

Open Access and Missing Markets in Artisanal Fishing

Christopher Liese*
Ph.D. Candidate

Martin D. Smith
Assistant Professor of Environmental Economics

Randall A. Kramer
Professor of Resource and Environmental Economics

Author Affiliations:
Nicholas School of the Environment and Earth Sciences
Duke University
Box 90328
Durham, NC 27708

*Corresponding Author
ph: (919) 613-8051
fax: (919) 684-8741
cl7@duke.edu

Selected Paper
American Agricultural Economics Association Annual Meeting
July 2002, Long Beach, CA

JEL Codes: Q22
Keywords: open access, missing markets, artisanal fishery

Abstract:

This paper combines a model of open access fisheries exploitation with a distance-based approach to missing labor and product markets. The model generates predictions about the circumstances under which exploitation increases or decreases with distance. An econometric model is estimated with survey data from artisanal fishing households in Minahasa, Indonesia. The results can be used to assess the impacts of improved transportation infrastructure on fishery exploitation.

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1. Introduction

In many developing countries, both ill-defined property rights and missing markets plague renewable resource industries. Small-scale artisanal fisheries are striking examples as open access is frequently present and the remoteness of small fishing communities contributes to incomplete labor and product markets. While over-exploitation is the typical result of open access, missing markets have an ambiguous effect that may mitigate or exacerbate open access forces. On the one hand, a missing product market decreases the returns to fishing effort and hence reduces aggregate exploitation. On the other hand, a missing labor market decreases the opportunity cost of the time spent fishing. A lower opportunity cost tends to increase exploitation because labor is the predominant input in artisanal fishing. This paper combines an open access fisheries model with a simple distance-based missing markets model in order to derive implications concerning these two contemporaneous market failures.

The analytical model incorporates a Schaefer production function for multiple, spatially discrete resource stocks, and the model imposes a zero-rent condition to depict open access. Our conceptual framework extends the standard model by introducing distance to market. Each fishing ground lies some distance from a central location at which well-functioning product and labor markets exist. As distance increases, the effective returns to fishing decline because fishermen are less able to sell their product at a central market or product quality degrades substantially en route. Increased distance may also decrease the opportunity cost of fishing because fishermen are less able to sell their labor for activities outside of their own fishing

enterprises.¹ Equilibrium effort, biomass, and harvest at each fishing location are functions of biological parameters, product price, subsistence value, wages in the central market, costs of non-labor inputs, and distance. By imposing open access bioeconomic equilibria, we are able to estimate cost and price parameters without simultaneously estimating biological parameters or having independent assessments of the fish stocks.

An econometric model is developed that describes catch per unit effort across multiple fish stocks that individually are characterized by open access equilibria with missing markets. The model is estimated using data from a cross-sectional household survey of artisanal coral reef fishermen in Minahasa, Indonesia. Each fishing village has a distinct corresponding reef fish stock. The results are used to discuss different policy implications for coral reef conservation and extension of transportation infrastructure.

Most bioeconomic studies in fisheries are conceptual, and empirical work in this area is limited (Wilén, 2000). Two studies that empirically model open access fisheries are Wilén (1976) and Bjørndal and Conrad (1987), though neither study addresses incomplete labor and product markets. Most research, both theoretical and empirical, on missing labor markets in developing countries comes from agricultural household production studies (de Janvry, 1991; Benjamin, 1992). This literature shows that dropping the efficient labor markets assumption leads to substantially different results and hence changes the anticipated effects of policy interventions. Previous work that combines renewable resource exploitation with missing markets focuses primarily on forest resources (Angelsen, 1999). Most of this literature characterizes exploitation of the resource as land-use change from forest cover to agriculture at an expanding “open access” frontier (the extensive margin). The lack of a resource stock concept

¹ The subsistence value of fishing may ultimately provide a floor for returns to fishing effort. Similarly, as the opportunity cost of fishing labor approaches zero (or some floor leisure value of time), costs of non-labor inputs

and the implied acquisition of property rights prevents these models from being transferred to the open access fishery case. An exception in the agro-forestry context is the work by Bluffstone (1995) on Nepali agriculturalists who exploit a forest commons for fuel and fodder. He conducts a dynamic simulation of a representative village model under varying labor market conditions. Bluffstone concludes that the availability of an off-farm labor market, even at low wages, stabilizes and possibly constrains exploitation, counteracting open access's tendency to overexploit. Our model treats distance as a market failure where transaction costs create a wedge between prices at the center and the periphery. Contributions by Chomitz and Gray (1996), Omamo (1998), and Jacoby (2000), again in the developing country, agricultural context, show that infrastructure, in particular roads, generate benefits for the rural households and influence their labor allocation decisions. Chomitz and Gray further shows that roads can facilitate deforestation. Do we expect transportation infrastructure to affect open access fisheries in a similar manner?

Our theoretical model suggests that more remote areas will exploit fish stocks more heavily if the distance elasticity of price exceeds the distance elasticity of cost. Since these elasticities are negative, this means that fishing effort increases with distance if the opportunity cost of fishing effort decays more rapidly over space than the product price. The empirical results, though preliminary, support the notion that product and labor market effects operate in different directions on overall fishing exploitation.

The next section outlines the conceptual model and derives the basic implications of an open access equilibrium with missing labor and product markets. Section 3 describes the empirical setting and data collection in Minahasa, Indonesia, while section 4 specifies and

provide a floor for the marginal cost of fishing effort.

estimates an empirical model of artisanal fisher catch per unit effort. Section 5 briefly discusses the results and policy implications.

2. A Simple Conceptual Model

To study the effects of distance in an open access setting, we modify the static open access framework of Gordon (1954). We assume that individual fishers are price-takers, and price (p) is a function of distance to market (τ). We further assume that costs are linear in fishing effort and that marginal cost (c) is a function of distance as well. As distance increases, the fisher's price decreases because either product quality degrades en route to market, or the fisher must sell to a broker who takes a portion of the wholesale price in the fish market. Further, increased remoteness of a fishing village tends to decrease opportunities to work outside of fishing. As such, the opportunity cost of an individual's fishing effort (E) is decreasing in distance. Thus, we assume $p'(\tau) < 0$ and $c'(\tau) < 0$. Now suppose that the fish stock (x) in each location evolves according to the following:

$$\dot{x} = F(x) - h, \quad (1)$$

where $F(x)$ is net growth and h is harvest. We assume a Schaefer production function such that harvest is proportional to the product of effort and stock size:

$$h = qEx, \quad (2)$$

where q is a catchability coefficient.

An open access steady state exists when fishing rents are zero, and $\dot{x} = \dot{h} = \dot{E} = 0$. Thus, the following two equations combined with (2) characterize an open access steady state with distance-induced missing labor and product markets:

$$F(x) = h, \quad (3)$$

$$p(\tau)h - c(\tau)E = 0. \quad (4)$$

By rearranging (2), substituting for x in (3), rearranging (4), and substituting for h in (3), we have:

$$F\left(\frac{c(\tau)}{p(\tau)q}\right) - \frac{c(\tau)}{p(\tau)}E = 0. \quad (5)$$

To find the net effect of distance (or remoteness) on fishing effort in an open access equilibrium, we totally differentiate (5) to find:

$$\frac{dE}{d\tau} = \frac{p(\tau)}{c(\tau)} \left\{ \left[F'\left(\frac{c(\tau)}{p(\tau)q}\right)q^{-1} - E \right] \left[\frac{c'(\tau)p(\tau) - p'(\tau)c(\tau)}{[p(\tau)]^2} \right] \right\} \quad (6)$$

If we are in the usual case of a globally concave net growth function, then the sign of

$\left[F'\left(\frac{c(\tau)}{p(\tau)q}\right)q^{-1} - E \right]$ is always negative. To see this, multiply both terms by qx/x and recognize

the qEx is h , which in equilibrium is $F(x)$. Hence, the term is positive whenever $F'(x) < F(x)/x$, or the marginal is below the average. This is always true for concave functions.² Violations of this condition would occur if there were biological depensation. Assuming concave net growth, effort increases with distance whenever:

$$c'(\tau)p(\tau) - p'(\tau)c(\tau) < 0. \quad (7)$$

Rearranging and multiplying both sides by τ , we have:

$$\frac{c'(\tau)\tau}{c(\tau)} < \frac{p'(\tau)\tau}{p(\tau)}. \quad (8)$$

Effort increases in distance when the distance elasticity of cost is less than the distance elasticity of price. Since both elasticities are negative, this implies that effort increases when the **magnitude** of the cost elasticity of distance is greater. In other words, exploitation goes up in villages further away from product and labor markets if the opportunity cost of fisher time

decays more rapidly over space than the product price. Although this basic result is not surprising, it provides motivation for empirically analyzing the effects of remoteness on the resource stock through the pathways of price and opportunity cost of fishing.

3. Empirical Setting and Data

Our area of study is the Minahasa region of Indonesia, which is located on the northern tip of the island of Sulawesi. This tropical region exhibits an abundance of terrestrial and marine biodiversity. Agriculture is the major economic activity, with cloves and coconuts being the major cash crops. The fertility of the land and some mineral resources generate significant wealth by developing country standards. The population of the Minahasa region was close to one and a quarter million in 1999 (BPS, 2002), living either in rural settings or in one of two truly urban areas (Manado and Bitung). Located on a thin peninsula, the region has over 350 km of coast line, much of it supporting coral reefs.

In coastal villages fishing is a significant activity. Mostly small-scale artisanal fishermen and their families depend on the coastal marine environment for their livelihood. These fishermen employ wooden boats and canoes, 3 to 6 meters long, usually propelled by paddle and sometimes by low horsepower outboard motors. Their gear consist predominantly of hook and line, small nets, spears and homemade spear guns. They go on daily fishing trips lasting between 4 and 12 hours, sometimes accompanied by a family member. Their catch, seldom exceeding 50 kilograms per day, is caught in the proximity of the reefs and consists to a large degree of reef fish. A portion of the catch is consumed by the households themselves and the rest is sold either to traders or directly to consumers in surrounding villages (often with the wife taking the roll of a trader) (Kramer et al., 2002). The limited range of the artisanal fishermen and the fact that most

² The authors thank Jim Wilen for helping to clarify this interpretation.

coral reef fish are stationary at the kilometer scale (at least in their non-larval stage), sanction the assumption of a discrete and independent resource stock at each village location.³

The artisanal fishermen supply the local markets and participate, through traders, in more distant, larger fish markets (inland and fish processing). The traders operate both by land and sea. An asphalt road network connects the bigger population centers. Smaller roads that connect villages to population centers are not always asphalt and are often poorly maintained. Tropical climate and mountainous terrain (up to 2 000 meters) makes these roads difficult and sometimes impassable. Some coastal villages do not have any road access. By sea, traders move fish to coastal towns with good road connections or directly to the urban areas for processing. In the smaller villages the only alternative work activity to fishing is farming, while in the larger towns and urban areas other forms of employment are available to varying degrees. The cities of Manado (the capital of the North Sulawesi province) and Bitung are, besides national air and sea transportation hubs, industrial processing centers of the region's agricultural and natural resources and are supporting a growing tourism industry.

This paper draws on an earlier study of marine fishermen and migration in Minahasa, Indonesia (Kramer et al., 2002).⁴ Interviews with stakeholders and experts at the local university and local NGOs over the last three years, a household survey and a survey to gather village-level data (interviews with village leaders) have led to the construction of an extensive data set. As part of the household survey, 600 households in the district of Minahasa and the urban areas of Manado and Bitung, whose primary occupation was fishing, were interviewed. Two focus groups with fishermen and a pretest served to develop and test the household survey instrument.

³ Unlike the Sanchirico and Wilen (1999) model, our system is “closed” both in economic and in biological terms. Fish stock linkages enter only indirectly through labor and product market connections but, by assumption, not through spatially explicit rents.

⁴ This research was funded in part by the John D. and Catherine T. MacArthur Foundation.

After a sampling frame was created by visiting most coastal villages (to collect fisher population data, not individual names), multi-stage random sampling was used to select five sub-districts and then 17 coastal villages within them. Finally, on location, the interviewers created a list of fishing households and sampled according to a preset routine. The survey was implemented in July 1999 with the help of recent graduates from the local university, who, after 3 days of training, served as our interviewers.

Descriptive statistics for the villages in our sample are presented in Table 1. The Table serves to illustrate the large variation among different dimensions among the 17 villages. Village populations range from 535 to 7115 individuals. At the upper end of this scale, villages represent jurisdictional units within larger urban areas, making it likely that the numbers are underestimates of the size of the effective economic units (markets) that are of primary interest to us. Over the preceding decade population growth averaged 2% which corresponds approximately to secondary estimates for the region (BPS, 2002). Large variation at the village level is probably due to both inaccurate population counts and to significant in- and out-migration. The shortest distance from the villages to large population centers with easy access to fish markets is on average 11.8 km. For 6 villages this distance reflects transportation by sea.⁵ Ethnic diversity, expressed by religion, and variation in the economic specialization of each village is also apparent.

⁵ These include three villages on islands off the coast of Sulawesi (5-16km), one village with no road connection, and two villages with roads of such quality that most transportation is done by sea.

Table 1: Characteristics of the surveyed villages (n=17)

	Average	Village Pop. Weighted Average	Minimum	Maximum
Population size	2518	3837	535	7115
Population growth rate	2%	2%	-5%	8%
Distance to market (km)	11.8	6.3	0	40
Muslim households	38%	49%	0%	95%
Fishing households	44%	48%	10%	95%
Number of fishing households	242	378	32	566
Catch per unit effort ¹	2.9	2.6	0.8	11.8

¹ Catch per unit effort represents the village average kilogram of fish per hour of time spend fishing by an artisanal fisherman with a 3 to 6 meter canoe with up to one extra crew member. This attempts to correct for different fishing types, i.e. capital investment, and is hence based on a sub-sample of our respondents.

The final entry shown in Table 1 is the village-level catch per unit of effort (in kilograms per hour). The average is 2.9 kg/hour, yet, amazingly, it varies by over a factor of 10 among the villages. While some of this variation will be due to omitted and unobservable differences in effort (such as differences in boat propulsion and fisherman skill, respectively), the magnitude begs for a more systematic explanation. The scant laws applying to coastal resources (originating from the federal level in Jakarta) are not communicated to the local level, much less enforced. Furthermore, more localized rule systems for allocating access to marine resources are not common in the study area. As a result, efficient resource management cannot serve to explain effort variation and the assumption of an open access property rights situation is justified. We argue that the economic forces that would bring about an open access spatial equilibrium are present, since substantial inter-village migration occurred in the 50 years prior to our sample

period. Of the survey respondents, over 50% were born outside the village they live in and 25% were born outside the Minahasa region altogether (Kramer et al., 2002).⁶

4. The Empirical Model and Estimation

To estimate a model of open access in multiple artisanal fishing communities, we posit that the zero-rent condition applies to individual fishermen (i):

$$p(x_i)h_i - c(z_i)E_i = 0, \quad \forall i, \quad (9)$$

where \mathbf{x}_i and \mathbf{z}_i can contain individual-specific determinants of product price and opportunity cost of fishing effort respectively. In our regression the regressor \mathbf{x}_i will vary only at the village level (implying that the village fish price is independent of the individual). The regressor \mathbf{z}_i will vary across individuals within the same village. Rearranging (9), we have the following:

$$\frac{h_i}{E_i} = \frac{c(z_i)}{p(x_i)}. \quad (10)$$

In words, the individual fisher's catch per unit effort (CPUE) in open access is the individual's cost/price ratio. We use kilograms of catch per hour of human labor for CPUE. High levels of catch per unit effort correspond to low levels of aggregate effort given standard assumptions about stock dynamics. According to the theoretical development earlier in the paper, the varying levels of open access equilibria are driven by differences in the prevailing prices and opportunity costs for the fishery participants at each location. Prices depend on access to the product market and would thus hinge on geographical location. However, opportunity cost depends both on geographical location and individual fisher heterogeneity.⁷ In essence, a fisher's choice of

⁶ We assume that each location is well characterized by an open access steady state, recognizing that we do not have sufficient data to test the equilibria against approach paths.

⁷ In the regression below, we account for heterogeneity in observable differences across individuals in the sample. We treat unobserved heterogeneity as random noise without any additional structure. In future work, we plan to explore group-wise heteroskedasticity at the village level.

equilibrium fishing effort is based on the individual's shadow wage. We do not directly observe individual prices and costs, but we do observe factors that influence them. Following our theory, we posit that distance from market is the primary determinant of price and opportunity cost.

Suppose that the cost and price functions of distance are Cobb-Douglass and assume a multiplicative error. Taking natural logs, we have the following estimation equation:

$$\ln(CPUE_i) = \beta_o + \sum_k \beta_k \ln(x_{ik}) - \sum_j \gamma_j \ln(z_{ij}) + \varepsilon_i, \quad (11)$$

where k indexes cost factors, j indexes price factors, β_o is the log-ratio of cost and price scaling coefficients, and ε is a random disturbance.

Abstract distance to market is not necessarily the same scale in physical distance for cost and price factors. In order to separately account for each, proxies are chosen that correlate well with one market and not the other. The variables that will serve as proxies in the regression for the price and cost gradients over space are the following: distance to major market in kilometers; a dummy variable to represent that sea transportation is the predominant form for villages on islands or without adequate roads; the village population size in multiples of 1000 individuals; and, at the household level, a dummy variable to signify the ownership of land and a variable for the education of the fisherman.⁸

How do these variables correlate with the labor market and (shadow) wages? While an average distance of 12 km to major market might not seem great, one must look at distance in relation to the transportation infrastructure. In a tropical developing country it is unlikely that individuals will commute large distances in the absence of private or reliable public

⁸ For each respondent the education level takes a value between 1 and 5, where 1, 2, 3, 4, and 5 represent completion of No Schooling, Primary, Secondary, High School and some University, respectively.

transportation.⁹ In the absence of significant commuting beyond a village, both distance to major market and the lack of adequate road connections are unlikely to influence a village resident's employment opportunities because there is no trade in labor beyond the village. The village size on the other hand is likely to be a significant proxy for work opportunities beyond fishing, as specialization and labor dependence are correlated with urbanization. Ownership of land and education should raise the opportunity costs of time of an individual, since he or she has the option to farm and more jobs from which to choose.

How do the above variables correlate with the product market (prices) and the return to fishing? Unlike in the case of labor, distance to major market and the lack of adequate road connections, i.e. transport by sea, will be less of a barrier to trade in fish. Yet both measures should significantly affect the price a fisherman receives for his catch since traders and middlemen will require a mark-up to cover their costs.¹⁰ Again, distance needs to be interpreted in light of a developing country's infrastructure. In the absence of refrigeration or ice even short distances can create situations prohibitive to trade in fresh fish.¹¹ More importantly, the logistics of coordinating fishing with appropriate and timely delivery to market impose a significant cost on distance. The next variable, the village population size, determines the local market available to the fishers. An argument that implies a lesser role for the impact of the village size on the product market (with respect to its impact on the labor market) is the following. When fish is traded beyond the local market, it implies that local demand is satisfied at the major market fish

⁹ This clearly ignores temporary migration to find work. Home ownership is very high among our respondents and practically none owned motorized transportation. Both facts tentatively argue for less mobility among household members.

¹⁰ For example, based on a price survey in three of the seventeen villages, the price level, expressed as a percentage of the retail price in an urban market, is approximately 90% in major markets and 55% for more remote villages on the coast of Sulawesi. Sea transportation from the islands and roadless villages will, almost surely, reduce the price level further.

¹¹ Dried and/or salted fish is an obvious response, which lowers the value of the product, i.e. the return to the fishermen.

price minus transaction cost, i.e. transportation and marketing. Empirically, the rural prices are a fraction of the major market prices, and villages do not import fish from major markets. Moreover, we expect that marginal prices will determine marginal exploitation. Thus, price of fish sold outside the village determines marginal exploitation, and village population size, especially for smaller ones, is unlikely to affect the fish price. Finally, it is fairly implausible that land ownership by- or education of- an individual will affect the fish price he or she receives for her catch.

By separately accounting for labor market distance and product market distance, we hope to test the distance decay assumptions of our conceptual model and to identify the offsetting effects. This leads to the following hypotheses. Distance to a product market increases the open access equilibrium catch per unit effort.¹² A larger local labor market, owning private land, and greater human capital also increase open access catch per unit effort.

We use Ordinary Least Squares to estimate the three regressions that we report. They differ from one another only with respect to the particular rule used to include observations. There are two reasons for this approach. First, the household survey identified two somewhat overlapping categories of fishermen in Minahasa. The first group, small-scale artisanal fishermen who rely on the near-shore coastal resources (in particularly the coral reef), are the focus of this paper. The second group consists of fishermen (both owners and crews) engaged in large-scale motorized fishing operations that target off-shore pelagic fish stocks. While the majority of observations clearly fall into one or the other of these categories, the full sample does contain observations that are not clear cut, requiring a subjective judgment. The second reason, related to the first, is that a major determinant of catch per unit effort is the technology employed. Since we do not include technology variables as regressors, differences among fishermen will increase the

unexplained variation in the regression. To address both concerns, the three regression impose differing restrictions on which households qualify as engaged in *artisanal fishing*, i.e. who exploit the village associated near-shore resource. Model I is the most inclusive, requiring only that the average catch per fishing trip be less than 100kg. Model II restricts the number of observations further by lowering this threshold to 50kg. Finally, model III adds restrictions on the fishing technology that qualifies as artisanal. Here, artisanal fishermen must fish entirely alone from a non-motorized, non-sail canoe of which they are the owners.

The regression results are shown in Table 2. The adjusted R^2 ranges from 0.077 to 0.140, increasing with additional sampling restrictions as would be expected. The F tests (joint hypotheses that all slope coefficients are zero) are 5.81, 6.73, and 5.38, all highly significant. Distance to major market is significant at the 1% (I and II) and 5% (III) level, while the island/sea-access-only dummy is significant at the 5% (I and II) and 10% (III) level. Both have a positive sign, which is consistent with their interpretation as proxies for the fish product market. Longer distances to market and transportation routes by sea, both of which correlate with number of middle men and transaction costs, raise the catch per unit effort in an open access equilibrium. Given standard assumptions about fish biology and fishing technology this implies a larger stock size and hence a less exploited resource.

The village population size is consistently positive and significant at the 1% level. A positive sign is consistent with its interpretation as a proxy for a labor market. Alternative employment opportunities will raise the opportunity costs of time for everyone in the particular location, such, that they require higher returns to fishing. Given the open access equilibrium assumption, villages with larger populations will hence exhibit higher catch per unit effort values. Again, given the standard assumptions, this implies a larger stock size and a less

¹² We assume concavity of the stock growth function.

exploited resource. Land ownership and education are both positive and, in all but one case, significant at the 5% level or better. Both are proxies for labor market possibilities and opportunity costs of time specific to an individual. These results reinforce the above in that higher opportunity costs imply higher equilibrium CPUEs and thus relatively less stock exploitation.

**Table 2: Catch per unit effort regression
(dependant variable: natural log of kilograms per hour)**

	I.	II.	III.
Constant	-0.67** -(2.22)	-1.18*** -(3.97)	-1.52*** -(4.09)
Distance to market (km)	0.02*** (2.87)	0.02*** (2.97)	0.02** (1.98)
Island or sea access dummy	0.45** (2.46)	0.48** (2.56)	0.4* (1.82)
Village population (1000)	0.18*** (3.73)	0.21*** (4.53)	0.21*** (3.54)
Owens land dummy	0.45*** (2.67)	0.38** (2.30)	0.47** (2.32)
Education ¹	0.09 (0.96)	0.2** (2.19)	0.32*** (2.72)
Number of observations	353	312	171
Adjusted R ²	0.077	0.099	0.140
Average kg/hour	3.33	2.63	2.18

Note: t-statistic in (...), * significant at the 0.10 level, ** significant at 0.05 level, *** significant at 0.01 level.

In summary, these regressions tentatively indicate that both cost and price gradients (with respect to distance) are active and relevant in determining the stock level and associated resource health of coastal fisheries in Minahasa, Indonesia. Socio-economic variables that might be

proxies for a subsistence requirement as a lower bound to the price gradient, such as household size or number of children, did not have any significance attached to them and were dropped from the regression. Given the wealth status of the fishermen in the sample it is not surprising that subsistence does not seem to influence behavior.

5. Discussion

Inadequately defined property rights and missing labor and product markets create significant resource allocation problems in many tropical, coastal communities. This paper has attempted to provide a systematic examination of how these two sources of market failure may reinforce or offset each other. Our conceptual framework, based on a Schaefer production function for multiple, spatially discrete resource stocks, allows us to combine an open access fisheries model with a simple distance-based missing markets model. The analytical results show that in a stylized world, fishing effort increases in distance from product and labor if the opportunity cost of fishermen's time decays more rapidly over space than does the product price.

We have presented a simple econometric model to examine variation in catch per unit of effort across multiple, open access fish stocks. The model is estimated using data from a household survey of artisanal coral reef fishermen living in coastal villages in eastern Indonesia. The preliminary empirical results support the notion that product and labor market effects operate in different directions on overall fishing exploitation. Although they are preliminary, these results suggest that development efforts may have perverse effects on the resource base. However, our current empirical specification does not allow us to assess fully the relative distance elasticities of cost and price.

In the non-standard case of biological depensation, the conceptual model indicates that the comparative static results switch signs. That is, increased remoteness increases fishing effort if **price** decays with distance more rapidly than opportunity cost. With critical depensation, extending market infrastructure without addressing the fundamental lack of property rights to the resource could easily produce stock collapses under certain circumstances. As such, a full assessment of the impacts of infrastructure development on the resource base ultimately requires a better understanding of the population dynamics of the exploited species. In related work, we are exploring independent assessments of reef quality and how they can be used as indicators of resource abundance and predictors of harvest.

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