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Fishing Skill in Developing Country Fisheries: The Kedah, Malaysia Trawl Fishery

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Abstract *Fishing skill is perceived to play a crucial role in catching fish. The question arises for fishery managers as to whether or not there are observable and measurable attributes of the skipper or vessel that can be monitored and regulated to account for skipper skill and, hence, this source of fishing capacity. Equating technical efficiency with skipper skill, this paper evaluates technical efficiency and skipper skill in the Kedah, Malaysia, trawl fishery to address this issue.*

Key words Fisheries management, Malaysia, skipper skill, technical efficiency.

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Introduction

Two questions that persist in fisheries are the nature of fishing skill, or the skipper effect, and the importance of skipper skill for policies intended to give sustainable resource harvesting. Skipper skill, or vessel managerial ability, has most often been defined as the ability to consistently catch the most fish given the vessel, crew, and other inputs (Barth 1966; Palsson and Durenberger 1982; Thorlindsson 1988). This definition is precisely that of technical efficiency in fisheries (Kirkley, Squires, and Strand 1998; Squires and Kirkley 1999).

The ongoing and persistent debate about the nature of skipper skill, recently summarized by Russell and Alexander (1998) and Squires and Kirkley (1999), attests to the unsettled discussion and scope for further understanding within the literature about this topic. Thorlindsson (1988), in summarizing the anthropological literature on skipper skill, observed that there are two notions of skipper effect. First, numerous authors have argued that any skipper effect should be consistent, giving a relatively stable comparative ranking of fishing success across time (Barth 1966; Palsson and Durenberger 1982). Captains performing well in one season should perform well in the following season. Second, the skipper effect is based on the performance of individual skippers. This notion does not require a stable hierarchy of fishing success, but rather only a few noteworthy skippers with the catch more or less randomly distributed between the rest of the captains.

Several aspects of these two notions of skipper effect stand out in the literature. Barth (1966) stressed that the decision on where to search for fish in the Norwegian herring fishery is the first and most important decision affecting the size of the catch. Acheson (1981) identified three components of skipper skill: (*i*) the ability to accurately navigate to find the best grounds; (*ii*) good knowledge of the ocean, such as its currents, depths, and types of bottom; and (*iii*) good knowledge of the species of concern. Thorlindsson (1988) identified three additional components of fishing skill: (*i*) the ability to "read the sea" and its ecological environment; (*ii*) the willingness of the skipper to search independently and to take calculated risks, which is probably a function of many factors; and (*iii*) the ability of a skipper to lead and manage the crew. In short, good landings are often associated with the skipper's attributes, knowledge of the fishery resource and environment, and exploitative skills.

The economics, sociological, and anthropological literatures have, to a limited degree, empirically examined these factors affecting skipper skill. They have concentrated on measurable and quantifiable attributes of the skipper — measures of the skipper's human capital — because of the difficulties in measuring and even defining attributes of fishing skill itself. Data limitations have also played a role, since detailed and consistent knowledge of skipper behavior on a fishing trip is difficult to obtain. Palsson and Durrenberger (1982), in a qualitative analysis, did not find a relationship between skipper experience and catch rates (as opposed to technical efficiency). Acheson (1975), reporting the results from a regression analysis, indicated that skipper age was not a good surrogate variable for fishing skill, and that education was marginally statistically insignificant. Within the technical efficiency framework, Squires *et al*. (1998) with a stochastic production frontier examined attributes of the captain and vessel and their influence on the technical efficiency of artisanal gill net fisheries of the east and west coasts of Peninsular Malaysia. They found that skipper characteristics were generally insignificant variables in explaining technical inefficiency in both fisheries. For the US Pacific Coast groundfish trawl fishery, Squires and Kirkley (1999) with a panel data approach found, through a Hausman test, that inter-vessel differences in catch rates, interpreted as technical efficiency in a panel data framework, were not correlated with input usage, but were instead related to inter-vessel differences. They attributed this result to skipper skill related to finding fish, dealing with unforeseen events, and handling environmental conditions rather than managing the inputs.

The vast majority of the discussion about skipper effect or skipper skill has centered on North Atlantic fisheries. Far less attention has been given to skipper skill in the fisheries of developing countries. Firth (1975) and Squires *et al.* (1998) examined skipper skill in Malaysia, and Russell and Alexander (1998) examined skipper skill for the Philippines. Russell and Alexander (1998, p. 146) observed that in contrast to the fishing fleets of industrialized nations, advances in electronic fish finding gear, the large and variable size of boats, and sophisticated navigational equipment have partly diluted the comparative advantage of traditional fishing skills. They further observed that in some fleets of developing countries, technological advances have not been sufficient to dilute fishing skill independent of fishing technology variables.

The ongoing discussion about skipper skill and the lack of conclusive empirical evidence on it, suggests the need to further examine the role and significance of skippers in influencing fish landings, and thereby shed further light on the first of the two persistent questions in fisheries. Hence, addressing this need forms the first purpose of this paper. That is, this paper empirically evaluates the differences in skipper skill, defined as technical efficiency, across different vessels in a developing country fishery and statistically assesses whether any measurable socio-demographic attributes of the skipper or fishing master — measures of human capital — contribute to differences in skill.

The second question concerning fishing skill addressed in this paper arises in the following context. Fishing capacity will not be capped or reduced in a license limitation program to the extent that the production capabilities are related to fishing skill and not only to the directly observed and controllable inputs (Hilborn and Ledbetter 1979). Skipper managerial abilities are not directly observable and are beyond the control of fishery regulators. This fishery management problem arises in two ways with fishing skill, but is related to the idea of "latent capacity." First, the most capable skippers tend to remain in a fishery, where they can earn intra-marginal rents. When the resource stock and rents begin to rebound under effective fisheries regulation, the most capable skippers can expand their catches faster than other skippers through expansions in input usage. Second, the lower the technical efficiency and skipper skill of a vessel remaining in the fishery, the greater the potential to expand catch through learning-by-doing or by transfer of licenses to skippers with greater technical efficiency.

The question thus arises for fishery regulators as to the degree that a skipper's skill, measured as technical efficiency, accounts for maximum potential and actual catches. The more that skipper skill accounts for catch, as opposed to measurable inputs, such as the capital stock and fishing time, the more difficult the problem for a license limitation program to control the capital stock and its utilization and thereby attempt to cap fishing capacity.[1] An ancillary question is whether or not there are observable and measurable attributes of human or physical capital — the skipper or vessel — that fishery regulators can monitor and possibly regulate to control expansions in fishing capacity from this source. Hence, the second and final purpose of this paper is to assess the relative importance of skipper skill in the fishing process as it relates to limiting fishing capacity.

We address these two questions concerning skipper skill through a case study of

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[1] Fishing capacity can be defined as the maximum potential output (Kirkley and Squires 1999). In general, there is only a nonlinear relationship between the capital stock and catch unless there is only a single capital stock, all variable inputs are in fixed proportions to the single capital stock, there are constant returns to scale, and the resource stock is constant (Kirkley and Squires 1999).

the Kedah, Malaysia, trawl fishery. We evaluate skipper skill, defined as technical efficiency, through estimation of a stochastic production frontier along with a technical inefficiency function, the latter which is a function of socio-demographic attributes of the fishing master. The balance of the paper is organized as follows. The next section gives a background of the fishery. The following section specifies the empirical model, followed by discussion of the empirical results and their relation to the fishing skill literature. Skipper skill and license limitation are discussed next, and the last section provides concluding remarks.

The Kedah Trawl Fishery[2]

The fisheries of Peninsular Malaysia are highly diverse, comprising a multiplicity of species and gear types. The 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. Demersal fish account for about 30% of the total fish harvested in Peninsular Malaysia. The west coast fishing grounds are generally muddy and shallow, which facilitates dragging a trawl net on or near the ocean bottom. Trawlers and purse seiners together contributed 81% of total fish landings and 77% of total wholesale value in Peninsular Malaysia in 1996. Trawlers catch fish indiscriminately, with a highly variable species composition, of which about one-third may be “trash” fish.[3] Overfishing in inshore areas of the west coast has led to an increasing composition of “trash” fish in total landings, reducing marketable output over time.

The 1981 Fisheries Licensing Policy aims to protect artisanal fisheries and control fishing capacity through the area licensing program.[4] This regulation prohibits trawling within the five-mile limit and allocates fishing grounds by zones and types of gear; that is, by traditional versus commercial fishing gear and by vessel size. The zonal licensing scheme attempts to fairly allocate fishing grounds and resources between the highly efficient trawlers and purse seiners versus the less efficient traditional gear types. This scheme is also expected to reduce competition and conflict between the operators of the commercial and artisanal groups, especially over the highly valuable prawn resource, found in abundance in coastal waters.

Although the regulations have been imposed to manage fisheries, in practice noncompliance and incidence of encroachment by the large-scale vessels and even foreign operators into the prohibited fishing areas is common (Kuperan and Sutinen 1998; Susilowati 1998). The outcome of noncompliance with the zonal regulation is overfishing and conflicts over the resource bases. Noncompliance with the zoning regulation

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[2] This section draws from Ishak (1994); Ishak, *et al*. (1991); Jahara (1988); Kuperan (1992); Majid (1985); Ooi (1990); Susilowati (1998); Teo (1998); Vincent, Rozali, and Jahara (1997); and Abu Talib and Alias (1997).

[3] Trash fish include an assortment of juveniles of commercial and non-commercial species that are unsuitable for human consumption. Due to their small size, trash fish are processed into fishmeal and sold as animal feed or turned into fertilizer. Trash fish can also include species that are unwanted, such as finfish caught while harvesting prawns. These trash fish jointly harvested with prawns are often discarded at sea.

[4] Malaysian fisheries are divided into four zones (Abdullah and Kuperan 1997). Zone A, which covers all areas within 5 miles from the shoreline, is reserved for traditional fishing gear owners or operated by traditional fishers. Zone B, which covers waters beyond 5 miles to 12 miles from the shoreline, is reserved for vessels with either trawl or purse seine gear weighing less than 40 gross registered tons (GRT). Zone C, which covers waters beyond 12 miles to 30 miles from the shoreline, is reserved for trawlers and purse seiners weighing less than 40 GRT owned and operated by Malaysian fishers. Zone D, which covers waters beyond 30 miles, is reserved for fishing vessels weighing greater than 70 GRT, either totally or partially Malaysian owned.

poses a serious problem and undermines the effectiveness of fisheries management.

Fishing and fish availability are seasonal. Primary oceanic and secondary biological production do not demonstrate strong seasonal fluctuations in the tropics (Pauly and Navaluna 1983). However, the adverse weather of the monsoon season makes the fishing operation more difficult. Heavy rains, rough seas, and strong winds make transit to and from fishing grounds more difficult and complicate deploying and retrieving nets. The monsoon season can also alter the distribution and availability of nutrients and fish.

The trawl fishery of concern in this study covers the fishing locality of Kuala Kedah in the state of Kedah on the west coast of Peninsular Malaysia. Table 1 and portions of table 4 report summary statistics of this fishery from a 1995 representative sample capturing about 25% of the vessels (the data sampling process is discussed below). Vessels average 33 gross registered tons (GRT), with a substantial range, from 5 to 65 (table 1). Horsepower averages 276, also with a substantial range, from 50 to 400 (table 1). The number of men per boat averages just slightly fewer than 4, with a range from 2 to 8 (table 1). The larger vessels are fully capable of fishing in the farthest reaches of the Malaysian Extended Economic Zone, whereas the smaller vessels are confined to innermost waters. All vessels harvest throughout the year and throughout all seasons. Most vessels are home ported in Kuala Kedah, and the rest are scattered among Tangkang Yard, Komplek's LKIM (Lembaga Kemajuan Ikan Malaysia), Kampung Masjid Lama, and Kuala Sala (table 4).

Skippers are generally highly experienced, with a mean of 24-years of fishing experience and a mean age of almost 46 years (table 1). About 50% of the skippers are Malay, and about 50% are Chinese or other (table 4). About 50% of the skippers are owner operators (table 4). Their education is generally at the primary level.

Trip characteristics vary by season (table 1). In the peak season, vessels average a catch of about 1,587 kg from a trip of almost 18 hours. In the off-season, average catch declines to about 609 kg per trip of almost 21 hours. In the normal season, vessels average a catch per trip of 908 kg from a trip of almost 22 hours. In sum, the productivity or catch per unit effort increases from the normal to peak season, but declines from the normal to the off-season.

Empirical Model

A fishing vessel's technical efficiency is a measure of its ability to produce relative to the fleet's best-practice frontier, the maximum output possible from a given set of inputs and production technology (Aigner, Lovell, and Schmidt 1977; Meeusen and van den Broeck 1977). Technical inefficiency is the deviation of an individual vessel's production from this best-practice frontier. The estimated frontier is specified stochastic, because fishing is sensitive to random factors such as weather, resource availability, and environmental influences (Kirkley, Squires, and Strand 1995). The estimation takes the current state of technology, resource abundance and availability, regulatory structure, and open-access property rights regime as given. The stochastic frontier and technical efficiency results could alter under a different set of conditions. Hannesson (1983) estimated the first production frontier in fisheries, albeit a deterministic frontier.

The translog stochastic production frontier for firm or vessel i in time or season t, where symmetry conditions have been imposed, is specified by:

$$\ln Y_{it} = \alpha_0 + \alpha_1 \ln K_{it} + \alpha_2 \ln L_{it} + \alpha_3 \ln T_{it} + \alpha_4 \ln K_{it}^2 + \alpha_5 \ln L_{it}^2 + \alpha_6 \ln T_{it}^2 + \alpha_7 \ln K_{it} \ln L_{it} + \alpha_8 \ln K_{it} \ln T_{it} + \alpha_9 \ln L_{it} \ln T_{it} + \varepsilon. \quad (1)$$

Table 1
Summary Statistics of the Data

Vessel and Fishing Characteristic	Mean	Median	Maximum	Minimum	Standard Deviation
Location	1.52	1	5	1	
Years experience as fisher	24.22	25	50	8	8.05
Age (years)	45.73	45	76	19	8.17
Ethnic group	1.59	2	4	1	
Boat ownership	1.56	2	2	1	0.50
Vessel tonnage (GRT)	33.47	33	65	5	12.62
Horsepower	276.15	250	400	50	82.15
Schooling experience	1.06	1	2	1	
Household size (persons)	5.99	6	18	0	2.25
No. of family members working	2.25	2	14	0	2.26
No. of children schooling	1.91	2	6	0	1.50
Peak season					
No. of hours/trip	17.65	12.5	72	2	13.30
Average kg catch/trip	1,586.82	1,300	20,000	100	2,007.56
No. of men in boat/trip	3.94	4	6	2	0.88
Off season					
No. of hours/trip	20.59	14.5	70	6	15.02
Average kg catch/trip	608.53	325	3500	10	634.02
No. of men in boat/trip	3.98	4	8	2	0.96
Normal season					
No. of hours/trip	21.75	14	72	6.4	15.58
Average kg catch/trip	907.54	675	10,000	10	1,134.59
No. of men in boat/trip	3.94	4	6	2	0.88

Notes: Location = 1 if home port is Kuala Kedah and 2 if elsewhere in Kedah.
Ethnic group = 1 if vessel is skippered by Malay, 2 if by Chinese, 3 if by Indian, and 4 if by other.
Boat ownership = 1 if vessel is owner-operated and 2 otherwise.
Schooling experience = 1 if formal education and 2 if no formal education.
Household size, family members working, and children schooling pertain to the captain.

Y_{it} denotes total output (catch) in kilograms measured as the geometric mean of all species landed, where revenue shares serve as weights. The vessel capital stock (K_{it}) is a volumetric measure given by vessel GRT; labor (L_{it}) is the number of crew employed per vessel for a fishing trip, including the captain. The hours per trip (T_{it}) represents variable input usage (*e.g.*, diesel and/or gasoline, lubricant and/or oil, ice, and miscellaneous variable inputs), and can be viewed as an indicator of effort. In addition, to provide service flows of capital and labor, K_{it} and L_{it} are multiplied by trip time T_{it}. Thus, T_{it} enters the stochastic frontier in two different ways, both as a variable input or fishing effort and to convert stocks of capital and labor to service flows.[5]

[5] Campbell and Hand (1998) and Kirkley and Squires (1999) provide extensive discussions of the use of stocks and flows in specifications of inputs in fishery production functions. The use of flow variables has the potential to introduce multicollinearity into the regression results. When data on capital value are available, a preferred approach is to calculate the user cost of capital and then transform this into a flow variable by dividing the total capital value by the capital services price/user cost of capital.

The error term ε_{it} for vessel *i* in time *t* in equation (1) is defined as $\varepsilon_{it} = V_{it} - U_{it}$. The two-sided error term, V_{it}, 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_{it}, captures differences in technical inefficiency and is assumed to be an independently distributed non-negative random variable, such that U_{it} is the truncation of a normal distribution at zero, with mean $\mu_{it} = Z\delta$ and variance σ_U^2, $N(Z\delta, \sigma_U^2)$.[6] The one-sided, non-negative random variable, U_{it}, representing technical inefficiency, must be non-negative so that no firm can perform better than the best-practice frontier. The independent distribution of V_{it} and U_{it} allows the separation of noise and technical inefficiency. *Z* defines a (1xM) vector of explanatory variables associated with the technical inefficiency function, and δ is an (Mx1) vector of unknown parameters to be estimated (Battese and Coelli 1995).[7]

The technical inefficiency function, comprised of the vector of variables *Z*, is specified as a function of measurable socio-demographic attributes of the skippers—proxy variables for the skippers' human capital—along with measurable attributes of the crew, vessel, and indicators of seasons. The technical inefficiency function is specified as:

$$U_{it} = \delta_0 + \delta_1 EXP_{it} + \delta_2 HOUSEHOLD_{it} + \delta_3 CREW_{it} + \delta_4 D_{OWN} + \delta_5 D_{EDU} + \delta_6 D_{AREA} + \delta_7 D_{ETHNIC} + \delta_8 D_{OFF} + \delta_9 D_{PEAK} + \delta_{10} D_{SMALL} + \delta_{11} D_{LARGE} + W \qquad (2)$$

where EXP_{it} denotes the captain's years of fishing experience; $HOUSEHOLD_{it}$ denotes total household size (in persons, including the captain); and $CREW_{it}$ denotes number of persons per vessel (including captain).[8,9] The eight D terms are dummy variables equal to one when: (1) the operator does not own the vessel (OWN); (2) the captain has not received formal education (EDU); (3) the vessel is home-ported in Komplek's LKIM, Kampung Masjid Lama, Kuala Sala, or Tangkang Yard (AREA); (4) the captain is Chinese, Indian, or an ethnic group other than Malay (ETHNIC); (5) the vessel fishes in the off-monsoon season (OFF); (6) the vessel fishes in the peak season (PEAK); (7) the vessel is less than or equal to 15 GRT (SMALL); and (8) the vessel is greater than 50 GRT (LARGE). These eight dummy variables are defined for vessel *i* and do not vary over a year; *i.e.*, the assignment is

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[6] The truncated normal distribution was originally proposed by Stevenson (1980).

[7] Kumbhakar, Ghosh, and McGuckin (1991) and Reifschneider and Stevenson (1991) first noted the inconsistency between inefficiency effects if, in the first stage, the error is independently and identically distributed and the predicted inefficiency effects in the second stage are specified as a function of a number of firm-specific factors (which implies that they are not identically distributed unless all the coefficients of the factors are simultaneously equal to zero). The two-stage procedure is unlikely to provide estimates which are as efficient as those that are obtained from the one-step estimation procedure (Coelli 1996).

[8] Household size is included as a proxy variable to capture sociological impacts from family size. Household size, for example, may provide a motivating factor that influences trip length, catch size and composition, choice and numbers of crewmembers (some of whom may be included to fulfill familial obligations), and the like. Household size is expected to be directly related to technical inefficiency.

[9] Inclusion of crew size creates a stochastic production frontier that is non-neutral along the lines of Huang and Liu (1994) and Battese and Broca (1997), except that there are no interactions between the inputs of equation (1) and the vector Z of equation (2). The technical inefficiency effects, defined by equation (2), imply that shifts in the frontier for different firms depend, in part, on the levels of the input crew. In addition, we include crew (labor) as a continuous variable, exclude fishing time, and include large vessel size as dummy variables rather than with the same specifications as in equation (1), in order to reduce multicollinearity. In the stochastic frontier, equation (1), labor is specified as a service flow, since catch rates depend on the flow over time. However, in the technical inefficiency function, equation (2), we specify labor as a stock, since we are interested in the relationship between technical inefficiency and the stock of labor (number of crew).

constant. The seasonal dummy variables allow for seasonal variations in weather, ocean conditions, and resource availability. The intercept δ_0 captures the case of a trawl vessel: greater than 15 GRT but less than or equal to 50 GRT which is home-ported in Kuala Kedah; owned and operated by a Malay captain with formal education; and which fishes in the normal season. A random error term, W_{it},was added to equation (2) for estimation.[10]

Technical inefficiency for each firm *i* in season *t* is defined as the ratio of actual output to the potential frontier output. U_{it} is not directly observable, but Jondrow *et al.* (1982) found its expected value of U_{it} conditional on the value of $\varepsilon_{it} = V_{it} - U_{it}$, *i.e.*, $E(U_{it}|\varepsilon_{it})$. Technical efficiency for each firm is defined as $TE_{it} = \exp(-U_{it}) = \exp(-Z_{it}\delta - W_{it})$, where exp is the exponential operator (Battese and Coelli 1988). The range of technical efficiency for firm or vessel *i* in season *t* (TE_{it}) is $0 \leq TE_{it} \leq 1$, where $TE_{it} = 1$ represents the achievement of maximum output (adjusted for random fluctuations) for the given inputs, or 100% efficiency.

The elasticity of mean production with respect to the k^{th} input variable, denoted X_k, for the translog non-neutral stochastic production frontier is (Battese and Broca 1997):

$$\frac{\ln E(Y_{it})}{X_k} = \alpha_k + 2\alpha_{kk}X_{kit} + \sum_{jik} X_{jit} - C_{it}\left[\frac{\mu_{it}}{X_k}\right] \tag{3}$$

where:

$$\mu_{it} = \delta_0 + \delta_1 EXP_{it} + \delta_2 HOUSEHOLD_{it} + \delta_3 CREW_{it} + \delta_4 D_{OWN}$$
$$+ \delta_5 D_{EDU} + \delta_6 D_{AREA} + \delta_7 D_{ETHNIC} + \delta_8 D_{OFF} + \delta_9 D_{PEAK} + \delta_{10} D_{SMALL} + \delta_{11} D_{LARGE}$$

$$C_{it} = 1 - \frac{1}{\sigma}\left\{\frac{\phi[(\mu_{it}/\sigma) - \sigma]}{\Phi[(\mu_{it}/\sigma) - \sigma]} - \frac{\phi[\mu_{it}/\sigma]}{\Phi[\mu_{it}/\sigma]}\right\}$$

and ϕ and Φ represent the density and distribution functions of the standard normal random variable, respectively.

The elasticity of the mean output with respect to the k^{th} input in equation (3) has two components (Battese and Broca 1997). The first component, $\alpha_k + 2\alpha_{kk}X_{kit} + \Sigma_{j\neq k} X_{jit}$, is the traditional production elasticity of output with respect to the *k*th input, and is referred to as the elasticity of frontier output. The second component, $-C_{it}[\partial\mu_{it}/\partial X_k]$, is non-zero in the non-neutral inefficiency model and zero for the neutral stochastic frontier model. This component is called the elasticity of technical efficiency with respect to the k^{th} input.

The stochastic frontier, equation (1), and the technical inefficiency function, equation (2), were jointly estimated by maximum likelihood using Frontier 4.1 (Coelli 1996), under the behavioral hypothesis that fishers maximize expected prof-

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[10] In addition, there may be correlations between the explanatory variables of the frontier and the inefficiency effects, especially the continuous variables that appear in both equations. In this case, the maximum likelihood (ML) estimators of the parameters would not be consistent. However, the asymptotic properties of the ML estimators for this type of model are currently under investigation (Battese and Broca 1997, footnotes 1 and 4).

its (Zellner, Kmenta, and Dreze 1966).[11] Campbell (1991) makes this case for fisheries due to the stochastic nature of output and acts of nature. The frontier and inefficiency functions are estimated as panel data by the approach of Battesse and Coelli (1995), thereby allowing for firm-specific fixed effects between vessels.

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; *i.e.*, H_0: $\sigma_U^2 = 0$. 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. Non-rejection of the null hypothesis, H_0: $\gamma = 0$, indicates that the *U* term should be removed from the model. This result further indicates that the stochastic production frontier is rejected in favor of ordinary least squares estimation of the average production function in which the explanatory variables in the technical inefficiency function are included in the production function.[12] The second hypothesis is whether or not the functional form of the stochastic production frontier, equation (1), is Cobb Douglas. The null hypothesis is $\alpha_4 = \alpha_5 = \ldots = \alpha_9 = 0$ in equation (1). The third hypothesis is whether or not the technical inefficiency function, equation (2), is influenced by the level of explanatory variables. 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 α_0, is null such that $\alpha_1 = \alpha_2 = \ldots = \delta_{11} = 0$.[13]

As discussed above, one of the two important features of the notion of skipper skill stressed in the literature is the consistent performance of an individual skipper over time. To test whether the individual skipper effect or skill, interpreted as comparative ranking of technical efficiency, is consistent over time, we use the Wilcox matched-pairs signed ranks test to test the null hypothesis that the distributions of technical efficiency are the same for all three seasons. We also use the Mann-Whitney test for testing the null hypothesis that the two independent samples of technical efficiency scores pertaining to two different seasons are from populations with the same distribution.

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[11] 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, it is likely that technical inefficiency that is unforeseen is more important than the foreseen. The point is that technical inefficiency is likely to never be 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, p. 336). If technical inefficiency is known to the firm, estimates of the production function parameters obtained directly from the profit function will be inconsistent.

[12] Any generalized likelihood ratio statistic associated with a null hypothesis involving the γ parameter has a mixed chi-square 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 = 0, is the difference in the number of parameters in the test of the OLS model versus the stochastic production frontier, equal to one for one 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 log-linear control variables, so that the degrees of freedom for H_0: $\gamma = 0$ is two.

[13] Not including an intercept parameter (δ_0) in the mean (Z_i δ) 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_i, being unnecessarily restricted (Battese and Coelli 1995). Battese and Coelli (1995) 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 (1980) model (Coelli 1996).

Data

Multistage sampling was applied to obtain the 126 respondents. Fishers were stratified based on gear type, and the list of fishing vessels in the area was collected from the fisher cooperative unit office for 1994, the period of the study. The 126 trawl vessels in the sample were selected randomly from a population of 488 trawl vessels in Kedah. The sampling unit was the fisher with a decision-making role while at sea. In other words, he was the fishing master who decided whether or not to fish. Data were obtained for each vessel for the normal, off (monsoon), and peak seasons, giving a total of 378 observations and a balanced panel data set. Respondents were queried about a "typical" (*i.e.*, mean) fishing trip in the different fishing seasons in the preceding year.[14] The data were verified with a selected number of fishers by asking them if the figures provided are along the lines of values they consider appropriate. Peak season refers to the season when catches are usually high (above one standard deviation from the mean catch). Off-season refers to the months when catches are low (one standard deviation below the mean) due to monsoons. Normal season refers to the months when catches are around the mean catch for the year. Each ethnic group had the same understanding of season.

Undergraduate students in the Faculty of Economics and Management, Universiti Putra Malaysia conducted the in-person interviews. The interviewers were selected based on their working experience as an enumerator, subjects or courses taken in their undergraduate programs, and proficiency in the use of local dialect/language. Training was given to all enumerators before they undertook the survey. Susilowati (1998) provides additional discussion of the data collection process.

Empirical Results

The generalized likelihood ratio tests of the three null hypotheses, summarized in table 2, indicate that at the 1% level of significance: (1) the stochastic production frontier is appropriate for the sample of data (H_0: $\gamma = 0$ is rejected); (2) the translog functional form rather than the Cobb Douglas is selected for the stochastic production frontier (H_0: $\alpha_4 = \alpha_5 = \ldots = \alpha_9 = 0$ is rejected); and (3) the technical inefficiency function is comprised of the vector of explanatory variables (H_0: $\delta_1 = \delta_2 = \ldots = \delta_{11} = 0$ is rejected).

Parameter estimates of the final form of the stochastic production frontier, equation (1), are reported in table 3. The distribution of technical efficiency scores, relative to the best practice frontier scores, is reported in table 4 and figures 1 and 2. Figure 1 illustrates the technical efficiency scores for all vessels over all three seasons. Season and vessel or data management unit (DMU) is presented in figure 2. The top panel gives technical efficiency scores for the peak season, the middle panel gives scores for the off-season, and the bottom panel gives scores for the normal season. The scores for each vessel are vertically aligned in figure 2. Hence, the score for a vessel in the peak season lies directly above the score for a vessel in the off-season, and a vessel's scores for the peak and off-seasons are directly above that vessel's score for the normal season.

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[14] The use of recall data from a "typical" trip introduces both measurement error and heteroskedasticity to the extent that a "typical" trip represents a mean performance (which gives grouped data and hence heteroskedasticity). There is no obvious correction for any measurement error and likely heteroskedasticity given the current state of development of the stochastic production frontier.

Table 2
Generalized Likelihood Ratio Tests of Hypotheses for Parameters of the Stochastic Frontier Production Function and Technical Inefficiency Function

Null Hypothesis	Likelihood Ratio	df	Critical Value (5%)	Critical Value (1%)
1. $\gamma = 0$ (No stochastic frontier)	193.504	2	5.138	8.273
2. $\alpha = \alpha_5 = \ldots = \alpha_9 = 0$ (Cobb-Douglas frontier)	32.599	6	12.592	16.812
3. $\delta_1 = \delta_2 = \ldots = \delta_{11} = 0$ (No technical inefficiency fn.)	157.110	11	19.675	24.725

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 specified for the technical inefficiency error term.

Table 3
Parameter Estimates of the Stochastic Production Frontier

Variables	Parameter	Coefficient	Std. Error	t-Ratio
Intercept α_0	–0.81	0.32	–0.25	
ln *K*	α_1	1.75	1.30	1.35
ln *L*	α_2	6.50	2.49	2.61
ln *T*	α_3	–0.79	0.73	–1.08
ln K^2	α_4	–0.42	0.20	–2.13
ln L^2	α_5	–2.29	0.97	–2.37
ln T^2	α_6	0.31	0.09	3.55
ln *K** ln *L*	α_7	0.92	0.82	1.12
ln *K**ln *T*	α_8	0.28	0.23	1.25
ln *L**ln *T*	α_9	–1.26	0.34	–3.71
σ^2		0.94	0.18	5.22
γ		0.71	0.07	10.03
Log-likelihood			–0.428	
No. of observations		378		

Notes: 1. *K* = GRT (vessel tonnage); *L* = no. of men in boat/trip; *T* = no. of hours/trip.
2. Translog functional form.

Perhaps the most salient feature throughout the year is the wide range of technical efficiency, ranging from 0.01 to 0.95 (table 4, figure 1). The efficiency scores are distributed around the mean of 0.49, with, given the sample size of 378 observations, remarkably few vessels in the low and high score tails (figure 1). The mean of 0.49 across all three seasons is lower than that generally found from stochastic frontiers for developing country agriculture (Bravo-Ureta and Pinheiro 1993, table 1) and the comparatively high value found by Squires *et al.* for the Peninsular Malaysian gill net fleet of artisanal fishers. The comparatively low mean level of technical efficiency found in this study contrasts with Schultz's (1964) thesis of "poor and efficient" smallholders and peasants in developing country agriculture.

Table 4
Frequency Distribution of Technical Efficiency Scores

Range	(0,0.2)	(0.2,0.4)	(0.4,0.6)	(0.6,0.8)	(0.8,1.0)
Total count	56	91	88	94	49
Location (count)					
(1) Kuala Kedah	46	75	73	82	42
(2) Kompleks	3	1	2	0	0
(3) Kampung Masjid Lama	3	4	0	2	0
(4) Kuala Sala	4	3	1	1	0
(5) Tangkong Yard	0	8	12	9	7
Years experience as fisher (mean)	25.53	24.42	23.27	24.73	23.06
Age (mean)	47.11	45.21	44.88	46.68	44.84
Ethnic group (count)					
(1) Malay	51	52	34	32	5
(2) Chinese	5	39	52	57	42
(4) Others	0	0	2	5	2
Boat ownership (count)					
(1) Boat owner	35	48	38	34	13
(2) Others	21	43	50	60	36
Vessel tonnage (mean GRT)	27.28	31.43	35.67	35.26	36.96
Horsepower (mean)	227.29	263.24	287.61	290.27	307.96
Schooling experience (mean)	1.05	1.08	1.05	1.05	1.04
Household size (mean)	6.21	6.35	5.93	5.82	5.49
No. of family members working 2.16	2.27	2.26	2.33	2.10	
No. of children schooling	2.16	2.05	2.02	1.64	1.69
Peak season (mean)					
Count	1	7	16	55	47
No. of hours/trip	24.00	24.00	16.53	15.31	19.68
Average kg catch/trip	200.00	264.00	316.88	1,229.44	2,663.83
No. of men in boat/trip	3.00	3.57	3.38	3.98	4.15
Off season (mean)					
Count	36	51	27	12	na
No. of hours/trip	16.99	19.13	25.59	26.33	
Average kg catch/trip	89.86	435.88	1,118.89	1,750.00	
No. of men in boat/trip	3.53	4.06	4.19	4.58	
Normal season (mean)					
Count	19	33	45	27	2
No. of hours/trip	17.68	15.24	22.20	32.81	8.00
Average kg catch/trip	125.79	366.37	930.44	1,592.59	7,500.00
No. of men in boat/trip	3.37	3.64	4.16	4.29	4.50

Mean: 0.49; minimum: 0.01; maximum: 0.95; std. dev.: 0.24.
Note: Measures are in terms of efficiency, not inefficiency.

The frequency distribution over all seasons also differs from that typically found in less developed country agriculture, where the agricultural distribution is typically skewed toward higher efficiency levels (figure 1). At first blush in this fishery, in contrast, the distribution tends towards the normal (wider intervals would push the distribution towards the normal). The distribution, however, settles down as a hybrid between a normal and a skewing toward the high end due to a peak fre-

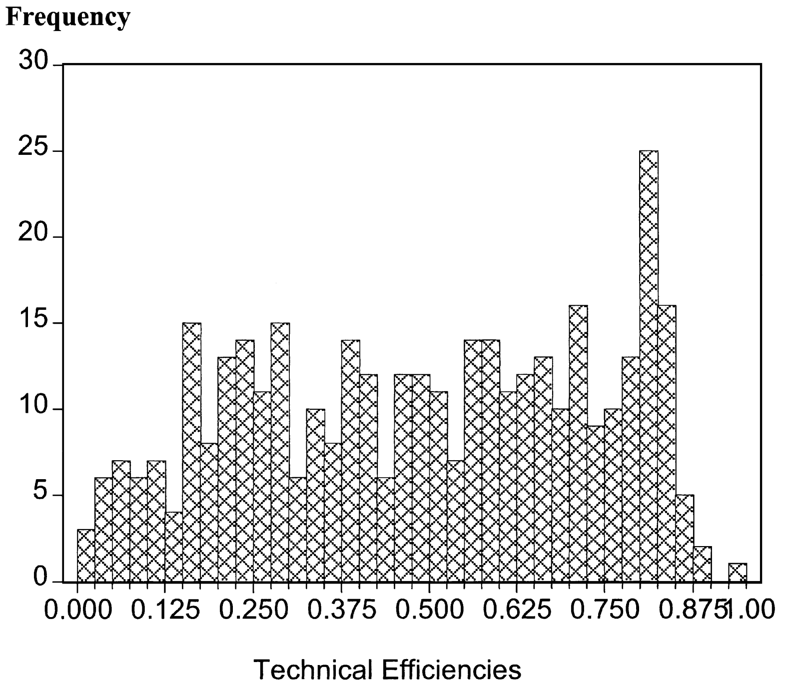

Figure 1. Frequency of Technical Efficiencies

quency at a comparatively high level of efficiency. In sum, the vast majority of the Kedah trawlers have comparatively low levels of technical efficiency over all seasons and face substantial scope for technical efficiency gains, given the state of their technology.

The magnitude, algebraic sign, and significance of the estimated coefficients in equation (2), the technical inefficiency function, can analyze the factors affecting technical inefficiency in the model, given the sample data. Table 5 provides the estimated technical inefficiency function, where the dependent variable is technical inefficiency as opposed to technical efficiency. Thus, a negative sign indicates a *decrease* in technical inefficiency or an *increase* in technical efficiency. The statistically significant variables in the technical inefficiency function are the intercept, ethnicity of the captain, fishing in the off and peak seasons, and a large (> 50 GRT) vessel.

Efficiency and Season

Season is one of the most important of these statistically significant variables affecting efficiency. The most striking result is the variation of technical efficiency by season (table 4, figure 2). Most vessels are technically efficient (around 0.8) during the peak season, so that there is only one regime of efficiency in the peak season. Compared to the normal and off seasons, the largest mean catch per trip and the lowest mean number of hours per trip are found in the peak season (table 1). The vessels that are strongly inefficient in the normal season are also very inefficient in the other two seasons (figure 2). In the normal season, there are two efficiency regimes, moderate efficiency (around 0.6) or very low efficiency, with overall effi-

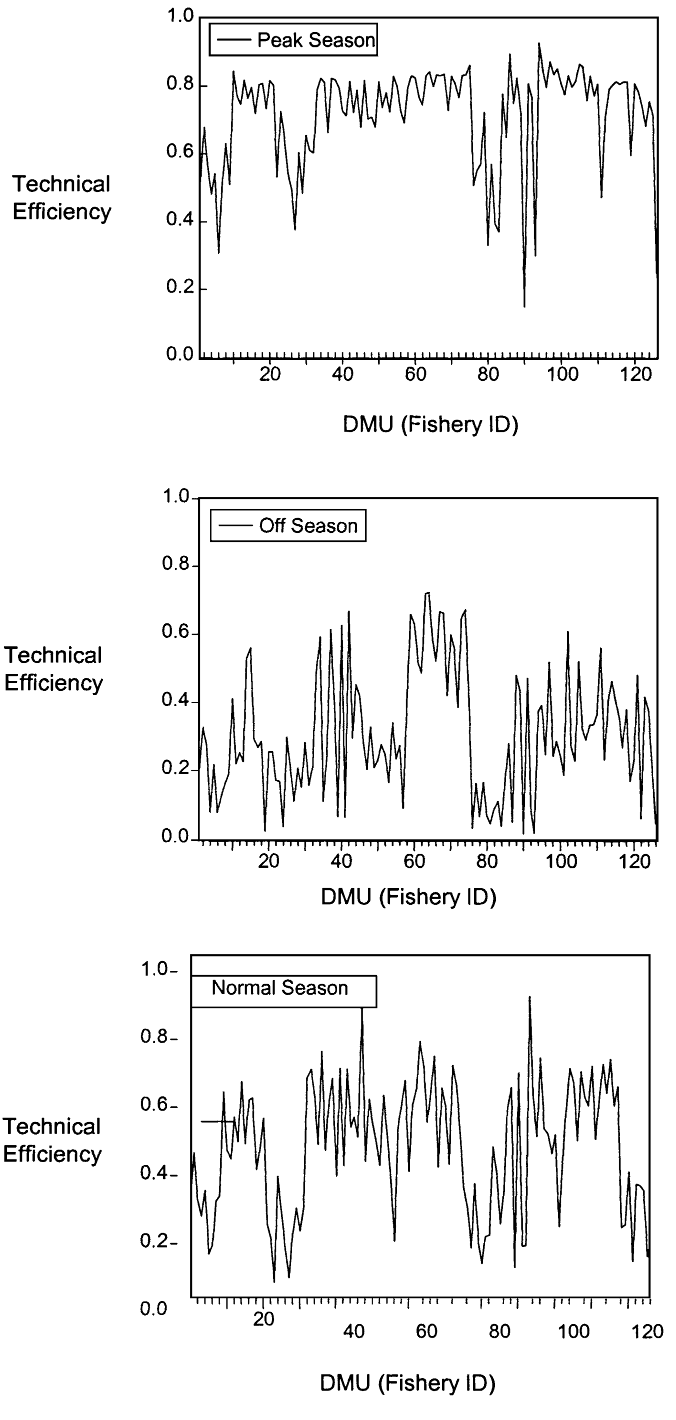

Figure 2. Technical Efficiency over Season by DMU

ciency much lower than found during the peak season. Moreover, the lower efficiency regime dominates the higher efficiency regime during the normal season. The normal season efficiency level lies between the levels of the peak (highest) and off (lowest) seasons. The normal season means (catch and hours per trip) lie intermediate between the peak and off-seasons, although the highest number of hours per trip is found for the normal season (table 1).

During the off-season, there are also two efficiency regimes, but the lower-level regime dominates the higher-level regime, giving a very low overall level of efficiency (table 4, figure 2). Resource abundance, and especially availability, decline during the off-season. The number of hours per trip and mean catch per trip decline compared to the peak and normal seasons, while the number of men in the boat rises. Hence, the immediate source of efficiency decline in the monsoon season is clear: a smaller volume of fish is caught by a slightly higher number of persons in the boat. These immediate factors, in turn, are the consequence of reduced resource availability and less favorable operating conditions. Campbell and Hand (1998) similarly found that season had an important effect on technical efficiency in the Solomon Islands pole-and-line fishery.

Efficiency and Vessel Size

Technical efficiency rises slightly with vessel size (table 4). The lowest-efficiency vessels average 27 GRT, and GRT increases with vessel tonnage to an average of almost 37 for the most efficient vessels. The dummy variable for the largest vessel size class (> 50 GRT) is negative and statistically significant, indicating that vessels of this size class decrease technical inefficiency (table 5). Similarly, technical efficiency rises with engine horsepower, from a mean of 227 for the least efficient vessels to a mean of 308 for the most efficient vessels (table 4). Along similar lines, crew size increases with technical efficiency for all three seasons (table 4), although

Table 5
Estimated Technical Inefficiency Function

Variable	Coefficient	St. Error	t-Ratio
Intercept	1.97	0.93	2.12
Years experience as fisher	0.02	0.01	1.64
Household size of fishing master (persons)	–0.06	0.04	–1.37
No. of men in boat/trip	–0.14	0.20	–0.71
Dummy variables for:			
Boat ownership	–0.35	0.20	–1.72
Formal education of fishing master	0.08	0.41	0.20
Area of home port	0.05	0.29	0.17
Ethnicity of captain	–1.30	0.29	–4.55
Off season	0.72	0.20	3.58
Peak season	–1.77	0.60	–2.95
Small vessel	–0.34	0.37	–0.93
Large vessel	1.18	0.47	2.51

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: <15 GRT and large vessel >50 GRT.

this variable is statistically insignificant in the estimated technical inefficiency function (table 5).

Efficiency and Skipper Ethnicity

Technical efficiency varies by ethnicity of the skipper (tables 4, 5). The dummy variable for Indian, Chinese, and other skippers is negative and statistically significant in the technical inefficiency function (table 5). Similarly, the number of Malay skippers declines with increases in efficiency, whereas the number of Chinese and other ethnic group skippers rises with increases in efficiency (table 4). This result contrasts with those of Squires *et al*. (1998) for the Peninsular Malaysian artisanal gill net fishery, where ethnicity of the skipper did not affect technical efficiency. Chinese skippers generally entered first into the trawl and purse seine fisheries, and Malays were comparative latecomers. Mean years of fishing experience does not appreciably differ by technical efficiency class or ethnic group (tables 4, 5). Nonetheless, the greater length of time for Malaysian Chinese as a group in this fishery may have led to accumulated knowledge that has been passed down within this group and has not been disseminated outside of it. Among Chinese skippers or fishers, there may also be greater networking and sharing of information within the Chinese community as opposed to Malay fishers. Training among the Chinese community may also take place earlier, and the Chinese were the first to acquire and use modern equipment, such as echo sounders and fish detection devices. Chinese fishers also have bigger boats and more sophisticated fishing equipment and are generally better trained in their use than the Malay fishers. Malay fishers might also be more subject to credit constraints. Squires *et al*. (1998) found that participation in a skipper training program did not affect technical efficiency of artisanal gill net fishers, but perhaps in this offshore fishery such a program might find more room for success.

Efficiency and Owner-Operatorship

The absence of a statistically significant owner-operator effect on technical inefficiency provides an indication that, in this fishery, the asymmetric information problem between the owner (principal) and operator (agent) and the general “contractual” problems between principals and agents may not be noteworthy. The potential moral hazard problem may not arise due to the share system or perhaps other factors, such as a strong personal relation to the owner or close observance by others.

Efficiency and Skipper Skill Literature

The null hypothesis that some skippers consistently demonstrated superior skipper skill, as measured by comparatively higher technical efficiency scores across seasons, was rejected by both the Wilcoxon matched-pairs signed-ranks test and the Mann-Whitney test (table 6). This absence of consistently superior technical efficiency across time periods by some skippers differs from Squires and Kirkley (1999), who found such skipper skill for the Pacific coast trawl fishery.

The Malaysian trawl result is inconsistent with Thorlindsson’s (1988) summary of the two notions of the skipper effect, in that the skipper effect is inconsistent across the three seasons. Perhaps over multiple years, a skipper’s technical efficiency might be consistently higher for one or more seasons.

Table 6
Hypothesis Tests of Consistent Skipper Skill Across Seasons

	Wilcoxon Matched-Pairs Signed Rank		Mann-Whitney Test	
Null Hypothesis	Test Statistic	Significance	Test Statistic	Significance
Peak season = Off season	9.738	0.000	12.200	0.000
Peak season = Normal season	9.621	0.000	10.428	0.000
Normal season = Off season	8.065	0.000	–5.058	0.000

Note: Skipper skill equated to superior technical efficiency.

The limited number of statistically significant variables in the technical inefficiency function (intercept, ethnicity of the captain, fishing in the off and peak seasons, and large vessel) suggests the difficulty in finding suitable socio-demographic measures of skipper skill. The components of skipper skill identified by Barth (1966), Acheson (1981), and Thorlindsson (1988) are all highly intangible and difficult to capture by readily observable proxy variables. The statistically significant intercept may be capturing some of these intangibles. Education and experience, the two most obvious measures of human capital, did not. Vessel size may indirectly capture skill to the extent that there are disadvantages to vessel size, and the superior skipper gravitates to smaller vessels. In any case, the factors explaining skipper skill are clearly a difficult problem to capture, and additional research in this area is required.

The limited number of readily observable and measurable skipper characteristics significantly affecting technical efficiency and skipper skill, combined with the wide variation in technical efficiency, highlights how little is known about the socio-demographic factors — measurable attributes of the skipper's human capital — that play a role in affecting relative catch rates. In contrast, in developing country agriculture, certain observable farmer characteristics, such as education, experience, and contacts with extension agents generally affect technical efficiency (Bravo-Ureta and Pinheiro 1993). Knowledge of these socio-demographic factors in developing country agriculture facilitates policies that raise yields and incomes to be more clearly and consistently formulated.

Production Elasticities

The production elasticities for the estimated model, estimated from equation (3) at the mean of the data set for each season and comprised of the elasticity of frontier output and the elasticity of technical efficiency, are inelastic for all three variables, capital (K), labor (L), and effort (T) (table 7). The production elasticities vary only slightly by season. The negative elasticity for labor, L, in all seasons suggests that the mean vessel may be subject to input congestion in which the isoquant has a positive slope and in which it operates in Stage III of the production function.[15] This result is consistent with the comparatively low level of technical efficiency found in

[15] The negative sign for L could also reflect multicollinearity, even in the face of panel data and large number of observers.

Table 7
Elasticities of Production

Input	Peak Season	Off Season	Normal Season
Capital	0.866	0.919	0.925
Labor	–0.099	–0.340	–0.363
Effort	0.245	0.328	0.375

Note: Calculated at sample means for each season following equation (3).

this study. Vessels may be crewing their vessels too heavily for social reasons.

Alternatively, the smallest value for labor's production elasticity occurs in the peak season, when the value is almost zero and when the greatest need for labor occurs. The results suggest that vessels operators may determine their crew size for the peak season (when the largest catches occur), and due to rigidities in the labor market, maintain a larger crew than otherwise required in the other seasons. Maintaining a crew throughout the year to keep it intact and available in the peak demand periods is a common practice in, for example, the construction and building trades industries. This interpretation of input congestion would suggest that vessels either do not strictly maximize profit, they impute a very low opportunity cost to labor, or they incorrectly calculate their crew requirements during the peak season. Further research is required in this area.

Returns to scale, calculated as the sum of the production elasticities, are 1.012 in the peak season, 0.907 in the off season, and 0.937 in the normal season. Hence, returns to scale vary slightly by season, influenced by the elasticity of technical efficiency and the strong seasonality in technical efficiency. Returns to scale in each season are all decreasing (or very close to one), due to the input congestion for labor. Reductions in crew sizes, thereby eliminating labor congestion, would help vessels enjoy increasing returns to scale and some size economies.

Skipper Skill and License Limitation

License limitation programs, especially those limiting vessels by areas or zones, form the cornerstone for the regulation and sustainable resource use of many fisheries in the tropics (Abdullah and Kuperan 1997). Tropical ecosystems are characterized by highly diverse species and complex interactions among species within their habitat. In many areas, there are also real or potential gear conflicts (especially between artisanal and commercial-industrial fisheries). For these reasons, area license programs are likely to remain the linchpin to fisheries management in most of these fisheries. Moreover, conventional management measures, such as catch quotas, have generally proven ineffective in fisheries of these countries (FAO 1983).

Skipper skill, defined as the technical efficiency of a skipper, represents the most difficult component of fishing capacity to monitor, measure, and account for in license limitation programs and in regulation by total allowable catches (TACs). The lower the level of technical efficiency, the greater the scope for expansion in maximum potential output for any given input bundle, state of technology, and environmental and resource conditions.

In the Kedah trawl fishery, technical efficiency was comparatively low with a wide range, indicating a broad range of skipper skill and substantial potential for increasing production. Skipper characteristics, other than ethnicity, did not significantly affect technical efficiency and skipper skill. Considerable scope for increased catch exists during the off seasons for virtually all vessels and for many skippers, even during the normal season. Hence, there is scope for increased capacity utilization (defined as the ratio of observed to maximum potential catch) and consequent pressures on resource stocks under license limitation.

Concluding Remarks

Fishing skill of captains in developing countries, interpreted as technical efficiency of the skipper, has received little attention in the literature. This study sheds light on this issue through a case study of the Kedah, Malaysia trawl fishery. The statistically significant variables affecting skipper skill were season of the year, ethnicity of the captain, and use of a large (> 50 GRT) vessel. The greatest scope for increasing skill was during the off-season, when monsoon weather and resource conditions substantially lower production. Ethnicity was the only socio-demographic variable that significantly affected skill. Skill appears to be very difficult to capture by socio-demographic attributes of the skipper-proxy variables for the skipper's human capital and additional research could be informative in this area.

On issues of efficiency, vis-à-vis fishing skill, the empirical results from this study indicate considerable potential for increased catches and capacity utilization through improvements in fishing skill, especially during the off-season. Nonetheless, given the limited number of variables significantly affecting skill, it remains unclear just how these gains could actually come about.

On issues of equity, vis-à-vis fishing skill, the empirical results indicate that a captain training program for the least efficient skippers may be called for to meet the objectives of equity and fairness as expressed in Malaysia's New Economic Policy and its successor, the New Development Plan. Such a training program would also be consistent with one of the initial aims of the license limitation program, which was to promote equity among all ethnic groups in Malaysian society. Jahara (1988) observed that the objective of allocating fishing grounds represented a strong emphasis on equity, and that the issue was as much politics as equitable allocation of fishery resources between highly efficient trawlers and less efficient small-scale fishers. It is only one more simple step forward to raise the level of efficiency of all skippers, regardless of ethnicity, to a minimum standard, thereby contributing to equity and, hence, the objectives of the license limitation program and the New Development Plan.[16]

Increasing the efficiency of all skippers, regardless of background, will increase output. Nonetheless, the threat to sustainable resource use in an open-access resource must be blunted by other means to prevent overfishing to achieve sustainability in social relations within the broad society.

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