Fishing Rights: The Case of the Peruvian Anchoveta Fishery

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Abstract

The implementation in 2009 of maximum catch limits per vessel (LMCE) in the industrial anchoveta fishery has engendered a series of changes in fisheries management. Under this regime, fishing rights, which should strictly represent the resource rent payment made by a boat owner to the state for the use of a public good, were fixed for a period of ten years. This research estimates the resource rent for the industrial anchoveta fishery for 2011, which entails maximum rent, and compares effort under open access and the LMCE regime. The current payment for fishing rights will also be discussed along with private sector contributions, and contrasted to the results found in this study.

Key words: Fishing quotas, fishing rents, fishing rights, Peruvian anchoveta fishery.

Acronyms:

D.L.	Decree Law (Peru)
D.S.	Supreme Decree (Peru)
Foncopes	Compensation Fund for Fisheres Management (Fondo de Compensación para el Ordenamiento Pesquero)
IATTC	Inter-American Tropical Tuna Convention
IHC	Indirect human consumption
Imarpe	Peruvian Institute of the Sea (Instituto del Mar del Perú)
LMCE	Maximum catch limits per vessel (Límites máximos de captura por embarcación)

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Vol. XL, N° 73, Second Semester 2013: pages 7-42 / ISSN 0252-1865

MEP	Maximum economic production
MEY	Maximum economic yield
MSY	Maximum sustainable yield
MSP	Maximum sustainable production
MT	Metric Ton
OA	Open Access
ONP	Pension Standardization Office (Oficina de Normalización Previsional)
OROP	Regional Organization for Fisheries Management (Organización Regional de Ordenamiento Pesquero)
PMCE	Maximum catch percentage per vessel
Produce	Ministry of Production
PVCPD	Surveillance and Control Program for Maritime Sector Fishing and Landings (Programa de Vigilancia y Control de la Pesca y Desembarque en el Ámbito Marítimo)
Sisesat	Satellite system
SNP	National Fisheries Society (Sociedad Nacional de Pesquería)
UIT	Unidad impositiva tributaria[2]
WACC	Weighted average capital cost

2. UIT (Unidad Impositiva Tributaria) is an officially established Peruvian tax unit used to determine tax liability.

INTRODUCTION

Fishing rights have been conceptualized in a variety of ways in fisheries around the world. In some countries, fishing rights are imposed or require fishing licenses, while in others, they are based on the underlying concept of resource rent. In this respect, the definition and calculation of fishing rent is an interesting exercise, albeit not an easy one, since it enables recognition of the payment that the state should receive for the use of a renewable natural resource: in this case anchoveta.

The anchoveta fishery is of particular interest, not only because it ranks among the world's largest, but because in 2008 Peru passed the Maximum Catch Limit per Vessel Law (Ley de Límites Máximos de Captura por Embarcación), which entails the assignment of resource usage rights. Economic theory holds that the implementation of this instrument means that resource rent is the maximum possible compared with the open access status that previously existed.

Peruvian fishing regulations stipulate a charge for fishing rights as payment for the use of a resource belonging to the nation. Each boat owner is charged for fishing rights based on a percentage of the price of fishmeal per ton landed. Recently there has been debate as to the relevance of the quantity of fish landed and whether this genuinely reflects the resource rent, given that the implementation of LMCEs have prompted an increase in the value of the anchoveta resource.

The objective of this paper is to estimate the resource rent for the case of the Peruvian anchoveta fishery, comparing the situation prior to 2009, when open access to the resource existed,[3] to that under the LMCEs introduced in 2011. Furthermore, fishing rights and the payments made by boat owners as a result of the implementation of the quota system is discussed in order to establish whether the estimated rent amount is covered. In this sense, the purpose is to clarify the problems that arise when calculating fishing rent and the extreme variability to which fishing rent estimates are subject as well as to provide recommendations for the effective collection of rents.

This study is divided into five sections. The first introduces the theoretical concept of rent and its application to fisheries. The second section presents the case of the anchoveta

3. It is worth noting that prior to 2009, the anchoveta fishery had been declared fully exploited and the entry of new boat owners was thus prohibited. Moreover, though an overall catch quota existed, the competition for the resource was high, leading to a fishing season of just 49 days per year. This period can therefore be seen as one of open access since the consequences were the same.

fishery and an estimate of rent in the current situation. In the third section, a review is provided of the literature on rent application in a range of fisheries and the methodologies employed. Then a proposal is presented for the model applied to the case of the anchoveta fishery. In the fourth section, a rent estimate is provided for the Peruvian case. Finally, in the fifth section, the results are discussed in light of developments in the anchoveta fishery.

1. THE CONCEPT OF ECONOMIC RENT

The concept of rent in economic theory originates with the classics, specifically with David Ricardo, who in *On the Principles of Political Economy and Taxation* (1973, 1816) defined rent (in accordance with the approach used in his time) as that portion of the land's produce paid to the landowner for its use, apart from production factors. For Ricardo, rent is a consequence of the value of the land, which increases due to its limited quantity and its quality and as a result of population growth. Many authors refer to this as differential rent, which is associated with variations in the quality and fertility of the land.

The concept of rent is also applied to mining, another use of land for which rent is paid to its owner. In Ricardo's conception, the justification for rent paid to the owners of natural resources is the same as that for rent revenue received by a property owner or a franchise awarded by an owner of a brand or formula, among other cases.

Therefore, every factor payment for land is known as Ricardian rent and is determined on the basis of the difference between financial gain and costs. More modern authors use Ricardian rent to refer to the long term profits that can be obtained by low cost producers or to the yield obtained by owners of scarce resources (Nicholson 2007). Thus, from a neoclassical viewpoint, rent is the marginal productivity of the natural resource, whatever this may be.

The economic theory of rent

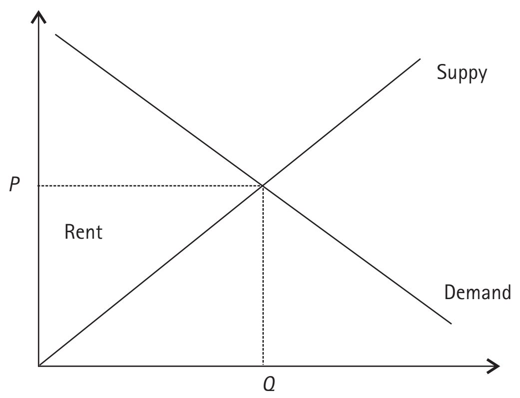
According to Campbell and Haynes (1990: 5), resource rent is a form of economic rent. In general, economic rent is found in company profits, individual earnings, and in the price paid for goods. Undoubtedly, however, economic rent does not cover all profits, only earnings from any activity above or below what is required to render that activity economically justifiable in the long run. This definition requires consideration of two important economic concepts: opportunity cost and normal profits.

Rent is not usually identifiable in regular accounting in companies. In businesses, gross earnings have two components: revenue that covers costs, and profits that provide a return on capital investment. From the economic point of view, gross revenue can be split in two: normal returns, and rent.

Normal returns for an activity are accounted for by revenue that covers production costs (labor, basic ingredients, and other inputs), but also include returns on capital investment, in terms of depreciation of machinery and equipment, as well as the opportunity cost of that investment[4]; that is, that which is not obtained from the best alternative use of this capital must be taken into account (Nicholson 2007). When opportunity cost is considered, the activity returns are regarded as normal returns in the sense that they represent the best result that may be obtained from all available options.

The above mentioned concepts can be seen in Graph 1, in which the supply and demand for any good *Q* is shown. If this good is sold at a price *P*, then the revenue received by the producer is the rectangular area with height *P* and base *Q* (price per quantity). The area below the supply curve for *Q* goods produced represents the production costs, which are lower than the revenue received; the difference obtained is the rent. This graph shows a competitive market in equilibrium in which each producer receives the profits or normal returns on the investment.

Graph 1
Economic rent



4. This is not considered in a company's accounting reports.

In summary, rent is all revenue received in excess over and above production costs measured in terms of economic costs; that is, including the concept of opportunity cost.

Rent in fisheries

Following the definition of rent provided in the previous section, Owen (1998), Hartwick and Olewiler (1998), Charles (2001), Ithindi (2003) and DFID (2004) define fisheries rent as the difference between the landed value of the resource and the total economic costs of taking the catch to port. Simple though it may seem, the application of the concept of rent to fisheries requires the utmost care given the characteristics of this activity (stock variability and uncontrollable weather conditions), the fact that this is a renewable natural resource, and that the assignment of property rights plays an important role in determining rent.

First, it should be noted that boat owners face severe fluctuations in their revenue, which depends on the availability of the resource (species) in question, irrespective of the fisheries management model applied. This is because we are dealing with a natural resource that is subject to multiple uncontrollable factors such as weather variability, and biological and oceanographic factors. Nonetheless, one can expect that, in the long term, boat owners will be able to cover their direct and indirect costs. This situation causes problems in determining rent and the means of collecting it, as will be discussed later on.

Moreover, fishing costs are primarily comprised of fuel, labor, license costs, and costs of capital invested in the vessel and fishing gear (Paredes 2010). These costs depend on vessel type (wooden or steel) and size (hold capacity) and are related to the concept of opportunity cost of capital investment as the equivalent of investment in the best fishing related alternative. The variability of costs also poses a problem in determining rent, especially when consolidated into a single rate or a single per ton amount landed.

Another relevant aspect in determining rent in fisheries relates to resource property. According to Campbell and Haynes (1990: 5), rent should reflect the amount payable for an unexploited resource when an efficient market for it exists and, precisely because no market for the fish exists prior to its extraction, the resource cost is zero for the individual fisher. Therefore, there will be an incentive for fishers to continue fishing until the marginal value is zero and, thus, the rent disappears.

Among the different fisheries, efficient markets are not very common given the lack of property rights assignment. For instance, deep sea fishing resources do not have specific owners, they are found in international waters and therefore access is open, and their management is highly complicated.[5] Even inside the two-hundred mile limit or in the exclusive economic zone, where the Peruvian state is the legal resource owner, the application of property rights remains uncommon for fisheries (FAO 1999). As a result, resource access is traditionally considered to be open. Nonetheless, the fisheries management system, responsible as it is for assigning individual catch quotas, is required to secure maximum profits for the boat owner and the biological sustainability of the species. This system allows the generation of rent (the greatest possible amount) which is maintained over time, unlike in open access in which rent disappears as increasing numbers of boat owners participate in the activity.

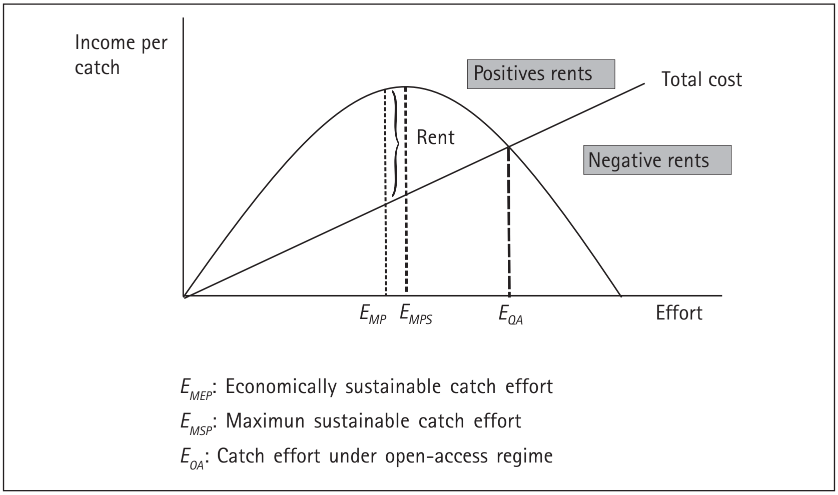
In summary, if a fishery is open access, there will be no resource rent due to the presence of a very large number of fishing boats, which leads to the extraction of the resource beyond biologically sustainable levels. Meanwhile, if a fishery falls under a regime of assigned property rights, the rent generated will be positive and will guarantee a biologically and economically efficient level of extraction.

This situation can be illustrated in a Gordon-Schaefer logistic growth fishery model (Galarza 2010). Here, total revenue (IT) for the fishery is the yield (H) multiplied by the species price (p). If one relates IT to the fishing effort,[6] Graph 2 indicates an initial increase and a subsequent decrease in IT. The total cost is determined, according to Owen (1998), as the unit cost (w), which represents the opportunity cost of factors multiplied by effort (E). Thus, costs increase as revenue increases. When the total revenue ($IT = p.H$) and total cost $CT = w.E$) curves are related, Graph 2 is obtained.

The widest vertical difference between the total revenue and total cost curves measures economic rent. This economically sustainable yield point occurs at a level of effort E_{MEP} and can be reached with a fishery regime that assigns property rights to fishers. In the case of an open access regime, competition promotes a higher effort level, E_{OA}, which leads to an economic rent equal to zero, known as common property yield. Even in the case when an effort level is achieved that allows a maximum sustainable catch (E_{MSP}); that is, biological equilibrium, the rent will not be optimal so there will always be a tendency to increase the effort and the rent will disappear. Therefore, the resource rent depends on the type of fishing regime applied to the fishery (see appendix for further details).

5. Today there are international organizations for the management of certain fisheries in international waters, such as the Inter-American Tropical Tuna Convention (CIAT) for tuna or the Regional Organization for Fisheries Management (OROP) for jack mackerel.
6. Fishing effort includes all costs necessary for extraction.

Graph 2
Sustainable fishing model



Source: Hanneson (1993).

2. THE CASE OF ANCHOVETA IN PERU

The history of the anchoveta fishery in Peru goes back to the 1950s, when development of the fishmeal industry commenced. For more than sixty years, this industry has gone through both expansion processes and crises[7] which were the result of deficient management as well as climactic factors such as the El Niño and La Niña phenomena.

Rent and the fisheries management system

The anchoveta fishery, like many others around the world, has experienced the «tragedy of the commons» (Hardin 1968); that is, the absence of property rights on fish stocks and their habitat, which resulted in the absence of market forces to guide the behavior of this public good. As economic theory has shown (Gordon 1954), common property fisheries present a market failure that is reflected in an excessive expansion of investment, which leads to the elimination of rent for the activity - especially given that a natural resource is concerned. The elimination of rent is accompanied by significant stock reduction (Arnason 2002: 8, 18) which, in some cases, results in the disappearance of a species.

7. In 2010, Peru processed only 3.3 million MT of anchoveta due to the presence of juvenile specimens, which necessitated the imposition of bans. Nevertheless, 787,000 MT of fishmeal was produced and US $1,614 million FOB was exported.

Open access to anchoveta prompted a rush to exploit the resource that resulted, on the one hand, in a progressive reduction of fishing days, from 240 days in 2001 to just 52 days in 2007, and, on the other, in a substantial increase in the daily catch, more than one hundred thousand MT. This meant there was a significant increase in anchoveta fishing and processing capacity as well as considerable environmental impacts as a result of the excessive concentration of landings and processing. According to Paredes' estimates (2010), the fleet's hold capacity stood at between 2.5 and 4.6 times its optimum size, while plant installed capacity was between 3 to 5 times its optimum size.

In 2008, following many years of discussions regarding the establishment of a quota system, the LMCE Law (D.L. N° 1084)[8] was passed for the Peruvian anchoveta and longnose anchovy (engraulis ringens and anchoa nasus) fisheries intended for indirect human consumption. Until then, an instrument of this type had never been applied to one of the world's largest fisheries, a category to which anchoveta belongs[9] (biomass of ten to twelve million tons) nor to one as variable as this fishery (due to the upwelling system in which it is located) (Freón *et al.* 2010; Clark 1976; Díaz *et al.* 2010). Individual catch quotas, as they are known in economic theory, constitute an economic instrument that assigns a property right and thus simultaneously promotes the efficiency and sustainability of fisheries. Unlike open access, this regime allows resource rent to be maximized.

Fishing rights

The concept of rent discussed in the previous section does not apply directly to the case of the anchoveta fishery or to many of Peru's other natural resources, with the exception of mining. Royalties have been applied as a form of taxation with the aim of extracting resources from mining because of the large earnings this industry generates. That is, resource usage rights are usually thought of as a tax - despite having different names - whose purpose is the redistribution of profits.

Nonetheless, the General Fisheries Law (Ley General de Pesca) and its regulations[10] stipulate that owners of large fishing boats (hold capacity of at least 32.6 m^3) and small boats are obliged to pay a sum for the right to extract fishing resources which are public property, and that payment of this sum confers fishing rights (Chapter III, Articles 40 to 47 of the regulations).

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8. This law was promulgated by the Presidency on June 27, 2008, based on legislative powers delegated by the Peruvian congress.
9. Individual catch quotas have been applied in hundreds of fisheries around the world (e.g., New Zealand, Iceland, Australia, Canada, United States and, most recently, Chile) and it has been calculated that more than 10% of the total worldwide catch corresponds to this type of regime.
10. D.L. N° 25977, General Fishing Law, and its regulations (D.S. N° 012-2011 Produce).

Methods of charging for fishing rights have undergone many changes over time, as can be seen in Table 1. Traditionally, the sum paid for the right was established as a percentage of the UIT, but when the price of fishmeal started to increase, the calculation method was changed. At present, the law establishes that rights are calculated by considering 0.25% of the FOB value per ton of fishmeal and the number of tons of anchoveta landed.

It should be noted that the current definition is not very precise. This means that how fishing rights are calculated is subject to interpretation. For example, one interpretation could be that 0.25% of the average fishmeal price per ton – equivalent to 4.5 MT of anchoveta[11] — would mean that the per ton value of this resource would be just 0.056% of the FOB value. Nonetheless, current collection figures show that the calculation has been carried out correctly; that is:

$DP = 0.25\%\ PPH \times AD,$

where *PPH* is the average FOB cost per ton of fishmeal and *AD* is the total tons of anchoveta landed.

Table 1
Fishing rights legislation

Norm	Right established
Chapter III of the General Regulations of the General Fishing Law (D.S. N° 012-2011-Produce)	0.075% UIT/MT landed for: anchoveta, sardine, jack mackerel and mackerel.
D.S. N° 007-2002-Produce	0.23% UIT/MT of hydrobiological resources landed for indirect human consumption.
D.S. N° 011-2002-Produce	0.116% UIT/MT landed for resources intended for indirect human consumption.
D.S. N° 024-2006-Produce	Based on 0.25% of the FOB value per ton of fishmeal (Aduanet average). Fishing boat owners can allocate 25% of the total sum that they are obliged to pay for fishing rights to finance scientific research projects, develop new technologies, train sector workers, etc.
D.L. N° 1084-2007: LMCE, final provision [article 1]	The sum payable and the calculation method for fishing rights associated with the extraction of hydrobiological resources intended for indirect human consumption is not to be modified for ten years from the entry into effect of this legislation.

11. The productivity of the fishmeal industry is highly variable since it depends on factors such as plant technology and the type of meal produced, etc. After the application of LMCEs, the industry's average productivity fell to 4.4 MT of anchoveta per ton of fishmeal.

Thus, between 2007 and 2010, fishing rights increased due to the rise in the price of fishmeal from US$ 2.39 to US$ 3.71 per MT. It is noteworthy that the sums collected have been lower than is legally provided for as a result of problems in enforcing and overseeing the sanctions established.

Fishing rights as applied in the anchoveta fishery have no relationship whatsoever to the resource usage cost or to what might be termed the royalty collected by the state, given that they permit the use of a public resource. As mentioned previously, fishing rights should be calculated based on resource rent; that is, the difference between total revenue and total costs.

Table 2
Fishing rights for anchoveta intended for indirect human consumption (CHI), 2007-2011

Year	Average price (FOB; US dollars per TM)	Fishing rights (US dollars per TM)	TM landed (thousands)	Collection of fishing rights payments (thousands of US dollars)
2007	957	2.39	6,160	14,737
2008	896	2.24	6,258	14,017
2009	953	2.38	5,935	14,140
2010	1,485	3.71	3,451	12,810
2011	1,357	3.39	6,994	23,727

Source: Paredes (2012).

On the other hand, S.D. N° 024-2006-Produce established that boat owners can allocate 25% of the total sum they are obliged to pay for fishing rights to financing scientific research projects, developing new technologies, training sector workers, etc. Though not clearly explained in the legislation, the logic of this provision is that this percentage would be allocated by the Ministry of Production (Produce) for the stated purposes. The ministry has established the corresponding mechanisms for the use of these funds.

Finally, a key element of the LMCE Law is that it establishes that the sum payable for fishing rights for landings intended for indirect human consumption as well as the calculation method to be used will remain unchanged for ten years. This provision came into effect in mid-2008, which means that the rights system cannot be modified until mid-2018. It was introduced because of the costs that the private sector must assume as a consequence of the new LMCE system, which can be summarized as follows:

A. Payment of US$ 1.95 per MT landed in industrial fish processing facilities for the creation of an intangible fund as a permanent solution to the problem of the fishermen's pension system (social contribution).
B. Contribution to the Fishermen's Social Security and Benefits Fund (Caja de Beneficios y Seguridad Social del Pescador), set at US$ 0.26 dollars per MT landed.
C. Payment of between 24 and 35 Peruvian soles per PMCE (maximum percentage catch per vessel),[12] assigned to each vessel as a fixed annual contribution to Foncopes[13] (covers fixed costs).
D. Variable payment per vessel to Foncopes, based on the number of workers on the benefits program (covers variable costs).
E. Payment towards the satellite system (Sisesat).
F. Payment towards the Surveillance and Control Program for Maritime Sector Fishing and Landings (PVCPD).[14]

In the first case, the payment of US$ 1.95 per MT constitutes a social contribution in response to the welfare problem of the fishermen's retirement fund. The contribution is fixed and is set for a period of ten years. Although this requirement is not directly related to the LMCE management system, it was considered appropriate to guarantee the instrument's social viability. The second payment mentioned above is a contribution to the retirement funds of the Fishermen's Social Security and Benefits Fund.[15]

Foncopes was created by the LMCE Law in an attempt to address the law's social implications; namely, the decline in the number of workers in this fishery resulting from efforts to curtail expansion of the fishing fleet. To this end, a special voluntary retirement scheme was introduced with incentives and an occupational retraining program, financed entirely by private contributions. In this case, the contribution has a fixed and a variable component, the latter based on the number of workers registered in the program.

In the case of the PVCPD, the aim is to tackle illegal exploitation of the sea's hydrobiological resources, whether in terms of vessels without fishing permits, landings that exceed authorized

12. In the case of vessels with permission to fish in the center-north zone, the annual payment varies between 25 and 35 soles while for vessels with permission to fish in the south zone, the amount ranges from 2 to 3 soles.
13. The Compensation Fund for Fisheries Management (Foncopes) was established with the aim of providing support and training to fishermen displaced from the anchoveta fishery as well as redeployment in other fisheries and sectors.
14. D.S. N° 027-2003-Produce.
15. The fund was declared insolvent this year and workers will now be reassigned to private insurance schemes or the Pension Standardization Office (ONP).

limits or the catching of unauthorized resources. This program was approved in 2003 and since then has contributed to strengthening the surveillance and control capacities for state resources. The program is notable for being financed by the private sector. Payment for services provided by private companies specialized in reporting, inspection, and control – currently SGS and Cerper – is assumed by the owners of licenses for industrial fish processing facilities through agreements of full and faithful compliance with the provisions contained in the program, in accordance with the models approved by Produce. Recently, by way of D.S. N° 008-2010-Produce, the program was extended to include industrial fish processing plants that manufacture products for indirect human consumption and residual fishmeal, plants that reuse discards and waste from hydrobiological resources, and plants that manufacture products for direct human consumption and conventional and/or high-protein fishmeal. The aim of all of the above is to improve levels of control.

The characteristics of the Peruvian fishing industry are such that a series of complementary measures were required to ensure the viability of introducing the quota system, such as support for the fishermen's pension system. As the state was unable to assume these costs, private sector contributions were introduced for the social programs mentioned above.

Fishing rights in other countries

As mentioned above, the concept of fishing rights is applied in a variety of different ways, some in order to reveal fishing rent, in which case fishing rights constitute a royalty, while in other cases, the approach is more comparable to taxation.

In the case of Australia, resource rent is extracted by levying taxes (Rodgers and Webster 2007: 3). In the abalone fishery, 6% of the gross annual value was collected in 2000 based on the average beach price. In 2004 the calculation method was altered in response to concerns that the levy was too high and the formula became based on an indexed sliding-scale linked to the average annual beach price. For example, if the price falls below $43 per kilo, no taxes are levied. On the other hand, if the price is between $43 and $52 per kilogram, between 0.5% and 5% of earnings are collected (5% in the case of $52). The more variable the price, the higher the rate of contribution.

In Chile (Peña 2008: 2), the so-called patent (*patente*) is conceptualized as a tax for recouping the costs of administering that country's fisheries management system. Prior to the latest reform, 2% was paid on annual fisheries sales under an individual quota regime. Under the current system, there is one part that is a fixed payment and another which is variable, depending on landings.

Owen (1998: 204) states that in the South American countries, access fees are calculated based on a percentage of expected revenue. In addition, he explains that an access fee based on total revenue is confused with a fee based on access value because the calculation method for the former has more in common with a revenue tax than a resource rent tax.

In the case of Namibia's horse mackerel fishery, Ithindi (2003: 15) notes that country's fisheries administration issues fishing rights through bids for four, seven and ten years. This process assesses factors such as investment in vessels and facilities, fishing experience and social investment. Namibia extracts fishing rent via an *ad valorem* tax of between 5% and 15% of fish prices, adjusted for vessel type.

3. THEORETICAL FRAMEWORK

As with all economic activity, producers (boat owners in our case) aim to maximize rent. Under an open access scheme, the incentives lie in maximizing rent in the short run without addressing the resource's biological factors. In an assigned rights scheme there are incentives to both maximize rent and to sustain the resource over time. In other words, fishing effort is reduced with the aim of extracting a smaller quantity of the resource so as to insure the largest possible difference between total revenue and costs. Earnings acquired via this level of effort are termed fishing rent.

As mentioned in the previous section, setting the rent in the fishing sector is challenging as it depends on factors of both supply and demand. Thus, for example, rent may vary due to changes in technological factors, input prices and biomass size, etc. Likewise, not all fisheries contain the same number of vessels, technology, experience, and cost structure. Overestimated rent could result in the penalization of those with a lesser capacity to meet costs, potentially giving rise to efficiency losses. On the other hand, an undervaluation of rent creates a beneficial situation for the producer. According to Owen (1998: 201) this could encourage innovation, though certainly not on the part of the state.

Methods of charging fishing rent

According to Grafton (1995: 57), the literature defines four methods for estimating rent in fisheries. These are:

A. Quota rental charge: The rent (*R*) collected from fisher *i* over time *t* is determined as a proportion of the price of the quota multiplied by the number of quotas held by the fisher in a competitive market at a rate of interest *r*.

$$R_{it} = \alpha C_t r q_{it},$$

where α is the quota charge rate, C the quota price at time t, r the competitive interest rate, and q the number of quotas held by fisher i at time t. One of the main problems with this method lies in recognizing the expected quota price, especially in the absence of a competitive market, when quotas are concentrated in the hands of a few. The other problem is that this method is *ex ante* and therefore rent is captured based on expected rather than real profits.

B. Profit charge: *ex post* method that captures rent as a fixed proportion of fisher profit.

$$R_{it} = \begin{cases} p\,\Theta_{it}\; si\; p\Theta_{it} > 0 \\ 0,\; d.o.m. \end{cases}$$

Where p is the profit charge rate and Θ the profit of fisher i at time t. This method can only capture rent when the profits are positive. However, the government is vulnerable to problems of information asymmetry and it would be very difficult to ascertain the profits attained by producers. In addition, those fishers who invest with borrowed capital will profit more under this method if the interest payments are deductible or if there are measures such as accelerated depreciation or other schemes that render book profits different from real profits. Therefore, the effects of this charge are not uniform among fishers.

C. Lump sum charge: the total rent to be collected, R, is divided by the percentage quota for fisher i at time t; the charge is similar for all quota holders, although it cannot be assumed that all fishers will incur the same costs. Administratively, this method is very easy to implement once the rent has been determined. Unlike the previous method, there is no scope for the boat owner to attempt to reduce profits in order to avoid payment of rent. Nevertheless, the fixed charge will not vary if the rent varies, making it necessary to recalculate rent and the charge.

D. *Ad valorem* charge: collection of rent as a percentage of the landed resource price times the number of individual quotas held. This method is flexible against rent value changes arising from fluctuations in product price. It also reduces the likelihood of collecting rent when fishers suffer losses. Moreover, its flexibility allows differentiated rates to be established according to profit levels.

There are countries that use one or another of these four methods to obtain fishing rent. Owen (1998: 198) states that in many cases an additional cost per unit of effort is applied, equivalent to an *ad valorem* royalty on the catch. In the countries of the southwest Pacific, for instance, access fees tend to be a percentage of expected revenues. In Namibia, rent collection is calculated using the *ad valorem* method (Ithindi 2003: 15).

The model

Rent estimation requires the determination of the profits generated in the fishery. To this end, the Gordon-Schaefer (Arnason 2007) method will be employed, which allows the consideration of two moments in time: 2006, under an open access regime in the anchoveta fishery, and 2011, under a catch quota scheme. According to economic theory, rent maximization should occur in the 2011 context as a consequence of the bioeconomic catch level; that is, when the profits that are subject to the conservation of the biological resource are maximized.

To estimate catch and effort levels in conditions of open access and of assigned property rights, the following equations are used:

(1) Biomass growth function: $x = G(x) - y$
(2) Extraction function: $h = H(E,x) = q.E.x$
(3) Biomass growth function: $G(x) = a.x - b.x^2$
(4) Costs function: $C(E) = c.E + fk$
(5) Revenue function: $I(H) = p.H(E, x)$
(6) Profits function: $\pi = p.H(E,x) - C(E)$;

where x, h, q, E, π, p, c and fk represent: biomass, volume extracted (catch), catchability coefficient,[16] fishing effort, profits, landed fish prices, marginal cost and fixed costs, respectively. The costs function (4) includes the capital opportunity cost.

If it is assumed that the biomass is at equilibrium, the growth function is equal to zero (x = 0). Thus, equation (1) would be represented as follows (Arnason 2007: 4):

(7) Condition of biological equilibrium: $G(x) = H(E, x)$

If functions (2) and (3) are replaced in expression (7), the following relationship is obtained:

(8) $a.x - bx^2 = q.E.x,$

and rearranging it, we obtain:

(9) $$x = \frac{a}{b} - \frac{q}{b} . E$$

16. The catchability coefficient (q) measures the level of technology employed in fish extraction.

Relationship (9) is replaced in the catch function (2), obtaining:

(10) $H(E,x) = \frac{a}{b} . q.E. - \frac{q^2}{b} . E^2$

If $\frac{a}{b} . q$ *and* $\frac{q^2}{b}$ are expressed as α and β, an extraction function is obtained that depends on effort, E:

(11) $H(E, x) = \alpha.E. - \beta.E^2$

Then, on replacing function (11) in expressions (5) and (6), we obtain:

(12) Revenue function: $I(E) = p. (\alpha.E .- \beta.E^2)$

(13) Profits function: $\pi = p. (\alpha.E. - \beta.E^2) - C(E)$

The maximization of the biomass growth function (3) or the attainment of the condition of equilibrium (7) allows the MSP to be found, which constitutes biological equilibrium. The level of effort that maximizes profits (13) allows the maximum economic production (MEP) to be obtained; that is, bioeconomic equilibrium.

A fundamental element in calculating the rent is the use of a price that reflects the value of the resource. With this in mind, the shadow price[17] or social price should be used, which is defined as the marginal value of a stock unit in terms of its contribution to future profits, taking into account the growth of the stock as well as its implications for extraction costs (Hatcher n.d.). The shadow price of the resource can also be defined as that which is constructed for those goods that are not traded on the market; thus, it can be said that it expresses the value of the resource for society (De Bruyn *et al.* 2010).

Method of estimating variables

The results provided by the model are the levels of stock, catch and equilibrium effort. On this basis, the economic variables of revenue and costs are resolved in order to then calculate the rent. Table 3 provides a summary of the coefficient and variable estimation methods.

17. The shadow price can be represented by the fishing quota price, provided that a competitive market exists.

Table 3
Characteristics of coefficient and variable estimation methods

Coefficients & variables	Nomenclature	Description	Permissible values	Method or source[1]
Biological coefficients				
Biomass growth function	a	Intrínsic growth rate	$a > 0$	Authors' own calculation
Biomass growth function	b	Intrínsic growth rate	$b > 0$	Authors' own calculation
Maximum carrying capacity	K	Maximum biomass that can be sustained by the ecosystem		a/b
Captura de MPS	$H^{(2)}$	Maximum sustainable catch		$\frac{4.K}{a}$
Catch coefficient				
Catch function	q	Catchability	$q > 0$	$q = e^{\frac{\Sigma_t^n \ln(CPUE_t/X_t)}{n}}$
Catch function	α	Coefficient of catch function	$\alpha > 0$	$\frac{a}{b} \cdot q$
Catch function	β	Coefficient of catch function	$\beta > 0$	$\frac{q^2}{b}$
MPS effort	$E^{(2)}$	MSP effort	$E > 0$	$\frac{\alpha}{2.\beta}$
Economic coefficients				
Cost function	fk/CT	Proportion of fixed cost over total cost	$fk / CT > 0$	National Fisheries Society (SNP)
Cost function	fk	Fixed cost		$fk = (CT).(\frac{fk}{CT})$
Cost function	c	Marginal cost over variable		SNP
Income function	$P(t)$	Historical beach prices		Produce
Income function	P	Cost of catch		$P = \frac{C.E^*}{H^*} + \alpha$
Variables (in base year)				
Landings	$H(t)$	Volume of landings	$H(t) > 0$	Produce
Biomass growth	$X(t+1)-X(t)$	Biomass growth		Instituto del Mar del Perú (Imarpe)

Notes:
[1] Here and in tables 4 and 7, the data was provided directly by the SNP, Produce, Imarpe and the Vice-Ministry for Fisheries.
[2] Values that correspond to biological equilibrium.
Source: World Bank (2009); authors' own calculations.

Coefficients *a* and *b* of the biomass growth function (3) are calculated through an ordinary least squares regression of historical catch and biomass data for the period 1990-2011.

Because of information limitations, the shadow anchoveta price has been estimated as that which allows us to arrive at the point of perfect competition equilibrium; that is, zero profit, at a level of MSP. Following the Gordon-Schaefer model, the condition of equilibrium will be given by:

(14) $P = Cme$,

which, including cost components, results in:

$$P = \frac{C.E^*}{H^*},$$

where C, E^* and H^* are the cost per unit of effort of the most inefficient vessel,[18] the MSP effort, and the MSP catch, respectively.

Rent calculation for the industrial anchoveta fishery
Utilizing the above model, the estimate was carried out based on the data in Table 4.

The average costs per ton were calculated using a weighted average of steel and wooden vessel costs. The assigned weights represent the proportion of the catch quota for each vessel type. This average weighted cost was multiplied by the WACC to incorporate the opportunity cost of capital.

(15) Average costs per MT: $Cprom = (0.8.Cme + 0.2.Cma) * (1 + \text{WACC})$,

where: *Cme* and *Cma* are the costs per MT for metal and wooden vessels respectively. In addition, it has been assumed that the proportion of fixed and variable costs is the same for both vessel types and that the WACC and vessel participation for 2011 is maintained over the period 2006-2011.

18. For 2011, the most inefficient vessel costs are those corresponding to wooden vessels.

Table 4
Characteristics of the data utilized

Variables	Value	Unit	Period	Source
Fishing effort (*E*)	-	Thousands of m^3	1990-2011	Vice-Ministry of Fisheries
Landings (*H*)	-	Thousands of TM	1990-2011	Produce
Biomass growth ($\dot{X}$)	-	Thousands of TM	1990-2011	Produce / SNP
Cost of landing	-	US$	2000-2011	Produce (deseasonalized)
Fixed and variable costs of representative metal vessel	-	US$ per TM	2006-2011	SNP
WACC (weighted average cost of capital)	13	%	2011	SNP
Variable costs of wood	90	US$ per TM	2011	SNP
Fishing effort (*E*), 2011	179	Thousands of m^3	2011	Produce
Landings (*H*), 2011	6,994	Thousands of m^3	2011	Produce
Landing cost, 2011	227.63	US$	2011	Produce
Fixed coefficient cost, 2011	0.27	Ratio	2011	SNP
Total cost, 2011	692,195.62	Thousands of US$	2011	SNP
Profits, 2011	899,832.40	Thousands of US$	2011	Produce
Fishing effort (*E*), 2006	213	Thousands of m^3	2006	Produce
Landings (*H*), 2006	5,935	Thousands of MT	2006	Produce
Landing cost, 2006	101.85	US$	2006	Produce
Fixed coefficient cost, 2006	0.45	Ratio	2006	SNP
Total cost, 2006	452,853.64	Thousands of US$	2006	SNP
Profits, 2006	151,596.58	Thousands of US$	2006	Produce

4. RESULTS

The rent for 2011 is calculated according to two points of reference: MSP and MEP effort. The empirical data utilized is shown in Table 5.

Table 5
Estimated data

Variable	Value	Unit
Maximum sustainable yield (MSP)	7,323.68	Thousands of MT
MSP effort	181.87	Thousands of m^3
Biomass growth function (*a*)	1.8038	Coefficient
Biomass growth function (*b*)	0.0001	Coefficient
Catch function (α)	80.53	Coefficient
Catch function (β)	0.2214	Coefficient
Shadow price	103.33	US$
MSP effort	181.87	Thousands of m^3
Landings (*H*)	7,323	Thousands of MT
MEP effort, 2011	120.18	Thousands of m^3
MEP landings, 2011 (*H*)	6,481	Thousands of MT
MEP effort, 2006	156.31	Thousands of m^3
MEP landings, 2006 (*H*)	7,179	Thousands of MT

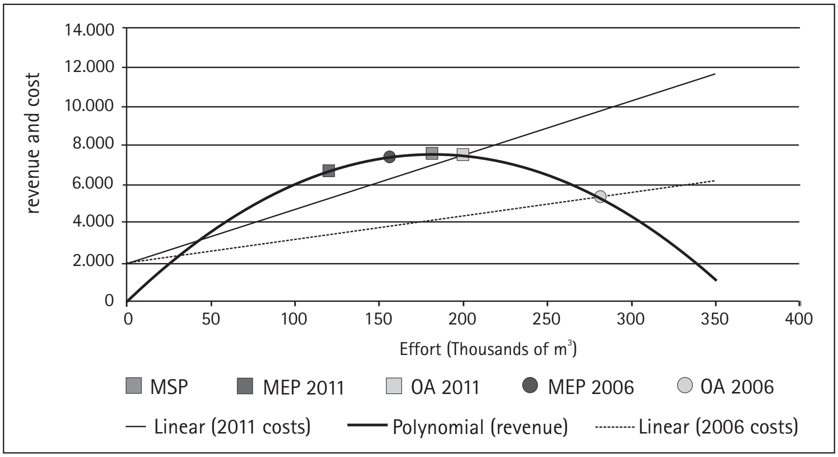
The estimated data allow the following functions to be obtained:

(16) Costs function: $C(e) = 2{,}822.e + 186{,}892.82$

(17) Income function: $I(p, H) = 103.33.H$

Graph 3 shows the total revenue and total cost curves for 2006 and 2011.

Graph 3
Anchoveta fishery revenue and costs



The total revenue curve was calculated by multiplying the proposed shadow price by the catch function, which depends on effort. As mentioned earlier, this price - US$ 103.33 per MT of anchoveta – results in an MSP catch in which the profits are zero. The LMCE Law prompted a change in the negotiating power of the boat owners, who have seen their prices increase from 2009 (the first season under the LMCE regime). Thus, the average price for the period 2000-2008 was US$ 79 per MT of anchoveta, while for the period 2000-2011 it was US$113 per MT. The calculated shadow price lies within a range of reasonable prices, though there are still improvements to be made in the method of estimation. In addition, more detailed information is needed.

As regards costs, a reduction of those incurred by the fleet's extraction was anticipated insofar as the LCME regime encourages cost minimization; that is, a smaller number of boats could be used to attain the same catch level. Nonetheless, the issue of cost reduction has still not been completely settled. In 2011, the proportion of fixed costs fell versus 2006, while the variable costs rose. In that year, the variable cost was US$ 41.97 per MT and in 2011 it was US$ 72.25 per MT. Among other reasons, this increase was explained by the change in the boat owners' production strategy, especially among owners of fleets who seek to extract high quality raw material, which entails, for example, not operating at full capacity.

The maximization of profits based on the preceding functions allows us to find $\hat{E}$, $\hat{H}$ and the rent at the point of MEP, as shown in Table 6.

Table 6
Results

	$\hat{H}$ (thousands of TM)	$\hat{E}$ (thousands of m^3)	Rent 2011 (thousands of US$)
At MEP	6,481	120.18	143,547.73
At MSP	7,324	181.87	56,469.32
OA	7,255	199.39	0
Real	6,994	179.00	

The results are as expected according to the economic fishing model. The MSP effort is greater than that of the MEP, and the real 2011 effort is less than the MSP. The real effort for 2006 of 213,000 m^3 reveals a trend approaching the bioeconomic equilibrium point (MEP). Moreover, the MSP rent is less than the rent at the point of MEP, also in line with expectations.

5. REFLECTIONS ON FISHING RIGHTS AND RENT

If one deems payment for fishing rights to be those charges that represent the resource rent, then it is necessary to discuss two aspects: the first concerns the quantification of payments made by boat owners for the right to fish and of the other charges assumed as part of the commitments required following the implementation of LMCEs in relation to estimated rent. The second aspect relates to the method of charging for fishing rights (rent), with the understanding that, to date, the vehicle for charging has not been the most effective means of recovering rent.

As mentioned earlier, there are commitments assumed by the private sector as a result of the implementation of LMCEs whose quantification is presented in Table 7. These commitments cover six line items: social contributions for retirement; contributions to the fishermen's fund; fixed and variable payments for the retraining program (Foncopes); payment towards the surveillance and control program for landings (SGS and Cerper); and payment for the Sisesat.

Table 7
Contributions made by the private fishing sector, LCME Law, 2011 (thousands of US$)

Contributions	
Social contribution for retirement	13,638.50
Contribution to the Fishermen's Benefits and Social Security Fund	1,818.44
Fixed payment to Foncopes	2,580.22
Variable payment to Foncopes	7,175.80
Surveillance and control program of landings	9,092.20
Sisesat	1,888.38
Total	36,193.54

Sources: Produce (2013); SNP (2013).

In Table 7, the stated figure for the variable payment to Foncopes is an annual average of Foncopes account statements, given that no information is available for individual payments. In that year, the total payments made by the private sector were US$ 36.2 million. According to the estimates made, payments for fishing rights - set at 0.25% of the FOB price of fishmeal per ton of anchoveta - for 2011 was US$ 23.7 million. Therefore, the total paid by the private sector in 2011 was US$ 59.9 million (Table 8).

Table 8
Economic rent: private contributions and payment for rights, 2011 (dollars)

Rent or right	Value (hundreds of thousands of US$)	Value per MT (US$)	Percentage of profits	Percentage of MEP rent
Private sector contributions	36,193.54	5.17	4.02	25.21
Fishing rights	23,727.00	3.39	2.64	16.53
Total (costs and rights)	59,920.54	8.57	6.66	41.74

If the total paid by the private sector is compared with the estimated rent for 2011 in MEP, the former only covers 41.74% of the latter; that is, an average equivalent of US$ 8.57 is paid per MT of anchoveta landed. This shows that even when the additional contributions for fishing rights are taken into account, private boat owners do not cover the resource rent, with 58.26% going uncharged.

This outcome may be interpreted in diverse manners and it is not within the scope of this paper to discuss the reasons why this situation exists. Nevertheless, the fact that the state does not collect the total rent does not mean there has been a decline in social efficiency. In this case, surpluses for boat owners have led to additional investment in other fishing subsectors,[19] resulting in greater industry diversification.

This situation makes it evident that the method of charging for fishing rights should be reviewed with a view to establishing a more effective alternative that extracts the entire rent resource. Without doubt the complex reality of the fishing sector requires that the method employed be sufficiently flexible so that it can be adapted to the variability of anchoveta prices and resource catch conditions.

Therefore, as an exercise we propose a rent capture method that contains one part that is flexible and another that is variable.[20] The logic of this form of collection lies in the dependence of rent on total revenue and cost. The latter tends to be more stable over time while revenue has two large sources of variability: the catch and the evolution of prices. In this sense, rent is a variable number and hence its collection must also have a variable component.

19. For instance, companies that previously operated only as fishmeal producers have ventured into the fish canning industry or other fisheries.
20. The economic basis is a two part fee.

At present, 40% of the fishing quota is determined by a vessel's hold capacity; that is, by the effort, which in turn determines the company's total cost. The remaining 60% is made up of the catch, which together with the price, determines total company revenue. For the proposed exercise, the fixed part is based on the quota percentage rather than vessel hold capacity, given that the latter still varies.

The fixed part of the 2011 fishing rights will be 40% of the economic rent for the same year (US$ 57.4 million). When this amount is divided by 0.01% of the 2011 PMCE, one finds that vessels would have had to pay US$ 5,741 per 0.01% of PMCE, which is equivalent to US$ 8.21 per MT (see Table 9).

Table 9
Exercise in estimating fixed rent charge, 2011 (dollars)

Variable	Value	Unit
MEP rent	143,547,731.76	US$
Fixed rent (40%)	57,419,092.70	US$
Quota	100%	% of PMCE
Fee per percentage	5,741.91	US$ per 0.01%
Dollars per TM	8.21	US$ x MT

Sixty percent of the economic rent corresponds to the variable rent charge; that is, US$ 86.1 million. The collection of this variable rent, by metric ton of anchoveta extracted in 2011, is equivalent to US$ 12.3 per MT (see Table 10).

Table 10
Exercise in estimating variable rent charge, 2011 (dollars)

Variable	Value	Unit
MEP rent	143,547,731.76	US$
Variable rent (60%)	86,128,639.05	US$
Total catch	6,994,000.00	MT
Fee per MT of anchoveta	12.31	US$
Fee per MT	0.9%	% of HdP price

In summary, the fishing right should be equal to:

DP = 5,741 US dollars * (per 0.01% PMCE) + (0.9% of the average FOB fishmeal price) * (MT of catch)

Since the goal of charging for fishing rights is to extract the resource rent, if there were no rent, nothing would need to be paid. Therefore, fishing rights would require a set minimum below which rights would not be charged. The indicated minimum could be the anchoveta price at which the rent is equal to zero.

This simple exercise in distributing total estimated rent for 2011 allows us to visualize the scale of the «prices» that should be used in charging for fishing rights as synonymous with rent. Nonetheless, more detailed studies are required to establish the optimum parameters for a two part fee, such as that proposed for fishing rights.

Finally, this study is considered an initial estimation of fisheries rent of anchoveta in the Peruvian case. A series of variables have been identified that change over time and this makes it necessary to estimate rent for each period. Therefore there is a need for research into the incorporation of dynamic models that consider uncertainty variables. As in the case of this study, one of the main constraints on such research is the lack of detailed information in terms of both complete series and consistent sources.

Another element that requires more in depth analysis is the estimation of the shadow anchoveta price. According to the literature, complex models do exist which require more analysis time as well as information that, in some cases, is not registered.

Finally, to enhance the impact of this research, alternative fee schemes for the collection of rent should be proposed in order to contribute to sustainable management of fisheries.

APPENDIX

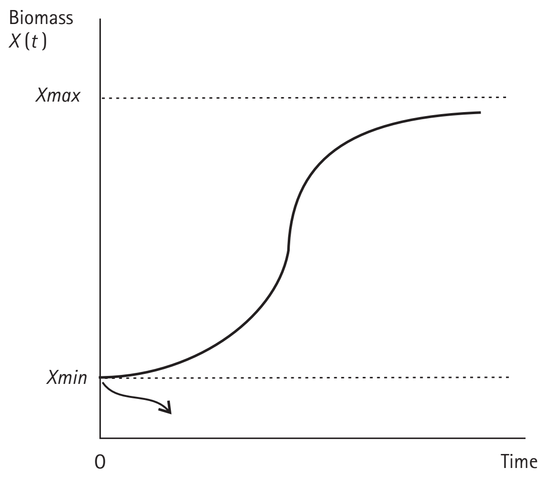
Fishing rights[21]

The classic Gordon-Schaefer bioeconomic model is useful for analyzing how fishing effort and biomass behavior determine the sustainable yield of a fishery.

Population biological mechanisms

Given a particular marine species in a specific geographical location, the population or biomass size will be naturally limited. According to Graph A1, the biomass grows over time based on a minimum stock (X_{min}), initially at an increasing rate due to the abundance of food and later decreasing growth until reaching a level X_{max} of the habitat's maximum self-sustainability capacity (biomass saturation level).

Graph A1
Biomass growth over time

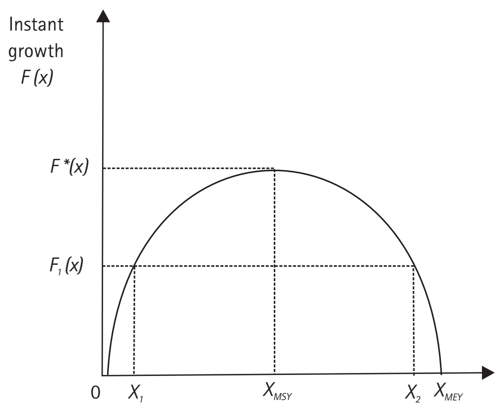


The change of stock between one period and another will be represented by $dX(t)/dt$. Thus, the growth rate of a population over a period of time, when the resource is not exploited, will be given by $F(X) = dX(t)/dt$; that is, the net growth rate of biomass X stock for a short period of time.

21. This model is based on chapter five of the book *Economía de los recursos naturales* (Galarza 2010).

Graph A2 represents instantaneous growth in relation to stock size, in which $F(X)$ is represented by a logistic function. It can be seen that with a small but positive stock, biomass grows rapidly, and when growth reaches its maximum level, to stock X_{MSP}, it then starts to decline until reaching its maximum level of habitat support, with a stock equal to X_{max} and a growth rate equal to zero. It should also be noted that, with two different stock levels, *X1* and *X2*, the same net growth rate applies. This is because in *X1*, the stock is small so there is enough food for all specimens and the number of births over deaths represents a large proportion of the stock; in *X2*, on the other hand, births still exceed deaths and represent an equal growth rate over a larger stock.

Graph A2
Biomass growth function



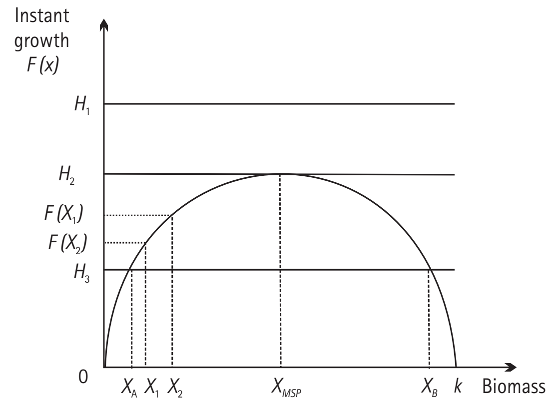
Graph A2 shows that sustainable revenue (on the y-axis) increases along with fishing effort (number of vessels on the x-axis), since the volume of fishing increases (ascending part of the curve). Nonetheless, given that fishing volume is a function of biomass and that biomass is inversely related to the fishing effort, the slope of the sustainable revenue curve decreases until it reaches zero, the point that corresponds to the maximum sustainable yield (MSY). After this point, all increases in fishing effort are reflected in a decrease in sustainable revenue (descending part of the curve), and correspond to overexploitation of the fishery. The distance between the sustainable revenue curve and the total costs (CT) line represents economic rent, which is maximized at the point of MEY which, as can be seen on Graph A2, is lower than the MSY. This result is very interesting and not necessarily intuitive since it shows that economic maximization does not necessarily correspond to the maximization of fishing effort, even if this is sustainable from a biological point of view.

Bioeconomic equilibrium in a simple model

If one introduces the economic analysis of fishing activity, a bioeconomic equilibrium will result, which involves a biological and economic equilibrium.

Graph A3 shows that if the extraction rate is H_2, then the growth function $F(X)$ is found at its point of MSP. Given the logistic growth function, the MSP point will have a stock equal to half the habitat support capacity (*k/2*). Since H_2 exceeds $F(X)$ for any stock value between X_{MSP} and *k*, the stock will gradually decrease until reaching X_{MSP} (o *k/2*). In this case, the remaining biomass will grow to the maximum rate since space and food exist.

Graph A3
Stock and extraction levels



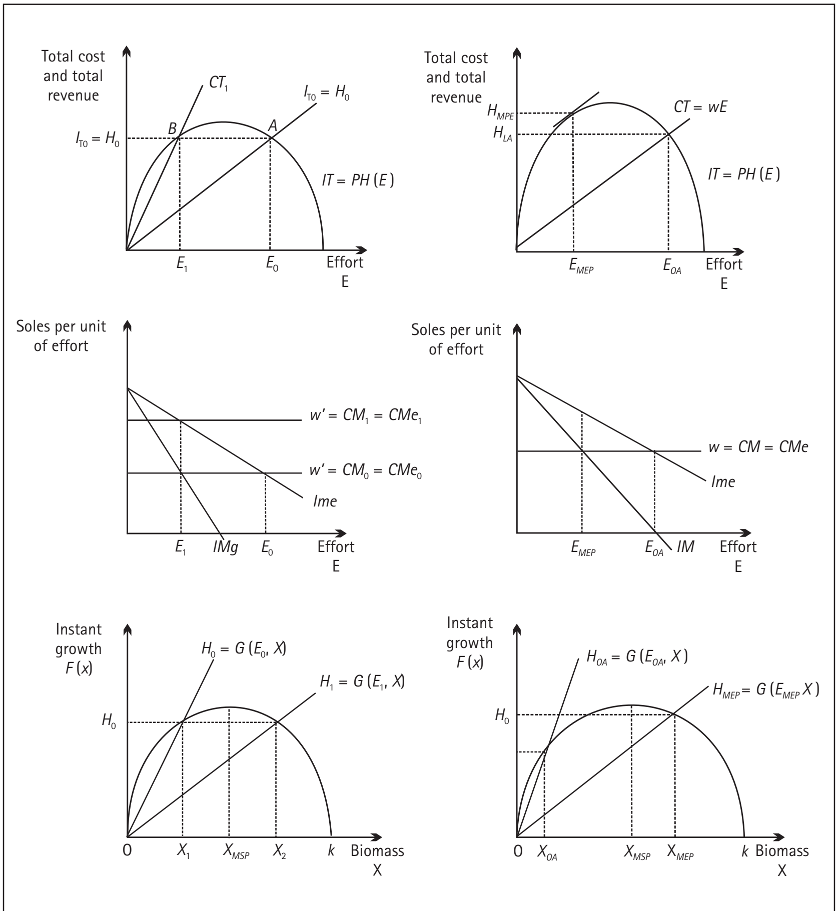
This extraction level H_2 o H_{MSP} is the maximum sustainable and is the result of extracting exactly the biomass growth level (in a unit of time); that is, the maximum stock growth level. Given a simple fishing model, in which there are no extraction costs and future revenue is not discounted, this level of extraction will be the fishery's desirable biological equilibrium. As we will see, this equilibrium will coincide with the fishery's point of maximum revenue.

Extraction with open access and private property

First, an extraction function is defined for the industry by assuming that the fishing industry is perfectly competitive; that is, price taking (including factor price), with these being constant over time. Furthermore, fishing effort (*E*) is a measure of the production factors used by the industry: capital, work, materials and energy, and may be measured by vessel hold capacity or the number of nets with which the fishing industry is provided. The other factor that determines extraction is fish stock (*A*) over a period *t*: the bigger the stock given the same effort level, the higher the number of fish that can be caught (graphs A4 and A5).

Graph A4
Equilibrium in open access

Graph A5
Equilibrium in private property



Let us assume that there is open access to a given species; that is, anyone with a boat and nets can catch it if he wishes to do so and the extraction unit costs, measured in soles per unit of effort, are constant and equal to *«c»*. Graph A4 shows the total industry costs, represented by line CT_0 whose slope is equal to *«c»*($CT_0 = cE$). Total industry revenue is given by the species price multiplied by the quantity caught. Given total costs CT_0 and total revenue, the open access equilibrium level will be at point *A*. Lower effort levels have positive profits, which encourages the entry of more companies into the industry, thus increasing the effort level. At point *A*, costs equal revenue, thus discouraging the entry of companies and the increase of effort. The equilibrium of open access will utilize an effort E_0.

Open access equilibrium can also be analyzed based on the marginal extraction cost ($dCT/dE = CMg$), which is equal to «*c*»; of the mean revenue ($IT/E = IMe$) and of the marginal revenue ($dIT/dE = IMg$). Open access equilibrium occurs at the point where mean revenue intersects with marginal cost. As can be seen, at this point *CMg* is greater than *IMg* and the *IMg* are negative; therefore, it cannot be economically efficient. To be efficient, industry profits ($IT - CT$) must be maximized, which is achieved via an effort level that complies with the condition of maximization: $IMg = CMg$.

Finally, sustainable extraction levels are shown for different stocks. It can be seen that two compatible levels of stock, X_0 and X_1, exist for the level of extraction H_0. As the open access effort level E_0 falls to the left of the MSP extraction point, the biomass stock for this level of effort will be less than X_{MSP}. Graph 4 shows that more effort than is necessary is used to extract the same level of biomass H_0 ($E_0 > E_1$).

In summary, two conclusions can be drawn regarding open access equilibrium in fishing. First, this equilibrium occurs when $IT = CT$, which means that $IMe = CMg$. In addition, at this point *CMg* is greater than *IMg*. Second, open access equilibrium can be economically and bioeconomically inefficient. It is economically inefficient since efficiency requires $CMg = IMg$, which is not achieved. It can be bioeconomically inefficient if, as in the case presented, equilibrium is to the left of stock, X_{MSP}, so that the same extraction can occur with greater stock. Nonetheless, if the extraction unit cost is greater (c'), then this equilibrium is bioeconomically efficient.

The individual decisions of companies do not ensure socially optimal distribution of resources because of market failures caused by the absence of property rights. Therefore, it is now assumed that each company is assigned exclusive rights to catch a species in a given region. If companies have well defined property rights, the industry behaves competitively and there are no other externalities; thus, the assignment of property rights guarantees that the social optimum is reached.

This is explained by the fact that since each company is the sole possessor of an extraction area, companies incorporate into their decisions the effect of the effort applied to the fish stock and the level of extraction. In this way, the stock effect is internalized by companies and their production decision goes from equaling the mean product at marginal cost to the marginal product at its marginal cost (*IMg* = *CMg* of effort). On the other hand, each company will limit its number of nets to the quantity that maximizes its profits, thereby obtaining an E_{MEP} (Graph A5). The efficiency of this equilibrium is reflected in the equilibrium stock X_{MEP}, which is found to the right of X_{MSP}.

Graph A5 shows that E_{MEP} is lower than that used in E_{OA}, despite both having the same revenue and costs. Another difference is the maximum rent received by companies under private property. In open access, the rent disappears. In addition, the equilibrium stock is greater, X_{MEP}, than in open access.

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