

# Open access in a spatially delineated artisanal fishery: the case of Minahasa, Indonesia

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**ABSTRACT.** The effects of economic development on the exploitation of renewable resources are investigated in settings where property rights are ill defined or not enforced. This paper explores potential conservation implications from labor and product market developments, such as enhanced transportation infrastructure. A model is developed that predicts individual fish catch per unit effort based on characteristics of individual fishermen and the development status of their villages. The econometric model is estimated using data from a cross-sectional household survey of artisanal coral reef fishermen in Minahasa, Indonesia, taking account of fishermen heterogeneity. Variation across different villages and across fishermen within the villages is used to explore the effects of development. Strong evidence is found for the countervailing forces of product and labor market effects on the exploitation of a coral reef fishery.

## 1. Introduction

In many developing countries, besides the lack of property rights (open access), other forms of market failure and imperfections plague renewable resource industries. Of central importance in determining the status of a particular resource is its location relative to labor and product markets, as these drive the effective prices and opportunity costs faced by the traditional users. Small-scale artisanal fisheries are striking examples because open access to the resource is typical, and the remoteness of small fishing communities contributes to high and often prohibitive transaction costs in the labor and product markets. The combination of these economic forces largely determines the biological status of the resource base and profoundly affects human well-being. Because regional development is the driving

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force behind changes in the market setting, understanding the development patterns in artisanal fishing communities is vital.<sup>1</sup>

The impacts of development on open access resource industries differs substantially from its impacts on managed resource industries.<sup>2</sup> A common occurrence throughout the developing world is that open access resources are often more degraded close to densely populated areas and centers of development (Deacon, 1994). Usually, the more remote a location is, the healthier the resource is. This phenomenon leads to the general presumption that development, especially in its early stages, is detrimental to unmanaged environmental resources.<sup>3</sup> On the other hand, it is often suggested that expanding employment opportunities might counteract this pressure on open access resources. This paper examines the link between market development and the level of resource exploitation in a traditional, open access, coral reef fishery in Indonesia.

Although the fisheries economics literature in general understands the implications of open access as a single source of market inefficiency, the importance of market development cannot be underestimated. *Economic* overexploitation in an open access equilibrium does not necessarily translate into biological consequences, but high levels of effort usually do, especially when destructive fishing is included. An individual's shadow wage is a key determinant of the intensity of exploitation in an artisanal fishery. While economic overexploitation is the typical result of open access, the levels of market development have an ambiguous effect in that they may mitigate or intensify high effort levels. When development takes place, for example the building of infrastructure, the impact on local opportunity costs and on product prices is a critical determinant of the net impact on the open access resource.

The village is usually the smallest market unit in a less developed country. Markets in developing countries are often characterized by various inefficiencies and failures, which can broadly be defined as imposing transaction costs. The process of development – distribution and creation of information, connection of the village to transportation networks, and integration into a modern economy – facilitates more efficient markets. Village development, or development of the region, creates more opportunities to supply products and labor.

<sup>1</sup> The process of economic development can have a direct impact on the health of coral reefs. Land clearing and construction activities can result in increased loads of sediment and other pollutants in coral reef areas (Richmond, 1993). These environmental stressors contribute to coral bleaching and may cause irreparable harm to coral reefs (Brown and Ogden, 1993). However, the focus of this paper is on the effects of fish harvesting on the reefs.

<sup>2</sup> For our analysis, we assume that general, society-wide development is exogenous to the fishery. In societies that are extremely dependent on fishing, the general development might be tied to the fate of the fishery. In this case, development would be endogenous and would have to be treated differently.

<sup>3</sup> Development of property rights or policies for efficient management are usually the last to evolve, probably due to the difficulty of allocative and distributional issues involved. This paper is only concerned with open access resources.

In the product market – typically regional – transaction costs create a wedge between the purchase price and the sales price received by the fishermen. Less physical and institutional infrastructure, less information, and higher risk – all elements of less development – increase this band. We define transaction costs in the broadest terms. Besides transportation costs, we include for instance the loss of value as fresh product degrades en route to market. Similarly, switching from a high value product to a less valuable one can be conceived of as imposing transaction costs. This might be the case if the catch cannot be sold fresh at all but rather has to be dried or salted for shipment to market. Finally, it should be noted that market failure in terms of transaction costs is household and not commodity specific (de Janvry *et al.*, 1991).<sup>4</sup>

Labor market transaction costs occur in part because it is prohibitively costly to commute from a remote fishing village to another village for employment, implying a missing regional labor market.<sup>5</sup> In very remote villages, virtually all individuals are self-employed, leading to a truly missing market. Further, local employment opportunities are only available to varying degrees and with specific requirements. In rural villages that are less remote, employment opportunities exist for manual labor in fields. In small towns, the labor market is quite diverse, even within the category of manual labor. As village size and development increase, other work activities requiring education and other skills become available, and these jobs pay higher wages.

Regardless of whether labor markets exist or not, each individual faces an opportunity cost of time, be it either a shadow wage or an actual one. Household specific shadow prices for fish and leisure will clear the internal time market, if a household engages solely in fishing. Alternatively, if the household can sell some of its labor in a market, the marginal returns (in terms of utility) across all activities must all equal the going wage rate. Different scopes and scales of village labor markets lead to different wages. Along this progression of increasing, alternative uses of a household's time, the value of this time increases.

An individual's shadow wage is a key determinant of the intensity of exploitation in an artisanal fishery. Artisanal fishermen in developing countries use predominantly wooden boats and cheap, easily produced gear (Munro, 1996). While this capital is clearly indispensable to the fishing enterprise, most of it can be produced by the fisherman himself; and the maximum supply, contrary to labor and land, is not fixed. The acquisition of the capital represents a sunk cost, and variable costs (maintenance) are low. Hence, the dominant input in a developing country artisanal fishery is human labor (Dalzell, 1996). The level of exploitation of the resource is, therefore, principally a function of the labor supplied.

<sup>4</sup> Whether these high transactions costs are true market failures depends on whether there exist investments that would reduce these costs and have positive net benefits, but the investments are not being made for institutional or other reasons.

<sup>5</sup> Seasonal migration, often a prominent factor in developing countries, is ignored in this article. In the study area it is only a minor activity among fishermen.

In summary, we hypothesize that in a developing country as the distance from well-functioning modern markets increases, the added transaction costs in the labor and product markets lead to falling returns to resource exploitation and falling opportunity costs of time. While lower returns reduce pressure on the resource, lower opportunity costs increase it. Development, and development of markets in particular, can thus either exacerbate or ameliorate the tendency toward high levels of effort of open access resource industries.

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), while Smith and Wilén (2003) develop an empirical bioeconomic model of a spatially delineated limited-entry fishery. However, none of these studies focusses on labor or product market failures. Most research, both theoretical and empirical, on missing labor markets in developing countries comes from agricultural household production studies (de Janvry *et al.*, 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 studies renewable resource exploitation under various market assumptions focuses primarily on forest resources (Bluffstone, 1995; Angelsen, 1999; Pendleton and Howe, 2002). While these models do not transfer well to our case, they do generally show the critical importance that markets play. In a numerical model, Bluffstone (1995) finds that the net effect of labor market development is a decrease in deforestation, while Pendleton and Howe (2002) empirically show that increasing product market integration exacerbates deforestation. Contributions by Chomitz and Gray (1996), Omamo (1998), and Jacoby (2000), again in the agricultural development context, show that infrastructure development, such as roads, generates benefits for the rural households and influences their labor allocation decisions. Chomitz and Gray further show that roads can facilitate deforestation. We will show that in artisanal fisheries, whether roads increase or decrease open access resource exploitation depends on how roads affect labor and product markets.

The next section outlines the conceptual model and derives the basic implications of an open access equilibrium under different labor and product markets settings. The core of this paper develops an empirical model of the resource status as a function of the level of market development. Empirically, we look for evidence that the determinants of behavior, i.e. market characteristics, actually impact the resource. Creating an empirical model and testing its predictions is difficult, due to the lack of independent data on the biological health of the resources. Ideally, measures of the resource status for each village would serve as dependent variables in any such regression. Instead, we develop an empirical model based on the insight that each fisherman's catch per unit effort (CPUE), when corrected for variation specific to the individual, mirrors the aggregate resource status. In this manner, household sample survey data can be used to link the resource health to village and market characteristics. Using the productivity of labor as a proxy for the scarcity of a renewable resource

has been done before in the context of fuelwood collection and non-timber forest products in general (Sills *et al.*, 2003). Section 3 describes the pertinent elements of the empirical setting, while section 4 specifies and estimates an empirical model. Section 5 discusses the results.

## 2. A simple conceptual model – illustration of the ‘fishing effort market’

In an equilibrium, open access situation, additional effort applied to the fishery has a negative impact on the overall value of the resource to society. The only assumption that we make concerning the resource is about the relationship between the resource status and the aggregate effort exerted on it. We posit that an increase in aggregate effort will degrade the resource and make it less productive, i.e. (the value of) CPUE will decrease.<sup>6,7</sup> For example, the degradation of a coral reef resource could take the form of reduced fish stocks, impaired reef areas, loss of high-valued species or any combinations thereof. Graphically, this implies that CPUE (such as kg per hour) is a downward sloping function of *aggregate effort*.<sup>8</sup> The health of the resource deteriorates along this curve toward the bottom right. At low CPUE values, the large fishing impact will likely create an unsustainable and possibly irreversible situation.<sup>9</sup> Incorporating this catch – effort relationship into a demand and supply diagram of effort leads to figure 1.

Figure 1 depicts a hypothetical or ‘shadow’ market for the effort exerted on one resource. In an artisanal setting, this will usually correspond to a labor market, as this is the primary component of effort. For illustrative purposes, the effort supply curves, or labor supply curves, are assumed to be horizontal (infinitely elastic). We relax this assumption in the empirical analysis. These curves can be thought of as being derived from the minimum return or implicit reservation wage an individual expects for one unit of labor, i.e. the opportunity cost of his or her time. The downward-sloping effort ‘demand’ curves are derived by multiplying the CPUE function from above by a constant price for the catch. We also relax the assumption of constant price in our empirical work. They represent the possible return (revenue) to one unit of labor given an aggregate effort level (or marginal product of labor). The return is determined by the health of the resource, which itself is a function of the total effort, and the price of fish.

<sup>6</sup> We are comparing steady states, i.e. we are ignoring transitional effects (such as rent appropriation).

<sup>7</sup> It is also possible that the resource could be degraded without CPUE dropping if higher trophic species are extracted first followed by lower trophic species. In our field work, we did not notice that CPUE differences were attributable to catch compositions, but our data do not allow us to rule out this possibility.

<sup>8</sup> This imposes no restriction on the aggregate catch (*catch per unit effort* times *total effort*). The total catch can increase or decrease with an increase of total effort depending on the particular shape of the curve.

<sup>9</sup> The most extreme example is the use of destructive fishing methods like cyanide fishing and dynamite fishing.

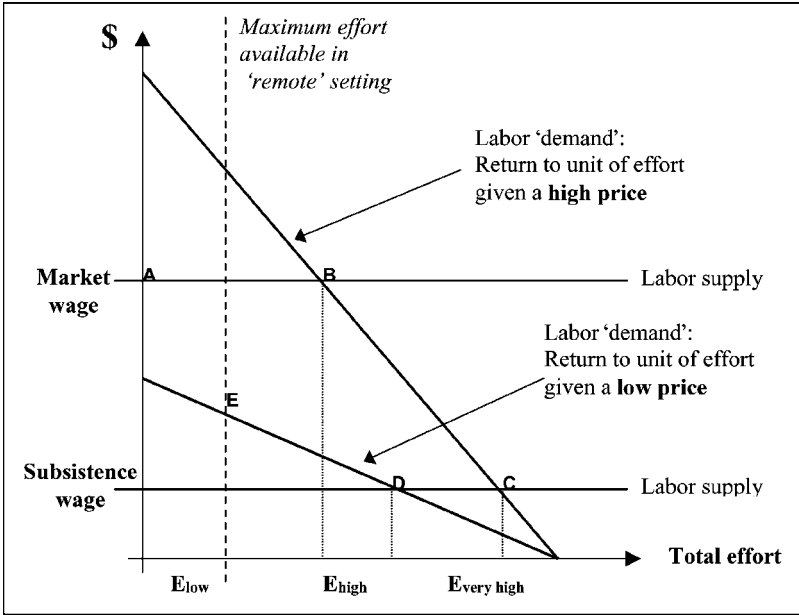


Figure 1. Fishery effort market – Labor supply and demand curves

By assuming fixed prices and fixed costs, a medium-to-long-term perspective is implied. For now, we offer no explanation for what might determine these prices and costs and assume them to be exogenous. We also ignore the various forms this effort increase might take in a traditional fishery, be it fishing intensity, entry, migration, population growth or any other conceivable way. In essence, this is a simple, straightforward depletion story.

Figure 1 depicts two effort demand and two effort supply curves. The demand curves correspond to low or high price situations. The two effort supply curves correspond to situations of low and high opportunity cost of exploiters' time. Four economic equilibria, A through D, are shown. A low price combined with high opportunity costs will lead to a resource that is close to pristine (zero to low effort) [A]. A resource with similarly high opportunity costs but with high prices will be substantially exploited (high effort) [B]. When opportunity costs are low and prices high, the pressure on the resource will be highest [C]. Yet, even if prices are low, low opportunity costs could still lead to high level of exploitation [D] if the population of exploiters is large relative to the resource.

So far we have ignored the size of the resource. Horizontal effort supply curves imply an unlimited availability of labor, i.e. the population size (the potentially available labor) is large relative to the resource. Intuitively, this means that the human effort that can be brought to bear on a resource exceeds, by a large margin, the level of aggregate effort, where the individual's net return is negative. This will be the case for situations

with high opportunity costs<sup>10</sup> [A,B] and with high prices (as this implies demand) [B,C]. In these situations the resource, regardless of its size, will be fully exploited economically. Whether the resource is depleted biologically in these cases depends on costs and prices. Only in situation [D] might the size of the resource matter. If the population is small relative to the resource, the horizontal effort supply curve is inappropriate. In this case, labeled the 'remote' setting, the maximum level of effort that can be exerted by the population will determine the total pressure on the resource [E]. In other words, the exploitation of the resource is constrained by the available effort, and the situation will not be an open access equilibrium in the conventional sense.

As indicated above, in the absence of regulation, resource exploitation is driven by benefits and opportunity costs, be they material or psychological. What might determine prices and costs in a traditional setting? The most important determinants underlying the prices and costs that drive overexploitation in open access situations are, on the one hand, high population density, large market size and good market access (proximity), and, on the other hand, poverty and a lack of alternative productive activities or employment, i.e. an economic environment where human effort has a low opportunity value (McManus, 1996). The latter occurs when low levels of economic development, high population density, and low agricultural productivity (low fertility of the land or lack of intensification) combine. In such an environment, individuals are likely to require little more than a subsistence wage, i.e. a return per unit of effort that covers the minimum necessary to survive. In a wealthier economic environment, where alternative forms of employment exist, exploiters will expect a return of at least the going labor market wage, i.e. they have higher opportunity costs. The remainder of this paper focuses on the determinants of these prices and opportunity costs. In particular, we will look at development as it relates to product and labor markets in a coral reef fishery in Indonesia.

### 3. Empirical setting and data

The empirical setting is the artisanal, coral reef fishery of the Minahasa region of Indonesia on the island of Sulawesi (see map in figure 2). Interviews with stakeholders and experts at the local university and local NGOs, a cross-sectional household survey and a survey to gather village-level data (interviews with village leaders) have led to the construction of an extensive data set on the coastal communities in the area (Kramer *et al.*, 2002). 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. Focus groups with fishermen

<sup>10</sup> This is difficult to see without expanding on the reasons for a high opportunity cost of time. The price of time will only be high if there are many alternative productive activities available. In theory, all of this labor could be redirected into resource extraction.

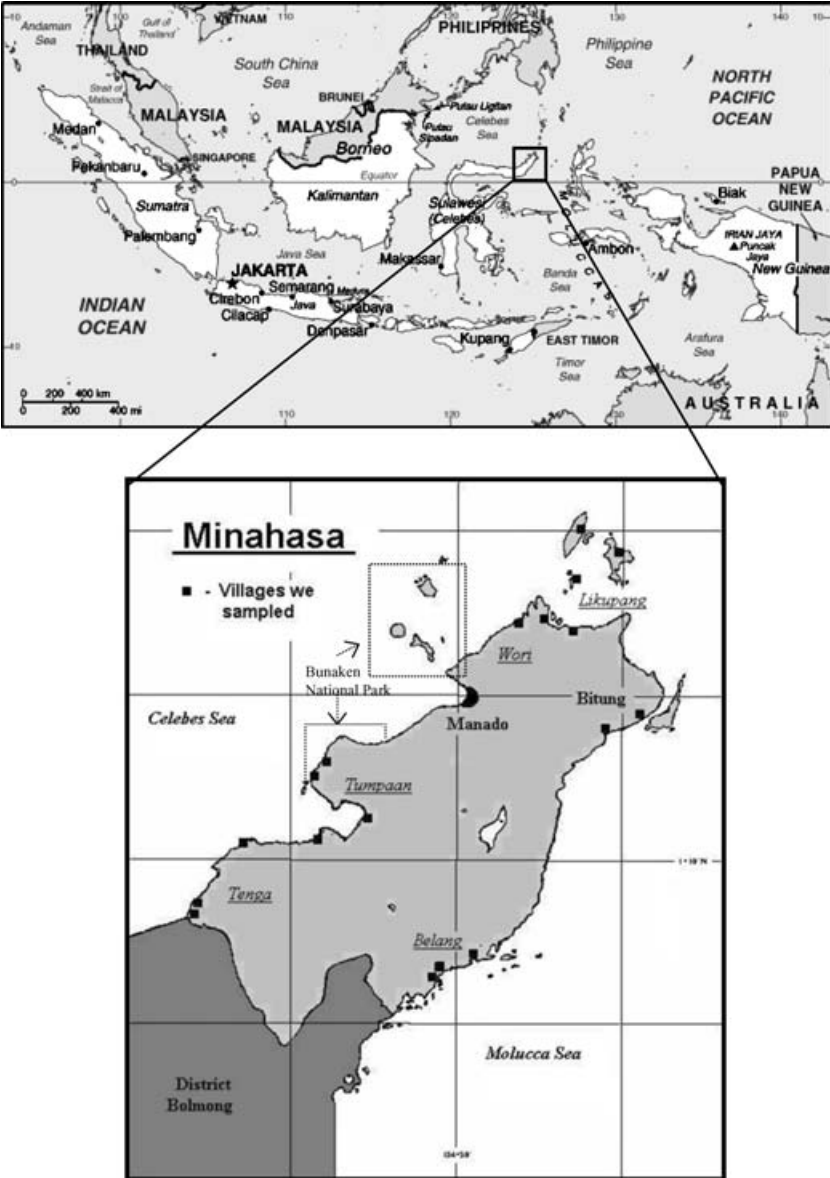


Figure 2. Map of study area, including locations of surveyed villages

and extensive pretesting assisted in the design of the household survey instrument. After a sampling frame was created by initial visits to most coastal villages, 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 that ensured population-weighted sampling of each selected



village. The survey was implemented in July 1999 with the help of recent graduates from a university in Minahasa, who, after three days of training, served as interviewers.

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 larger population centers. Smaller roads that connect villages to population centers are not always asphalted and are often poorly maintained. Tropical climate and mountainous terrain (up to 2,000 meters) make passage on these roads difficult and sometimes impossible. Some villages do not have any road access. By sea, traders move fish from these villages 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 and Bitung are, besides national air and sea transportation hubs, industrial processing centers of the region's agricultural and natural resources. Bitung also supports several canneries.

The village economy can be characterized as a cash economy with a significant subsistence element. In most of the villages, the primary productive activities besides fishing are coconut and clove farming. Both are valuable cash crops that are on average more profitable than fishing. However, we observe that a substantial portion of the villagers fish since land poses a constraining factor on agricultural production. Property rights for land are well defined and a functioning land market exists. A large fraction of the artisanal fishing households own a limited amount of land and hence engage in both farming and fishing. Because the land constraint typically binds before a labor constraint, fishermen without land have few opportunities for employment on coconut or clove farms.

The development level varies too (Liese, 2003). All but one village have electricity, yet the electricity supply is often rationed and unreliable. Water, especially for washing, is usually drawn from wells within the villages themselves, while drinking water is brought in from outside, either by hand or by cheap, above-ground piping. Trash is burned or buried, but is also frequently discarded in the sea. All villages have at least an elementary school and many have a secondary school as well. Nurse offices can be found in most villages and a health team visits those without an office once a month. Only larger towns have high schools and clinics. Recently, the government supplied each village head with a telephone. Very few individuals own cars. A general indicator of the village development level is the percentage of households that cook with wood as opposed to modern fuels or electricity. The use of wood averages 44 per cent in our sample villages and ranges from 5 per cent to 100 per cent (table 1).

For our analysis we conceive of the coral reef resource as simply as possible. An artisanal fishery's resource is best represented by the entire coastal ecosystem. The service it produces for the fishermen, the catch, depends on three inter-related characteristics of the resource: the extent of the habitat, the quality of the habitat, and the size of its component fish stocks. Yet general methods to actually estimate the sustainable yield of

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

	<i>Average</i>	<i>Weighted Average (village pop.)</i>	<i>Standard Deviation</i>	<i>Minimum</i>	<i>Maximum</i>
Population size	2,518	—	2,482	535	7,115
Distance to market (km)	11.8	6.3	10.84	0	40
Fishing households	44%	48%	0.25	10%	95%
Number of fishing households	242	378	180	32	566
Wood as primary cooking fuel	44%	39%	0.33	5%	100%
Wage of coconut picker (Rp.)	21,346	20,203	5,851	14,750	30,000
Catch per unit effort <sup>1</sup>	2.9	2.6	4.55	0.8	11.8

*Note:*<sup>1</sup>Catch per unit effort represents the village average kilogram of fish per hour of time spent 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.

different reefs, much less individual species, still remain elusive (Polunin, 1996). Reef fishermen use many different types of gear across spatial and temporal dimensions in order to catch a large variety of species. As a result, a clear distinction between different fish stocks, as well as the resource's spatial size and its health, disappears. We abstract from these distinctions and focus on an index of the overall resource level or status at the village-level stock. The limited range of the artisanal fishermen and the fact that most 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.<sup>11</sup>

Descriptive statistics for the villages in the 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 7,115 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 here. The shortest distance from the villages to large population centers with easy access to fish markets is on average 11.8 km. For six villages, this distance reflects transportation

<sup>11</sup> Unlike the Sanchirico and Wilen (1999) model, this 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.

by sea.<sup>12</sup> Variation in the economic specialization of each village is also apparent. The daily wage paid for the most menial of manual labor, that of the coconut picker in the villages, varies by a factor of two. The average wage across the villages, 21,346 Indonesian Rupiah, corresponds to approximately US\$2.40.

The final entry shown in table 1, the average CPUE of artisanal fishermen in each village (in kilograms per hour), is central to this article. The overall 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 unobserved differences in gear use and fisherman skill) and some may be attributable to natural productivity differences across reefs, 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.<sup>13</sup> As a result, efficient resource management cannot serve to explain effort variation, and the assumption of an open access property rights situation is justified.<sup>14</sup>

Combining this empirical context with the earlier conceptual model leads to the following hypotheses: (i) transportation distance to a product market increases the open access equilibrium CPUE<sup>15</sup> and (ii) a larger local labor market, possession of private land, and greater human capital also increase open access CPUE. We set out to separately account for each of these effects.

#### 4. The empirical model and estimation

We now develop an econometric model that describes the CPUE across multiple resource stocks that individually are characterized by open access equilibria with varying levels of economic development. Each fishing village has a distinct corresponding reef fish stock. The open access equilibrium condition, that CPUE must equal the cost/price ratio, serves as a moment for the estimation procedure. Moreover, this cost/price ratio condition must also hold at the individual level. As a result, we use as the dependent variable the CPUE of each individual fisherman. The cost/price

<sup>12</sup> These include three villages on islands off the coast of Sulawesi (5–16 km), one village with no road connection, and two villages with roads of such poor quality that most transportation is done by sea.

<sup>13</sup> In interviews with local fishermen and key informants, reasons mentioned for the lack of local management are low overall organization, low priority of marine issues, village administration is overworked, and lack of jurisdiction.

<sup>14</sup> 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 the sample period. Of the survey respondents, over 50 per cent were born outside the village they live in and 25 per cent were born outside the Minahasa region altogether. 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.

<sup>15</sup> We assume concavity of the stock growth function.

ratio, which is the opportunity cost of each individual's time over the price of fish in his particular village, depends critically on the level of labor and product market development.

Dividing the aggregate catch by the aggregate effort yields the CPUE ( $CPUE = h/E$ , where  $h$  is harvest and  $E$  is effort), which is a central measure in fishery economics. Under the assumption of a Schaefer production function, the CPUE is always proportional to the resource stock ( $CPUE = qX$ ). The catchability coefficient  $q$  summarizes the bio-mechanical relationship between gear and fish and  $X$  is the fish stock. Under standard biological assumptions, a large CPUE implies a large fish stock, while a small CPUE implies a smaller stock. Furthermore, large stocks, i.e. large CPUEs, correspond to low levels of aggregate effort in the steady state. In an open access equilibrium, due to the zero rent condition, we further know that the CPUE must equal the cost ( $c$ ) to price ( $p$ ) ratio of fishing effort and fish ( $CPUE = c/p$ ).<sup>16</sup> This implies that the economic relationships (on land) that determine the effort cost (opportunity cost) and the fish price, also dictate the CPUE and hence the stock level under open access.

Theoretically a single stock has a single CPUE, which is constant as long as the stock size and the catchability coefficient do not change. Dividing the catch of a representative individual by his effort will also recover a consistent estimate of the stock-wide CPUE. Hence we can in principle use individual observations to recover the CPUE. The advantage from an empirical perspective is that by using individual CPUE neither data on aggregate effort and catch nor biological data on the stock size need to be collected in order to create an indicator of the resource stock. For our purposes this is a very helpful approach, given the limits to data collection in a developing country, compounded by the complexity of coral reef fish stock assessment.

Yet it is a standard observation in fisheries that some individuals known as highliners consistently have high catches relative to their effort (Johnson and Libecap, 1982). When compared with others, they seem to violate the open access zero-rent condition. One explanation for this phenomenon is that the apparent fishery rents are not rents accruing to an open access resource, but rather are returns to an individual's fixed input, such as entrepreneurial skill. In an artisanal fishery where effort predominantly consists of human labor, a measurable CPUE is kilograms of fish per hour of time spent at sea. While the theoretical CPUE construct omits individual heterogeneity, we must assume that the measured CPUE fully captures individual skill heterogeneity in an artisanal fishery. Effectively, this means that individuals who have higher opportunity costs due to education, land ownership, or access to non-fishing employment opportunities will appear as more skilled fishermen. While the observed individual characteristics may be correlated with fishing skill, it may also be true that individuals with other opportunities are selectively choosing the days on which to harvest. That is, they are taking advantage of intra-seasonal variation in

<sup>16</sup> This assumes that price and cost are constant.

the resource base and selectively fishing on days when they are likely to capture more fish.

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

$$p_i h_i - c_i E_i = 0, \forall i, \tag{1}$$

where  $h_i$  and  $E_i$  are individual catch and effort, and where  $p_i$  and  $c_i$  are the relevant fish price and opportunity cost. Opportunity costs depend on the availability of employment opportunities and individual fisherman heterogeneity.<sup>17</sup> In essence, a fisherman’s choice of equilibrium fishing effort is based on the individual’s shadow wage. We do not directly observe individual prices and opportunity costs,<sup>18</sup> but we do observe factors that influence them, such as market development. Rearranging (1) and substituting functions for cost and price, we have the following

$$\frac{h_i}{E_i} = \frac{c_i}{p_i} = \frac{g(\mathbf{z}_i)\varepsilon_i^c}{f(\mathbf{x}_i)\varepsilon_i^p}, \tag{2}$$

where  $g(\mathbf{z}_i)$  and  $f(\mathbf{x}_i)$  are unknown opportunity and price functions, respectively. The vectors  $\mathbf{x}_i$  and  $\mathbf{z}_i$  can contain observable individual-specific determinants of product price and opportunity cost of fishing effort, whereas  $\varepsilon_i^c$  and  $\varepsilon_i^p$  contain unobservable individual-specific determinants. We assume that the unobservable components are strictly positive such that they scale the functions of observables. In the regression, the regressors  $\mathbf{x}_i$  will vary only at the village level (implying that the village fish price is independent of the individual). The regressors  $\mathbf{z}_i$  will vary across individuals within the same village.

Equation (2) states that the individual fisherman’s CPUE in open access must equal the individual’s cost/price ratio. We generate the CPUE measure by dividing the average catch in kilograms per trip of each fisherman by the length in hours of his fishing trip. Taking the logarithm of both sides yields

$$\ln(\text{CPUE}_i) = \ln\left(\frac{h_i}{E_i}\right) = \ln g(\mathbf{z}_i) + \ln \varepsilon_i^c - \ln f(\mathbf{x}_i) - \ln \varepsilon_i^p. \tag{3}$$

Since we have no a priori reason to choose a particular specification for the functions of fish price ( $f(\mathbf{x}_i)$ ) and opportunity cost ( $g(\mathbf{z}_i)$ ), we used the Box–Cox regression model with separate Box–Cox transformation parameters for the left-hand and right-hand side variable(s). The model tested down to the simpler semi-log model, where the dependent variable is re-scaled with

<sup>17</sup> 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.

<sup>18</sup> The large variety of species, different customers for different species and seasons make it impossible to observe a full price vector for each individual. Similar considerations obscure wage data.

the natural log, while the independent variables remain linear.<sup>19</sup> The latter part implies that the price and cost functions are exponential functions. As a result the estimation equation becomes

$$\ln(\text{CPUE}_i^{\text{Empiric}}) = \beta_0 + \sum_k \beta_k z_{ik} - \sum_j \gamma_j x_{ij} + \eta_i, \quad (4)$$

where  $k$  indexes cost factors,  $j$  indexes price factors, and  $\eta_i$  is a composite random disturbance that reflects the difference  $(\ln \varepsilon_i^c - \ln \varepsilon_i^p)$  as well as sampling error. Though we cannot separately identify the components in  $\eta_i$ , normally distributed regression errors are consistent with normally distributed sampling error and  $\varepsilon_i^c$  and  $\varepsilon_i^p$  having IID log-normal distributions. This situation, in turn, is consistent with our assumption of strictly positive unobservables in (2).<sup>20</sup>

Following the earlier discussion, we posit that the level of market development, i.e. the distortions of the product and labor markets, are the primary determinants of price and opportunity cost. The variables that will serve as proxies in the regression for this variation over space are the following: geographical distance to major market in kilometers, a dummy variable to represent that sea transportation is the predominant form for villages on islands or those without adequate roads, the village population size in multiples of 1,000 individuals, and a dummy variable to signify the ownership of land and a variable for the education of the fisherman to correct for individual heterogeneity.<sup>21</sup> We also include a dummy variable to indicate whether the fisherman has a motor and a dummy variable to indicate whether there is at least one extra crew member on board. In the log-specification, including these variables on the right-hand side is consistent with them scaling fishing effort.

We use ordinary least squares to estimate the three regressions that are reported. 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 categories of fishermen in

<sup>19</sup> The coefficients and the standard errors for the Box-Cox transformation parameters for the three regressions reported later are the following:

Regression I: LHS 0.016 (0.040), RHS 1.013 (0.526)

Regression II: LHS -0.005 (0.043), RHS 0.605 (0.385)

Regression III: LHS 0.032 (0.058), RHS 1.117 (0.661)

The Box-Cox transformation parameters on the dependent variable are never significantly different from zero, calling for the logarithmic scale. The parameter on the independent variables is significantly different from zero (at 5 per cent, 12 per cent and 9 per cent confidence) and close to one, indicating a linear relationship.

<sup>20</sup> The joint hypothesis of the error distribution having zero skewness and being mesokurtic (i.e. being normally distributed) could not be rejected for the three ways of cutting the sample discussed later. The Wald statistics are 3.19, 1.82, and 0.01, while the 95 per cent confidence value is 5.99 for the chi-squared with two degrees of freedom.

<sup>21</sup> 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.

Table 2. Catch per unit effort regressions I through III (dependent variable: natural log of kilograms per hour)

	I	II	III
Constant	-0.76486** (-2.56)	-1.25987*** (-4.26)	-1.57384*** (-4.15)
Distance to market (km)	0.01921** (2.57)	0.02064*** (2.79)	0.02053** (1.99)
Island or sea access dummy	0.47787** (2.62)	0.48735*** (2.65)	0.40941* (1.84)
Village Population (1000)	0.17509*** (3.69)	0.20577*** (4.49)	0.21471*** (3.6)
Owens land dummy	0.36625** (2.18)	0.29935* (1.79)	0.4741** (2.32)
Education	0.11549 (1.28)	0.21957** (2.45)	0.33897*** (2.81)
Motor dummy	0.91141* (1.75)	0.82073 (1.52)	-
Extra crew dummy	0.38534** (2.52)	0.37656** (2.42)	-
Number of observations	353	312	169
R <sup>2</sup>	0.102	0.122	0.143
Average kg/hour	3.33	2.63	2.19

Notes: t-statistic in parentheses. \*, \*\*, and \*\*\* indicate significant at the 0.10, 0.05, and 0.01 levels respectively.

Minahasa. One group consists of small-scale artisanal fishermen who rely on the near-shore coastal resources (in particularly the coral reef). This fishery is the focus here. The other group consists of fishermen (both owners and crews) engaged in large-scale motorized fishing operations that target off-shore pelagic fish stocks and hence have no impact on the coastal resource. 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. The second reason, related to the first, is that the technology employed is a determinant of CPUE. Since we only have coarse technology variables as regressors (a motor dummy and a dummy for extra crew), differences among fishermen will increase the unexplained variation in the regression. To address both concerns, the three regressions 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 100 kg. Model II restricts the number of observations further by lowering this threshold to 50 kg. 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. As such, the motor dummy and crew dummy cannot be estimated.

The regression results are shown in table 2. The R<sup>2</sup> ranges from 0.102 to 0.143, increasing with additional sampling restrictions as would be

expected.<sup>22</sup> The F tests (joint hypotheses that all slope coefficients are zero) are 5.61, 6.06, and 5.45, all highly significant. Distance to major market is significant at the 1 per cent (II) and 5 per cent (I and III) levels, while the island/sea-access-only dummy is significant at the 5 per cent (I), 1 per cent (II), and 10 per cent (III) levels. The village population size is significant at the 1 per cent level.

The significance of these variables raises the question: which relationship do they capture? While an average geographical distance of 12 km to a major market might not seem great, one must look at this 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 transportation. In the absence of significant commuting beyond a village, both geographical distance to major markets 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. On the other hand, 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.<sup>23</sup> 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.<sup>24</sup> More importantly, the logistics of coordinating fishing with appropriate and timely delivery to market impose a significant cost on distance. Overall, this argues to think of the distance and the island/sea-access-only dummy as variables that primarily capture relationships in the product market.

Village population size could proxy for relationships in the labor market, yet it also determines the local fish market available to the fishermen. 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 price minus transaction cost, i.e. transportation and marketing. Empirically, the rural prices are a fraction of the major market prices, since villagers consume the lowest quality fish themselves, and villages do not import fish from major markets (i.e. villages are always in surplus). Moreover, we would expect that marginal prices

<sup>22</sup> The low  $R^2$  must be judged in the context of a cross-sectional, developing country data set based on each fishermen's recall of his *average* fishing behavior and outcomes. Further, there is much unexplained variation at the individual, village, and regional levels.

<sup>23</sup> For example, based on a price survey conducted by our research team in three of the 17 villages, the price level, expressed as a percentage of the retail price in the urban market, is approximately 90 per cent in small towns and 55 per cent for remote villages on the coast of Sulawesi. Sea transportation from the islands and villages without road access will, almost surely, reduce the price level further.

<sup>24</sup> Dried and/or salted fish is an obvious response, which lowers the value of the product, i.e. the return to the fishermen.



would determine marginal exploitation. Thus, the 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, 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 has more jobs from which to choose. It is fairly implausible that land ownership by – or education of – an individual will affect the fish price he receives for his catch. In essence, geographical distance and the island dummy are proxies for (the lack of) product market integration, while village size stands in for labor market development. Education and farming variables correct for differences in individuals' time allocation possibilities. These circumstances, where the regressors distinctly proxy for labor and product market distortions, allow us to identify the markets' offsetting effects on the resource and to speculated as to which effect dominates.

The distance to major market and island/sea-access-only coefficients have positive signs, consistent with their interpretation as proxies for relationships in the fish product market. Longer distances to market and transportation routes by sea, both of which correlate with number of middlemen and transaction costs, raise the CPUE 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 coefficient on village population size is significantly positive. This, our most important result, seems at first counter-intuitive: the larger a village, the healthier its resource, *ceteris paribus*. Yet a positive sign is consistent with its interpretation as a proxy capturing the labor market relationships. Alternative employment opportunities will raise the opportunity cost 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, *ceteris paribus*, will hence exhibit higher CPUE values. Again, given the standard assumptions, this implies a larger stock size and a less exploited resource. It should be noted that we would expect the impact of village size on the fish price, if it exists at all, to be positive. If the size of the village *does* raise the fish price to some extent (which we argued was not the case), this would counteract the labor market effect. In this case the magnitude on the village size coefficient is only a lower bound for the effect of the labor market on the resource stock, i.e. our most important empirical result is a conservative estimate.

Land ownership and education are both positive and, in all but one case, significant at (at least) the 5 per cent level. 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.

Finally, neither the significance nor the magnitudes of coefficients differ much between model III and models I and II. We take two different approaches to controlling technology: including regressors for motor and extra crew (I and II) and limiting the sample to small-scale individual fishermen with their own canoes and no crew members (III). The results

Table 3. *Illustration of changes in the CPUE due to market effects (Benchmark village: 10 km by road to next major market, 2,500 population)*

<i>If an otherwise equivalent village . . .</i>	<i>CPUE change (in kilograms per hour)</i>		
	<i>I</i>	<i>II</i>	<i>III</i>
. . . lacked a road connection	+0.90	+0.76	+0.57
. . . was an additional 20 km from a major market	+0.69	+0.62	+0.57
. . . had an additional population of 1000 people	+0.28	+0.28	+0.27

are consistent across models, suggesting that our results on labor and product market effects are not artifacts of measurement error in the effort variable. 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 regressions. Given the wealth status of the fishermen in the sample, it is not surprising that subsistence does not seem to influence behavior.

To illustrate the magnitude of the actual impact of distance on the CPUE, we make some comparison in table 3 based on the regression results.<sup>25</sup> The benchmark village is located, by road, 10 kilometers outside a major market area and has a population of 2,500. If an otherwise identical village lacked a road connection, i.e. was instead located on an island, an artisanal fisherman's catch would increase by 0.74 kilograms per hour spent at sea (averaged across our three models). On a typical trip lasting eight hours, this result implies an additional catch of almost 6 kilograms of fish. If the otherwise identical village was instead located 30 kilometers from the major market area, i.e. 20 kilometers further away than the benchmark, the catch per hour would increase by 0.63 kilograms per hour. Again, this would mean about 5 kilograms more fish per day for an artisanal fisherman. Finally, if the village grew to a population of 3,500, i.e. an increase of 1,000 individuals, the catch would increase by 0.28 kilograms per hour, an additional 2.3 kilograms per day.

In summary, these regressions and the illustration indicate that both cost and price differentials are active and relevant in determining the stock level and associated resource health of coastal fisheries in Minahasa, Indonesia. They provide support for the hypothesis that development does not necessarily degrade an open access marine resource. Instead, the net effect of development on the marine resource is determined by the differential impacts of the project on the labor and product markets.

## 5. Summary and discussion

This paper illustrates the conceptual effects of resource price and effort cost on an open access resource stock. Population density, market size and

<sup>25</sup> The numbers in the text are averaged across the three regressions, since they are mostly similar.

access, poverty and alternative productive activities, or employment are identified as the most important factors determining prices and opportunity costs. Incomplete labor and product markets, which create significant resource allocation problems in many tropical, coastal communities, are discussed, and their relationship to economic development explored. One insight is that regional or larger levels usually govern product markets, while more local conditions determine the labor market. While the results are not surprising, they emphasize that the specific resource status results from the interplay of opposing economic incentives, which might vary over space. This leads to the hypothesis that the expansion and integration of labor markets protect the resource against the tendency toward increasing exploitation of similar developments in the product market.

Next we generate empirical evidence for the hypotheses derived from the conceptual model. We develop an empirical model to examine variation in CPUE across multiple, open access fish stocks. The empirical model starts with the zero rent condition, which results from an equilibrium, open access model of fisheries exploitation. The model is estimated using data from a household survey of artisanal, coral reef fishermen living in coastal villages in Minahasa, Indonesia. Development levels and product and labor markets associated with each village reef stock differ across the region. The empirical results support the notion that product and labor market effects impact the resource status in opposite directions, and that both effects are statistically and economically significant. Also, fishermen are shown to differ with respect to their opportunity cost of time. Most importantly, we find evidence that development of the labor market lowers the pressure on the resource and hence leads to a healthier stock.

Beyond being the first empirical work to examine the effects of labor or product market imperfections on open access artisanal fisheries, we contribute to the broader literature on the effects of development on open access resources. Recall that Bluffstone (1995) finds a net decrease in deforestation from labor market development, and Pendleton and Howe (2002) find an increase in deforestation from product market integration. Our findings are consistent with both of these studies and are the first to combine these countervailing forces in the same model. However, the implications of property rights establishment are very different in our setting compared with open access forest resources. Angelsen (1999) theoretically shows that increasing land tenure security can worsen deforestation if forests are cleared for purposes of establishing property rights. In the marine environment, reefs are not cleared for some other use to replace them. If anything, we would expect establishment of property rights to reduce fishing pressure and potentially eliminate it altogether in places where benefits of establishing marine parks for tourism exceed the fishing losses.

There is a general presumption that development, especially in its early stages, is detrimental to open access resources, yet this paper shows that the link between development and resource exploitation is more complicated. Economic development drives the development of markets, which in turn govern the prices and costs that are key determinants of fishermen's exploitative behavior and the condition of the resource. We suggest that

development efforts will affect renewable resources depending on the degree to which product and labor markets are affected. Development projects that lower the effective distance of the product market, such as infrastructure projects, will lead to more exploitation. Development projects that raise the opportunity cost of time reduce the pressure on the resource. Projects could increase the opportunity costs of time by expanding the scope and scale of the labor market with new employment opportunities, increasing education, increasing the harvest per acre of agricultural land, or generally reducing poverty. Development, and development of markets in particular, can thus either increase or decrease excessive exploitation in resource industries.

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