differences the best we can, we introduce a small vessel size class dummy into the technical inefficiency equation. Because vessels on the west coast are smaller than those on the east coast, the small vessel dummy for west coast vessels corresponds to smaller vessels than on the east coast.

[13] Any generalized likelihood ratio statistic associated with a null hypothesis involving the γ parameter has a mixed χ^2 distribution because the restriction defines a point on the boundary of the parameter space (Coelli, 1996). The critical values are given in table 1 of Kodde and Palm (1986). The number of restrictions, and hence the degrees of freedom for the null hypothesis $\gamma = 0$, is the difference in the number of parameters in the test of the OLS model versus the stochastic production frontier, equal to 1 for γ, 1 for μ with the truncated normal (associated with δ_0, the intercept of the technical inefficiency function) plus the number of terms in the technical inefficiency function, excepting δ_0, which would not enter the traditional mean response function (Battese and Coelli, 1995, footnote 6). In this case, all variables in Z, except δ_0, would enter the translog production function as control variables, so that the degrees of freedom for H_0: $\gamma = 0$ is two.

The second null hypothesis is whether or not the functional form of the stochastic production frontier, equation (1), is Cobb–Douglas form. This null hypothesis, which is tested against the full translog form, is H_0: $\alpha_6 = \alpha_7 = \ldots = \alpha_{15} = 0$ in equation (1), i.e., all of the input interaction and second-order terms equal 0. There are 10 degrees of freedom, since there are ten independent restrictions. The third null hypothesis is whether or not the technical inefficiency function, equation (2), is influenced by the level of explanatory variables, and is tested with the final form of the stochastic production frontier (i.e., against either the translog or Cobb–Douglas). Under the assumption that the inefficiency effects are distributed as a truncated normal, the null hypothesis is that the matrix of parameters, excluding the intercept term δ_0, is null such that, H_0: $\delta_1 = \delta_2 = \ldots = \delta_{13} = 0$.

3.1. Data

The cross-sectional data used in the study were collected in 1988 using a multi-stage sampling procedure. The first stage of the sampling selected the states and the districts within the states where the fishers would be sampled and the second stage selected gill net fisheries within states where the sampling took place. The first stage used the *Annual Fisheries Statistics* of the Department of Fisheries, Malaysia, which provides statistics on landings of marine fish, number of licensed fishing boats and gears, number of fishers, and a host of other related information by fisheries districts, states, and fishing gears. Based on the criteria of gear concentration and their contribution to fisheries production and revenue, the states selected were Terengganu and Pahang from the east coast and Johor, Perak, Kedah, and Perlis from the west coast. The fisheries districts within the states were also chosen based on the same criteria.[14]

In the second stage, vessels were randomly selected from lists of licensed gill net vessels obtained from the Department of Fisheries and the fisher cooperative associations. After pretesting the questionnaire, vessel owners were interviewed and provided information on one month's fishing activity. The data were collected during the period from August to October, 1988.

All variables are self-reported. Moreover, data on artisanal fisheries are very difficult to obtain due to the great isolation of many villages and hamlets. This difficulty, coupled with the absence of formal record keeping by artisanal fishers, precludes data requests for periods of time longer than about a month or from very far in the past. Ideally, artisanal fisheries would be repeatedly sampled, but these types of data collection programs are very rare. Alam (1991) provides further details about the data and sampling procedure. The 40 west coast fishers came from the states of Perak (15 fishers), Kedah (10 fishers), and Perlis (15 fishers) while the 42 east coast fishers came from the states of Terengganu (23 fishers), East Johor (10 fishers), and Pahang (9 fishers).

Summary statistics of the data, reported in table 1, indicate that the

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[14] The selected fisheries districts from the east and west coast are available upon request.

Table 1. *Summary statistics of the data*

Vessel and fishing characteristics	*Mean*	*St. dev.*	*Minimum*	*Maximum*
East coast				
Hull length (meters)	12.17	1.82	8	15
Gross registered tons	10.57	3.62	3	18
Engine horsepower	25.79	8.87	8	37
Length of net (meters)	712.07	318.14	250	1,400
Mesh size (meters)	0.0987	0.0086	0.06	0.11
Remaining economic life: hull (yrs)	18.57	2.87	13	25
Remaining economic life: engine (yrs)	15.62	3.81	10	25
Remaining economic life: net (yrs)	6.83	1.73	4	10
Years of ownership: hull	8.12	3.96	0	18
Years of ownership: engine	7.10	2.86	1	14
Years of ownership: net	4.93	2.35	2	10
No. of fishing trips per month	19.14	5.16	7	25
Total fishing days per month	21.83	2.59	15	25
Trip duration (days) per month	1.14	5.70	1	3
Hauls of net per day	1.95	0.82	1	4
GRT-days per month	233.03	86.35	54	375
Labor-days per month	69.86	18.10	30	100
Net-haul-days per month	29,018.43	18,560.5	7,500	86,400
Operating distance (nautical miles)	9.57	5.12	3	20
Crew size (including captain)	3.17	0.62	2	4
GRT-crew size (capital–labor) ratio	3.31	0.87	1.50	5.33
GRT-crew size ratio vessels $<$ 10 GRT	2.60	0.58	1.50	3.50
Catch of all species per month (kg)	2,177.36	484.32	1190	3,165
Revenue of all species per month (M$)	387,591	79,628	213,900	541,260
Family size of captain	7	2.35	3	13
Fishing experience of captain (years)	22.67	7.49	10	35
Number of total observations	42			
Number of captains with training	3	(7%)		
Number of Malay captains	5	(12%)		
Number of Chinese captains	37	(88%)		
Number of owner-operators	34	(81%)		
Number of non-owner-operators	8	(19%)		
Number of respondents with:				
No schooling	9	(21%)		
Primary schooling	33	(79%)		
Secondary schooling	0	(0%)		
Number of vessels $<$ 10 GRT	17	(40%)		
West coast				
Hull length (meters)	10.50	1.83	7	13
Gross registered tons	6.33	3.01	2	15
Engine horsepower	17.35	7.81	4	36
Length of net (meters)	586.10	297.61	200	1200
Mesh size (meters)	0.0881	0.0189	0.06	0.11
Remaining economic life: hull (yrs)	17.53	1.93	15	21
Remaining economic life: engine (yrs)	12.50	2.48	8	18
Remaining economic life: net (yrs)	8.43	1.65	6	12
Years of ownership: hull	5.93	3.02	1	12
Years of ownership: engine	4.65	2.96	0	13
Years of ownership: net	3.00	1.99	0	7

Table 1. *Summary statistics of the data (continued)*

Vessel and fishing characteristics	*Mean*	*St. dev.*	*Minimum*	*Maximum*
No. of fishing trips per month	17.43	4.91	7	26
Total fishing days per month	21.68	3.16	15	27
Trip duration (days) per month	1.24	3.97	1	3
Hauls of net per day	3.23	0.73	1	4
GRT-days per month	133.65	61.55	40	300
Labor-days per month	53.43	14.74	30	81
Net-haul-days per month	38,561.6	18,820.8	14,400	100,800
Operating distance (nautical miles)	5.33	3.03	2	14
Crew size (including captain)	2.45	0.50	2	4
GRT-crew size (capital–labor) ratio	2.70	1.51	0.67	7.50
GRT-crew size ratio vessels $<$ 5 GRT	1.21	0.43	0.67	2.00
Catch of all species per month (kg)	819.35	256.66	478	1,620
Revenue of all species per month (M$)	175,757	52,584	82,835	310,350
Family size of captain	5.80	2.15	2	12
Fishing experience of captain (years)	14.40	7.09	3	33
Number of total observations	40			
Number of captains with training	5	(12%)		
Number of Malay captains	14	(35%)		
Number of Chinese captains	26	(65%)		
Number of owner-operators	31	(77%)		
Number of non-owner-operators	9	(22%)		
Number of respondents with:				
No schooling	2	(5%)		
Primary schooling	31	(77%)		
Secondary schooling	7	(18%)		
Number of vessels $<$ 5 GRT	11	(28%)		

Notes: 1. GRT-days is number of days at sea per month multiplied by GRT of vessel.
2. Labor-days is number of days at sea per month multiplied by crew size.
3. Net-haul-days is number of days at sea per month multiplied by net size and number of hauls per day.
Source: Alam (1991).

vessels used in the fishery are relatively small, with mean lengths of 10–12 meters, and that the captains on both coasts have considerable fishing experience. Compared to west coast vessels, east coast vessels are longer with larger GRTs and engine power, possess larger nets, operate further from shore, have larger crews, catch more fish, have larger revenues, and are more capital-intensive as measured by a larger capital–labor (GRT/fisher) ratio. This larger scale of operation reflects the larger and deeper South China Sea, the existence of fewer estuaries and coastal wetlands and sandier ocean bottom in comparison to the Straits of Malacca, and greater severity of monsoons. East coast vessel hulls, engines, and nets also have longer expected remaining economic lives than those of the west coast. West coast vessels make more frequent hauls of their shorter nets per day than do east coast vessels and tend to fish closer to shore and use smaller mesh sizes, thereby catching smaller fish. Both east and west coast vessels, however, fish about the same number of days per month. A greater proportion of east coast skippers are Chinese, rather than Malay, have larger families, have more years of fishing experience, but have fewer years of formal education. About the same proportion of captains are owner-operators on the west and east coasts.

4. Empirical results

The hypotheses about the model are tested using generalized likelihood ratio tests which are summarized in table 2. The hypothesis tests indicate that for both coasts, at the 1 per cent level of significance: (1) the stochastic production frontier is appropriate (H_0: $\gamma = 0$ is rejected); (2) the translog functional form is suitable for the stochastic production frontier (H_0: $\alpha_6 = \alpha_7 = \ldots = \alpha_{15} = 0$, i.e., the Cobb–Douglas functional form, is rejected); and (3), the technical inefficiency function depends on the vector of explanatory variables (H_0: $\delta_1 = \delta_2 = \ldots = \delta_M = 0$ is rejected).[15] Parameter estimates of the final form of the stochastic production frontier, equation (1), are reported in table 3.

Table 2. *Generalized likelihood ratio tests of hypotheses of the parameters of the stochastic frontier production function and technical inefficiency function*

Null hypothesis	*Likelihood ratio*	*df*	*Critical value (5%)*	*Critical value (1%)*
East coast				
1. $\gamma = 0$ (No stochastic frontier)	62.309	2	5.138	8.273
2. $\alpha_6 = \alpha_7 = \ldots = \alpha_{15} = 0$ (Cobb–Douglas frontier)	58.199	10	18.307	23.209
3. $\delta_1 = \delta_2 = \ldots = \delta_{11} = 0$ (No technical inefficiency fn.)	56.114	11	19.675	24.725
West coast				
1. $\gamma = 0$ (No stochastic frontier)	30.179	2	5.138	8.273
2. $\alpha_6 = \alpha_7 = \ldots = \alpha_{15} = 0$ (Cobb–Douglas frontier)	30.913	10	18.307	23.209
3. $\delta_1 = \delta_2 = \ldots = \delta_{13} = 0$ (No technical inefficiency fn.)	30.099	13	22.362	27.688

Notes: 1. Test for $\gamma = 0$ follows mixed chi-square distribution with critical values found in table 1 of Kodde and Palm (1986).
2. Df = degrees of freedom.
3. A truncated normal distribution is assumed for the technical inefficiency error term.

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[15] Not including an intercept parameter (δ_0) in the mean ($Z\,\delta$) may result in the estimators of the δ-parameters, associated with the Z variables, being biased and the shape of the distributions of the inefficiency effects, U, being unnecessarily restricted (Battese and Coelli, 1995). Battese and Coelli note that when the Z vector has the value 1 and the coefficients of all other elements of Z are 0, Stevenson's (1980) model is represented. The intercept δ_0 in the technical inefficiency function will have the same interpretation as the μ parameter of Stevenson's model (Coelli, 1996). The null hypothesis combining null hypotheses one and three into a single null hypothesis, given the translog stochastic produc-

Table 3. *Parameter estimates of the stochastic production frontier*

	East coast			*West coast*		
Variables	*Coefficient*	*Std. error*	*t-ratio*	*Coefficient*	*Std. error*	*t-ratio*
Intercept	10.5913	0.9057	11.694	12.7098	0.9746	13.040
$\ln K$	5.0371	0.9200	5.475	4.7873	1.0054	4.761
$\ln L$	−4,7997	0.8222	−5.838	−7.4008	0.8621	−8.584
$\ln T$	2.0509	0.8557	2.397	−3,5336	9,9736	−3.629
$\ln N$	−2.4563	0.8818	−2.785	1.2196	0.7266	1.678
$\ln OD$	0.6650	0.1533	4.337	−0.2487	0.1298	−1.916
$\ln K^2$	−0.4395	0.4154	−1.058	0.7444	0.2266	3.286
$\ln L^2$	−1.2599	0.1821	−6.918	−0.2749	0.3955	−0.695
$\ln T^2$	−0.1317	0.0814	−1.617	−0.5990	0.1556	−3.849
$\ln N^2$	−0.9716	0.4107	−2,366	−0.5460	0.2408	−2.268
$\ln K^* \ln L$	0.1949	0.2175	0.896	−1.3288	0.3558	−3.734
$\ln K^* \ln T$	−1.0061	0.2573	−3.910	0.4441	0.2747	1.617
$\ln K^* \ln N$	0.9470	0.3625	2.612	0.5746	0.4867	1.181
$\ln L^* \ln T$	1.6993	0.3055	5.562	0.2487	0.2304	1.080
$\ln L^* \ln N$	−0.0108	0.0910	−0.118	1.2194	0.3344	3.647
$\ln T^* \ln N$	0.0464	0.0463	1.069	0.0950	0.0696	1.364
σ^2	0.0491	0.0139	2.997	0.0127	0.0042	3.009
γ	0.9999	0.0001	24340.6	0.3380	0.1372	2.464
log-likelihood	47.5686			37.1789		
No. of observations	42			40		

Notes: 1. K = GRT-days (tens), L = labor-days, N = net-haul days (hundreds), T = no. of trips, OD = operating distance from shore.
2. Translog functional form.

Parameter estimates of flexible functional forms by themselves convey little meaning. However, the first-order variable *OD* (operating distance from shore) does not have any interaction terms, so that its parameter estimates are more meaningful. On the east coast, *OD* had a positive and clearly statistically significant estimated coefficient, but, on the west coast, *OD* has a negative and marginally statistically significant estimated coefficient. One possible explanation is that on the west coast, shrimp form a much more important component of the catch and are found close to shore, so that fishing farther from shore reduces catch. On the east coast, fewer nutrients reach inshore waters, the bottom is sandier, reefs are found farther offshore, and most of the catch is comprised of small pelagic species of fish, which can be found farther offshore than shrimp on the west coast.

The distribution of technical efficiency scores, relative to the best-practice frontier scores and reported in table 4, is similar for both coasts.

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tion frontier and truncated normal, is rejected for both coasts (1 per cent critical values are 27.026 with 13 degrees of freedom on the east coast and 29.927 with 15 degrees of freedom on the west coast). In addition, on the east coast, $\gamma = 0.9999$ with a standard error of 0.0001 (table 3) indicates that the vast majority of residual variation is due to the inefficiency effect, U, and that the random error, V, is almost 0, while on the west coast, $\gamma = 0.3380$ with a standard error of 0.1372 indicates that random error is relatively more important.

Table 4. *Frequency distribution of technical efficiency scores*

					Captain training		*Captain education*			*Owner-operator*		*Small vessel*		*Mean years of expected life*			*Yanmar Engine*	*Capital–labor ratio*		
Range	*Total*	*Malay*	*Chinese*	*Mean fishing experience*	*Yes*	*No*	*None*	*Primary*	*Secondary*	*Yes*	*No*	*Yes*	*No*	*Hull*	*Engine*	*Net*	*Yes*	*Mean*	*Min*	*Max*
East coast																				
0.90–0.99	21	3	18	23.76	2	19	2	19	0	17	4	10	1	19.44	16.67	7.71		3.33	1.50	5.33
0.80–0.89	6	0	6	18.67	1	5	2	4	0	4	2	3	3	18.17	16.83	5.83		3.28	2.50	4.00
0.70–0.79	5	0	5	23.00	0	5	1	4	0	5	0	0	5	17.60	15.40	5.40		3.93	3.00	4.67
0.60–0.69	2	1	1	24.50	0	2	1	1	0	2	0	1	1	22.50	12.50	6.50		3.00	2.67	3.33
0.50–0.59	8	1	7	21.13	0	8	3	5	0	6	2	1	7	17.00	12.88	6.25		3.56	2.00	4.50
Mean: 0.84 Minimum: 0.50 Maximum: 0.99																				
West coast																				
0.90–0.99	21	5	16	9.76	1	20	2	12	7	16	5	6	15	17.3	12.8	8.8	15	2.43	1.00	7.50
0.80–0.89	9	3	6	21.11	2	7	0	9	0	8	1	2	7	17.8	12.4	8.78	7	2.75	1.00	4.50
0.70–0.79	5	4	1	18.80	0	5	0	5	0	4	1	1	4	16.8	11.2	7.0	4	4.30	3.50	5.50
0.60–0.69	4	2	2	16.25	1	3	0	4	0	4	0	1	3	18.8	13.0	7.50	4	2.89	0.67	3.31
0.50–0.59	1	0	1	10.00	1	0	0	1	0	1	0	1	0	18.0	11.0	8.00	1	2.22	2.22	2.22
Mean: 0.88 Minimum: 0.57 Maximum: 0.99																				

Notes: 1. Measures are in terms of efficiency and not inefficiency.
2. Small vessels < 5 gross registered tons.
3. Fishing experience of captain in years.
4. Capital–labor ratio is GRT/fisher.

Technical efficiency scores are skewed towards higher levels of efficiency, where a score of 1.0 lies on the frontier, with concentrations in the 80th and 90th percentiles for both east and west coast vessels. Only a limited number of vessels display substantially lower levels of technical efficiency. The arithmetic means of the individual technical efficiency scores are 0.84 and 0.88 for the east and west coasts, and are somewhat higher than those generally found from stochastic frontiers for developing country agriculture (Ali and Byerlee, 1991; Bravo-Ureta and Pinheiro, 1994: table 1). The comparatively high level of technical efficiency is consistent with Schultz's (1964) thesis of 'poor and efficient' smallholders and peasants in developing country agriculture. In sum, the vast majority of the artisanal fishers have high levels of technical efficiency and face limited scope for technical efficiency gains, given the state of their technology and resource conditions.

The factors affecting technical inefficiency can be analyzed by the magnitude, algebraic sign, and significance of the estimated coefficients in equation (2), the technical inefficiency function, reported in table 5. The dependent variable is technical inefficiency as opposed to technical efficiency, so that a negative sign indicates a *decrease* in technical inefficiency or an *increase* in technical efficiency. These results are summarized into three broad areas: the expected life or vintage of the capital stock, the characteristics of the captain, and vessel ownership.

4.1. Vintage of capital stock

A vessel of an older vintage, embodying an older state of technology (construction material, hull design, size, configuration for sail or engine), may preclude that vessel from employing best-practice techniques of production, determined in part by the best-practice technology. To capture the effects of capital vintage for the hull, the estimated remaining economic life, in years, for the hull (*EXLIH*) was introduced in equation (2), where a longer remaining economic life is taken to represent a newer capital vintage.[16] Similar 'vintage' variables were included for the engine (*EXLIE*) and net (*EXLIN*).[17]

The variables *EXLIH* and *EXLIN* are statistically significant on the west coast, but only *EXLIE* is significant for the east coast (table 5). The positive sign for the *EXLIH* on the west coast is contrary to expectations and suggests

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[16] A newer vessel, engine, or net might also be in a better state of repair and maintenance, which could also increase its efficiency. In addition, in view of the complexities involved in obtaining information on the year of first purchase or construction of second-hand vessels, their actual age could not be assessed. Instead, estimated remaining economic life for the asset was chosen. The number of years that the asset has been owned by the present owner was available, but economic life was deemed a more reliable indicator of capital vintage.

[17] A new vessel does not directly contribute to the catch but increases seaworthiness, especially when the seas are rough such as during the monsoon (Bailey, 1983). New vessels also tend to be faster and require less general maintenance. Nets catch the fish. The relative condition of the net affects catch rates; netting in a poor state of repair may have gaping holes and thread so weakened by age that even a small fish may be able to free itself.

Table 5. *Estimated technical inefficiency function*

	East coast			*West coast*		
Variable	*Coefficient*	*St. error*	*t-ratio*	*Coefficient*	*St. error*	*t-ratio*
Intercept α_0	4.1338	0.7067	5.849	−0.6221	0.4441	−1.401
Remaining economic life: hull (years) (EXLIH)	−0.0261	0.0277	−0.939	0.0472	0.0169	2.788
Remaining economic life: engine (years) (EXLIE)	−0.0981	0.0262	−3.744	0.0273	0.0165	1.682
Remaining economic life: net (years) (EXLIN)	−0.0366	0.0479	−0.765	−0.0711	0.0259	−2.747
Fishing experience (years) (FEXP)	−0.0254	0.0110	−2.306	0.0107	0.00656	1.637
Mesh size (meters) (MESH)	0.4247	0.9968	0.426	0.3972	0.9859	0.403
Family size of captain (persons) (FSIZE)	−0.0766	0.0363	−2.133	−0.0333	0.0220	−1.510
Dummy variables for:						
Chinese capitain (D_{CH})	−0.4335	0.2264	−1.915	−0.2546	0.0981	−2.595
Non-owner-operator (D_{NOP})	−0.0847	0.2296	−0.368	0.0224	0.0828	0.271
Captain training (D_{CT})	−0.4763	0.4856	−0.981	0.4024	0.1244	3.235
Small vessel (D_{SM})	−0.5088	0.1754	−2.901	0.2531	0.1304	1.941
Primary education captain (D_P)	−0.4887	0.1511	−3.235	0.2545	0.2054	1.239
Secondary education captain (D_S)	–	–	–	1.1105	0.2694	0.410
Non-Yanmar brand of engine (D_B)	–	–	–	−0.2329	0.0930	−2.580

Notes: 1. Estimated coefficients from a truncated normal distribution for technical inefficiency error term and translog stochastic production frontier.
2. Coefficients obtained from estimation of equation (2) where technical inefficiency is the dependent variable.
3. Small vessel: < 5 GRT on west and < 10 GRT on east coast.

that an increase in economic life of the vessel hulls *decreases* efficiency.[18] One possible explanation is that in the artisanal gill net fisheries, a learning period may be required to master a new vessel and utilize its capabilities to its fullest extent. All coefficient values are, however, comparatively small, suggesting that those variables which are significant, minimally affect efficiency.

4.2. Technical inefficiency and human capital

The captain's fishing skill is often considered to be an important determinant of a vessel's catch and efficiency. Technical inefficiency can be related to characteristics of captains, which comprise the components of a captain's human capital in equation (2).

4.2.1. Ethnicity of captain

Ethnicity of captains may explain different fishing practices and variations in efficiency across vessels. Each ethnic group is more likely to have crews of its own ethnic group. The dummy variable for Chinese ethnicity (D_{CH}) in equation (2) was not significant for the east coast, but was negative and significant for the west coast, indicating that Chinese skippers *increased* efficiency on the west coast but not east coast vessels (table 5).[19]

4.2.2. Fishing experience of captains

Fishing experience of captains often provides better knowledge about the location of fish, weather patterns, currents and tides, bottom conditions, and how to best catch the fish. The variable for years of fishing experience (*FEXP*) was insignificant on the west coast, but negative and significant on the east coast (table 5) which indicates greater experience *increases* efficiency. East coast fishers travel further out to sea in more difficult conditions and in larger boats, so that the captain's expertise may play a more important role than in the west coast, where most fishing is much more confined to estuaries, river mouths, and nearshore fishing grounds.

4.2.3. Formal education of the captain

Additional schooling can improve literacy and cognitive skills which may reduce technical inefficiency by increasing the ability of captains to adopt technical innovations. Dummy variables for a captain's formal primary (D_P) and secondary (D_S) education were, however, both insignificant on the west coast, but D_P for the east coast (no fishers in the sample had secondary education on

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[18] These results could reflect measurement error of estimated remaining economic life. Maintenance could also differ by age but not be accounted for in the sample. Newer vessels could also incorporate experiments or innovations in hull design that actually inhibit inefficiency. The same result of an unexpected algebraic sign was found for auxiliary regressions when years of ownership was substituted for expected remaining economic life, providing some evidence for measurement error.

[19] The results might reflect the proportion of Chinese skippers in the sample. On the east coast, 37/42 of the skippers are Chinese (which is disproportionate to the population) but west coast the numbers are more even.

the east coast) was negative and significant (table 5). Thus, education appears not to affect efficiency of fishers on the west coast, but does *increase* technical efficiency on the east coast.[20] The differences may be explained by the relative isolation and lack of infrastructure on the east coast, where primary schooling may offer one of the few opportunities to learn skills what may be more readily learnt by fishers on the west coast outside of formal schooling.

4.2.4. Participation of captains in training programs

The Malaysian government has implemented a number of training programs for fishers to improve efficiency and increase incomes (Ishak, 1994). The dummy variable for captain's training (D_{CT}) is insignificant for the east coast but is positive, comparatively large, and significant on the west coast (table 5), indicating a *reduction* in efficiency.[21] The contrary result on the west coast may be due to the lack of participation of the most successful captains in training programs, and thus the real impact of fisher training may be disguised. Whatever the reason, the results do not provide evidence that participation in training programs by captains increases technical efficiency.

4.2.5. Captains' family size

The size of a fisher's family may provide information on an individual fisher's characteristics, including income and access to family labor. Family size (*FSIZE*) does not significantly affect efficiency on the west coast, but is negative and significant on the east coast, suggesting that an increase in family size *increases* efficiency (table 5). On the more isolated east coast, a larger family may provide fishing captains with greater flexibility as to when to fish, while crew who are family members may work more cooperatively and exert greater effort when fishing.

4.3. Technical inefficiency and vessel ownership

Both owning and operating a vessel can affect incentives. The non-owner-operator dummy variable (D_{NOP}) is insignificant in explaining differences in technical inefficiency for both coasts (table 5). Thus, Marshallian disincentives sometimes attributed to share contracts in agriculture do not appear to exist in the Malaysian gillnet fishery.[22]

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[20] The limited range of captains' formal education (few captains received secondary education on the west coast and no fishers on the east coast) may also affect the results.

[21] The training program might also be inappropriate. The fishers might require a more hands-on, rather than a government training program. Fishers have considerable local knowledge of conditions, and networks of fishing information are often only developed on the job.

[22] A non-owner captain operating in marine fisheries has avenues to demonstrate behavior contrasting to that found in agriculture. For example, unreported or illegal sales of fish caught can be made at sea. In addition, the percentage of owner-operators is quite high on both coasts (81 per cent and 77 per cent on the east and west coasts, respectively), which could affect the results.

4.4. Technical inefficiency and vessel size

The relationship between inefficiency and farm size has received considerable attention in the agricultural and development economics literature (Barrett, 1996 and Bravo-Ureta and Pinheiro, 1993 give recent surveys), but the comparable relationship between inefficiency and vessel size in the fisheries and development economics literature remains unexamined. The regressions indicate that in the Malaysian gillnet fishery the small vessel dummy variable (D_{SM}) was insignificant for the west coast, but was significant and negative for the east coast (table 5). Thus on the east coast, smaller vessels are more technically efficient than larger vessels.

The result may, in part, be attributed to differences in the fuel used, crew and mesh sizes, and resource abundance across vessel-size classes. Operating larger vessels, but with the same gear, may also impose coordination costs which may reduce technical efficiency. The results do not, however, suggest that efficiency changes with the level of capitalization, as defined by the capital/labor (GRT/fisher) ratio. Although the capital–labor ratio is higher on the east than the west coast, it is lower on both coasts for the small vessel size class (table 1) and does not appear to be related to the level of technical inefficiency (table 4).

4.5. Technical inefficiency and engine brand

The dummy variable for engine brands other than Yanmar on the west coast (D_B) is negative, significant, and comparatively large. Engines other than Yanmar *increase* efficiency. Data limitations prevent further investigation of how the brand of engine affects efficiency and whether it is a proxy for other variables.

4.6. Differences between coasts

Important differences exist in the variables that affect technical inefficiency on the two coasts. Individual characteristics of captains – proxies of human capital, appear to be more important on the more isolated and less-developed east coast while vessel characteristics – proxies of physical capital, appear to be more important in explaining differences in technical efficiency on the west coast. On neither coast, however, do fisher training programs provide a positive and significant impact in terms of technical efficiency. The differences imply that a uniform and national fisheries development strategy is likely to be much less successful than targeted regional or local development strategies.

5. Policy implications

The results suggest that, paradoxically, the most preferred form of assistance to artisanal fishing communities may be to redirect aid and development efforts away from the fishing and the harvesting sector. Short of completely transforming the fishery with a different method of harvesting fish, development strategies that focus on upgrading the vessel, engine, and gear and training fishers may provide few or no benefits in raising efficiency. This result goes beyond the existing literature which stresses the negative consequences of increasing harvesting in overfished artisanal fisheries (Smith, 1979) and the potential for technological change to affect traditional structures in communities (Lawson, 1984).

If the sustainable catch is fixed, improved technical efficiency is a benefit only if resources are freed from the catching sector for productive use elsewhere. Because there is a general labor surplus in the coastal areas, partly due to immobility, efficiency improvements may only generate widespread benefits if they are capital saving. Although no general relationship exists between the capital–labor ratio and efficiency on either coast, efficiency improvements may be capital saving for the smaller vessels on the least-developed east coast where smaller and older east coast vessels are more technically efficient.[23] To the extent that results from the Malaysian gillnet fishery can be generalized, the study suggests that greater levels of human capital (as proxied by formal education and fishing experience) may generate the greatest benefits in less-developed regions where education attainment is less and economic opportunities outside of fishing are fewer.

A strategy that redirects priorities away from technological innovation, capital formation, and improving efficiency in the harvest sector contrasts with the past development approaches in agriculture where technological innovations, such as the introduction of high-yielding varieties and mechanization, have traditionally been viewed as critically important to improving the welfare of farm households. In the case of agriculture, and in direct contrast to artisanal fisheries, the ‘poor and efficient’ hypothesis implies that raising the incomes of farm households can be effectively accomplished through technical innovation, capital formation, and raising efficiency without endangering the resource base.

6. Concluding remarks

Using individual vessel data from the artisanal Malaysian gill net fishery, the study finds that most fishers exhibit a high degree of technical efficiency. Moreover, the factors explaining efficiency significantly differ by region and overall level of economic development. For instance, in the poorer and less-developed east coast, primary schooling of the skipper, smaller vessel size, and larger family size significantly increase technical efficiency, but this is not true for the west coast. If these results hold true in other artisanal fisheries with similar technology and environments, it would suggest that South East Asian gill net fishers are ‘poor and efficient’, but the factors that contribute to technical efficiency differ considerably by locality.

The potential implications from our findings is that development projects targeted to artisanal fisheries must be locally based and tailor made by region rather than a broad and ‘one size fits all’ approach to fisheries development. Further, the results suggest that targeted assistance to human and social capital and away from vessel and gear upgrades, may yield greater efficiency payoffs for artisanal fishers. Further, if the relatively high levels of technical efficiency found in the Malaysian gill net

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[23] Selectively removing small vessels would save only a small amount of capital but might benefit the resource stock by lowering exploitation rates on the younger, sexually immature fish.

fishery exist in other artisanal fisheries, it suggests that targeted development assistance that has traditionally been focussed on the harvesting sector may be better directed to other priorities in artisanal fishing communities.

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