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Summary:
A key fishery policy issue decided by the new government of Namibia soon after independence in 1990 relates to the division of the total allowable catch for hake between wetfish and freezer trawlers. Using economic and social arguments, the government decided to use a criterion of 60:40 in favour of wetfish trawlers. The main question I pursue in this paper is, is this criterion economically sensible? How would the answer to this question be modified if, say, the employment generation capacity of the fishery were to be taken into consideration? The study suggests that based on purely economic and employment generation criteria, only the wetfish trawlers should be allowed to exploit the resource. However, the impact of other considerations such as biological, market, harvesting, and processing constraints tend to lend support to the current government policy.

Indexing terms:
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1. Introduction

Until 1993 freezer trawlers have been the dominant vessels employed in the harvesting of the hake stock in the Namibian Exclusive Economic Zone (EEZ). At independence in 1990, Namibia saw its rich fishery resources as one of the vehicles available to it for the badly needed economic development of its people. One of the important fishery policy decisions taken by the government to enhance the economic development of Namibia is the one that called for the restructuring of the trawler fleet in favour of wetfish trawlers (see section 2.2 below). An interesting question to ask here is, is this new development economically rational; if not, are there any reasons other than economic that may justify this move? For example, is it the case that the gains in employment due to the restructuring can compensate for the resulting economic loss, if any? Seeking answers to these questions is the main purpose of this paper. The paper, thus, sets out to study the exploitation of the hake stock off the Namibian coast, with a view to finding out the proportion of the total annual quota that should be landed by the wetfish and the freezer trawlers, respectively.

The principle underlying this work is *economic efficiency*, in other words, it is assumed that the primary objective is to harvest and process the stock in the most economically efficient manner. This assumption appears to be plausible in the case of Namibian fisheries, which unlike the fisheries of most developing countries, are mainly industrial.[1]

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[1] Although small coastal communities caught fish in coastal lagoons during pre-colonial times, the only indigenous fishing tradition amongst the peoples of the interior was freshwater fishing in the streams and rivers of the north.

Thus, most of the complications that usually arise due to the community-based nature of certain fisheries are simply not present here. There is, therefore, an excellent opportunity for pursuing and, indeed, achieving economically optimal management of the resources of the Namibian EEZ. Moreover, the results to be computed herewith are meant to serve as benchmarks for determining the trade-offs between different government policies: we should, for instance, be able to discover what is being sacrificed in economic terms due to a government policy that is geared towards increasing employment in the industry, as against one based purely on economic efficiency criteria.

In more concrete terms, this paper seeks to:

- Test the government quota allocation policy target of 60:40 for the wetfish and freezer trawlers, respectively, to see if it is optimal in an economic sense.[2] If not, what is the optimal share of the quota that should be landed by these two class of vessels?
- What discounted economic benefit would accrue to society at large under the optimal allocation regime?
- What is the optimal number of both wetfish and freezer trawlers needed to achieve these objectives?
- Finally, the paper would look at the employment generating capacities of the wetfish and freezer trawlers. The trade-offs between the economic gains and the employment generating capacities of the two class of vessels would also be discussed. There are at

[2] By an optimal quota allocation I mean the allocation that would maximise the social planner's, that is, the Namibian government's overall economic benefit from the resource.

least two levels at which the employment generation capacity of the two types of vessels can be analysed. First, the direct employment generation from the harvesting and processing of the fish in readiness for the market. Second, the indirect employment generation in the overall economy. Only an informal discussion of the latter is given in this paper. On the other hand, a full analysis of the former is carried out.

In the next section, I briefly discuss the hake fishery. Section 3 presents the bioeconomic model. The numerical computations are carried out in section 4. This section consists of two parts, the first sub-section discusses the data used in the analysis, while the other sub-section presents the computations and the results therefrom. I then proceed in section 5 to discuss the results of the study, while section 6 concludes.

2. The nature of the Namibian hake fishery

2.1 General

The hake stock is one of the three most important fish species of the highly productive Namibian EEZ. The others are horse mackerel and pilchard. The main reason for the high productivity of the Namibian EEZ is the Benguela upwelling system prevalent in the coastal zone of Namibia and other Southern African countries.

Among the species of hakes inhabiting the Namibian EEZ, that is, *Merluccius capensis* (also known as cape hake), *Merluccius paradoxus* (deep-water hake) and *Merluccius pollis*, only the former two are of major importance to the fishery. These two species are so identical in appearance that they are often treated as one and the same, both in fisheries statistics and in analysis such as this one. However, their biology, ecology and abundance differ considerably (Wysokinski, 1986). Both species are relatively long-lived, reaching ages up to and over 10 years. Hakes are usually found close to the bottom of the water during day-time but rise to intermediate water during night time, probably following their prey.

Hake catches reached a maximum of over 800 000 tons in 1972, averaging some 600 000 tons annually during the period from the late 1960's to mid 1970's. As expected these period of high catches was followed by lean years, with average catches of less than 200 000 tons from the mid 1970's to 1980. This, however, rose again and remained relatively stable between 300 - 400 000 tons for most of the 80's. It is stated in Hamukuaya(1994) that during those years of high catches there was a large proportion of young fish between the ages of 2 - 3 years old, probably accounting for the low catches in later years.

At independence in 1990 the total allowable catch (TAC) for hake was set at a low of about 50 000 tons mainly to help build up the stock. This has, however, been adjusted upwards each year since then, reaching 150 000 tons in 1994. These increases were due to the apparent improvement in the hake biomass in the years immediately following independence.

2.2 Structure of the hake fishery

A large variety of fishing vessels are used to exploit hake. These vessels differ in their gross registered tonnage (GRT), engine horse power (HP), processing equipment, and freezing capacity. Hake are predominantly caught by wetfish and freezer bottom trawlers. For instance, in 1994, out of a total of 108213 Mt. of hake landed, 99152 Mt. were by wetfish and freezer trawlers. This is well over 90% of the total landings of hake that year. The rest is landed using monk/sole trawlers, longliners, and mid-water trawlers. The structure of the Namibian hake fisheries for 1994 is given in Table 2.1 below.

As a result of the overwhelming dominance of the bottom trawlers in the demersal hake fishery, I focus my attention on these vessels and organise the wetfish and freezer trawlers into two separate and distinct entities managed by two different bodies, from now on, to be known as Wetfish Industry Group (w) and Freezer Industry Group (f), respectively. This is clearly a simplification, since different types and sizes of bottom trawlers owned by different entities are actively fishing the waters off the Namibian coast. The assumption would, however, make the analysis tractable without compromising the essence of the study: recall that the main essence of the study is to find out what share of the hake TAC should be allocated to the wetfish and freezer trawlers as separate groups. In other words, I am interested in determining the inter-vessel rather than the intra-vessel allocation of the TAC.

Before 1993 very little of the hake quota was landed by wetfish trawlers. In 1992 for instance, only about 5000 Mt. out of a total reported landings of 87498 Mt. were landed by wetfish trawlers. Then came a new government policy that sought to restructure the fleet in favour of the wetfish trawlers, mainly to encourage onshore processing, and thereby reap the benefits that are expected to follow it.

Table 2.1: The structure of the Namibian hake fisheries in 1994

Method and fleet	No. of vessels licensed	Hake as % of reported landings	Reported hake landed (Mt.)	Quota allocation (Mt.)
Demersal				
hake trawl	66	93.00	99152	130913
monk/sole trawl	18	31.53	4261	7919
longline	13	96.91	4265	7168
total	97	86.46	107678	146000
Mid-water	25	0.16	525	4000
Total			108203	150000

Source: Ministry of Fisheries and Marine Resources (MFMR), Namibia.

The announced policy is that 20%, 40% and 60% of the total quota for hake should be allocated to the wetfish trawlers in 1993, 1994 and 1995, respectively. The ultimate aim is to maintain an allocation of 60:40 in favour of the wetfish trawlers into the future. Performance against stated objectives has been quite good up to 1994: in 1993, 19.9% of the total quota was allocated to wetfish trawlers. The corresponding allocation for

1994 was 48.9%, well over the target of 40%. However, the target of 60% for 1995 could not be achieved mainly because there was no increase in the TAC in 1995. The 1994 allocation of 48.9% to the wetfish trawlers was, therefore, maintained in that year.

2.4 Hake in the national economy

Generally, the fishing sector is an important component of the economy of Namibia, with the hake fisheries being an important part of this. It has been estimated by the Ministry of Fisheries and Marine Resources (MFMR) of Namibia that hake contributed about 7.4% of Namibia's estimated exports in 1994. Furthermore, the contribution to GDP has been estimated at around N$ 230 million, representing around 3% of GDP at market prices. It should be noted that this includes only the direct contribution to GDP, additional contributions from secondary industries and the multiplier effects of spending hake-related incomes are not included.

3. The model

A typical freezer trawler is usually larger than a typical wetfish trawler. It fishes in deeper waters, probably catching larger and more valuable fish. In addition, it can stay offshore for longer periods than the wetfish trawler. The freezer trawler is equipped fully for catching, freezing and packaging at Sea. Therefore, all the processes needed, from actual harvesting to packaging in readiness for export, are undertaken offshore.

There are two kinds of participants in the wetfish business: factory owners who catch and process hake in their factories, and private concessionaires, who catch hake and sell their catch to the factory owners for further processing. In this paper, *w,* that is, the Wetfish Industry Group, refers to the former group of participants. The latter group will be discussed in a later section of the paper. The factory owners undertake two distinct activities, namely, offshore harvesting of hake and onshore processing.

This is a two-agent model for the hake fishery of the Namibian EEZ, the two agents being *w* and *f*, signifying the Wetfish and Freezer Industry Groups, respectively. Potentially, any situation where two or more agents with conflicting interests jointly exploit a common property renewable resource is capable of being analysed using a game theoretic framework. However, due to the assumptions underlying our model, listed below, it turns out to be a straightforward optimisation one. In addition to the fact that these assumptions seem reasonable, they can be further justified by using methodological and policy-needs arguments. Methodologically, it is always a wise preposition to start an analysis of this nature with a simple structure and then proceed to extend it as and when necessary. Policy-wise, it can be argued that the trade-off between landing hake by wetfish and freezer trawlers is one of the burning policy issues facing the MFMR at the moment.

3.1 The assumptions underlying the model

1. Annual quotas are assumed to be optimally and exogenously determined by the MFMR. Hence, this study does not seek to give advice on what the optimal quota for hake should be, but rather it seeks to advise on what percentage of the decided quota should be harvested by the wetfish and freezer trawlers, respectively. The implication

of this assumption is that it eliminates interaction at the level of the stock, thereby eliminating *dynamic externality.*[3]

2. It is assumed here that there are no interactions between the two agents at the market place. This assumption is reasonable because the agents sell their landings at competitive markets where prices are exogeneously determined. The implication of this assumption is to eliminate interaction by the agents at the marketplace (that is, *market externality*).

3. It is further assumed that there are no significant natural interactions between the hake species and others. This implies that externality due to say, predator-prey relations are ignored.[4] Given the lack of adequate studies on interspecies interactions between the species living in the Namibian EEZ, this assumption is considered to be a pragmatic one, which will be relaxed as more biological information becomes available.

4. The model is deterministic in the sense that all parameters of the model are assumed to be known with certainty. Also, future quotas are assumed to be known. Clearly, these are strong assumptions. In the case of future quotas, for instance, we know that yearly allocations are based on both scientific knowledge on the biomass of hake, and policy related considerations, both of which are sure to vary from year to year. A future task would be to introduce uncertainty into the model.[5]

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[3] Levhari and Mirman (1980) and Sumaila (1995), are studies where dynamic externality is present. A possible extension of this paper would be to relax this assumption. Indeed, this would be the next task in the series of studies planned for the hake stock.

[4] See Fisher and Mirman (1992) and Sumaila (1997, forthcoming) for analyses that incorporate the natural interaction between different species.

[5] In the meantime, the model is designed to be flexible enough to allow quick sensitivity analysis, making it possible to vary important parameters as new information flows in.

The overall implication of assumptions (1) - (3) above is that even though there are two agents exploiting a common property resource, we end up with a "trivial game theoretic model". To have a truly game theoretical situation, the agents have to interact either in the market place, at the level of the stock, or else there has to be natural interactions between hake and the other species in the habitat. Thus, what we have in this model is a straight forward constrained optimisation problem for each agent. Note that both players are jointly constrained by the total quota available to them in each year.

3.2 Modeling the price of hake

The assumption of no interaction at the market place necessarily implies that both wetfish and frozen fish are supplied at given prices, implying that the price they receive for their produce is inelastic to the quantities of fish they supply to the market. It should be noted that the main market for Namibian hake is Spain. This is a large international market supplied by many other sources of which Namibia is only one of many suppliers. For Namibia or any of the other suppliers to be able to influence the market, there has to be a withdrawal from the market of a large proportion (if not all) of her current output, or else there has to be a sudden large increase in the quantity supplied by such a supplier to the market - both of which are unlikely to happen under normal conditions.

3.3 Modeling the cost of landing hake

In general, two types of costs can be identified depending on whether one is talking of the costs directly incurred by the agents in the model, that is, *private costs* or costs incurred by society as a whole, that is, *social costs.*[6] Usually these two are not identical

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[6] It is the government that is concerned about these costs, private agents would usually be concerned with only their private costs.

because of distortions in market prices and/or costs. As the focus of this study is on the benefits to society as a whole, we will be concerned mainly with social costs in this paper. To get hold of these costs, I split the inputs that go into the harvesting and processing of hake into the following cost elements.

3.3.1 Cost elements associated with the freezer trawlers

Labour costs

The key variables that go into labour costs include, the size of the crew on a typical freezer trawler; the number of officers and skippers on the vessel; and the cost of hiring these class of labour for a given period of time to land a certain quantity of fish. These are used to compute the expected cost of engaging skilled ($E_{sc,f}$), and unskilled ($E_{uc,f}$) crew members; skippers ($E_{sk,f}$), and officers ($E_{off,f}$), to produce a unit weight of frozen hake[7]. Here, the subscript *sc*, *uc*, *sk,* and *off* stand for skilled crew, unskilled crew, skippers and officers, respectively, while *f* refers to the Freezer Industry Group.

Basic economic theory postulates that the socially optimal *E* is the alternative cost of the labour in question.[8] I assume here that the wages being currently paid out to skilled crew members, officers, and skippers, represent the alternative cost of their labour. This can be justified by the fact that there is no over supply of this class of labour in

[7] It should be mentioned here that normally payments to crew members, skippers and officers, are split into two - a fixed and a variable part. The latter depends on actual landings.
[8] Note that socially optimal is used here in an economic sense. For instance, by socially optimal cost, I mean minimum cost incurred by society as a whole to achieve a stated objective, which in most cases is different from private optimal cost.

Namibia. On the other hand, due to the high level of unemployment among unskilled crew members in the country, the current wages received by this class of workers are well above the alternative value of their inputs. Thus, current earnings of unskilled labour are adjusted by introducing a kind of "discounting" parameter for unskilled labour costs.

Now, the total annual cost of engaging the required labour force for a given vessel, $k_{l,f}$, can be expressed mathematically as

(1)

$$k_{l,f} = (\alpha E_{uc,f} + E_{sc,f} + E_{sk,f} + E_{off,f})\varphi_f$$

where φ_f is the annual fishing capacity of a freezer vessel in unit weight; k denotes costs, and the subscript l stands for labour as a whole; the parameter $0 < \alpha \leq 1$ is the percentage of unskilled crew labour earnings that can be said to be the alternative value of this labour. Notice that $\alpha = 1$ in the case of private costs.

Capital costs

The cost of acquiring a fully equipped freezer trawler will form the basis for calculating annual capital costs here. Suppose this cost is denoted by ϑ_f, then the annual user cost of capital, $k_{c,f}$ (where c stands for capital), can be expressed as[9]

[9] This is true only under the assumption that capital gains or losses due to changes in the acquisition value of capital are so low that they can be neglected.

(2)

$$k_{c,f} = (r + \sigma_f + \rho_f)\vartheta_f$$

Here, r is the real interest rate, σ_f the rate of depreciation of a typical freezer vessel, and ρ_f denotes a foreign exchange premium. The latter is necessary to account for the fact that foreign exchange is not completely determined by the market in Namibia, and that virtually all capital costs of acquiring a trawler are incurred in foreign currency.[10] All these parameters are in percent of the capital acquisition value. Again, there is a difference between private and social costs here: ρ_f is zero in the case of private costs because private agents care only about their direct private costs.

Operating expenses

These include annual costs of fuel and lubricating oil, repairs and maintenance, fishing gear renewal, telecommunication and radio expenses, and management and administrative costs. Others are general insurance cover for crew, catch, cargo, hull and machinery; license fees, levies and charges; harbour fees; and provisions. All these would be counted by the agents as part of their costs, but social costs would not include license fees, levies and charges.

[10] Labour costs are not subjected to this premium because the bulk of these are paid in local currency.

The annual costs listed above, excluding license fees, levies and charges, are added together to obtain the annual social costs of landing and processing the average annual harvest of a typical freezer trawler.

3.3.2 Cost elements associated with the wetfish trawlers

Labour costs

In addition to the offshore labour costs mentioned under freezer trawlers, some onshore labour costs are incurred in processing in the case of wetfish trawlers. Thus annual labour costs can be expressed as follows

(3)

$$k_{l,w} = \left[\alpha(E_{uc,w} + E_{ou,w}) + E_{sc,w} + E_{sk,w} + E_{off,w} + E_{os,w}\right]\varphi_w$$

where φ_w is the annual fishing capacity of a wetfish vessel in unit weight;

$E_{ou,w}$ and $E_{os,w}$ denote the cost of skilled and unskilled labour needed to process a ton of hake onshore, and $E_{uc,w}$, $E_{sc,w}$, $E_{sk,w}$, *and* $E_{off,w}$ represent the various offshore costs.

Capital costs

There are two components to capital costs here, viz., the cost of acquiring a fully equipped wetfish trawler and the cost of laying down the necessary infrastructure to process the fish onshore. These two will form the basis for calculating annual capital costs. The formulation of costs in this case is exactly as in equation 2 above, except that an extra cost component is introduced to capture the costs of laying the necessary onshore processing infrastructure, $\vartheta_{\inf,w}$, where the subscript *inf* denotes infrastructure. Then the annual user cost, $k_{c,w}$, of capital can be expressed as

(4)

$$k_{c,w} = (r + \sigma_w + \rho_w)\vartheta_{v,w} + (r + \sigma_{\inf} + \rho_{\inf})\vartheta_{\inf,w}$$

where the subscript v denotes vessel. Notice that in principle, the depreciation rate, and the foreign exchange premium for infrastructural and vessel costs can differ.

Operating expenses

Here too there are two components, expenses related to vessel operations and expenses related to onshore processing. The former expenses include, annual costs of fuel and lubricating oil, repairs and maintenance, fishing gear renewal, telecommunication and radio expenses, and management and administrative costs. Others are costs of general insurance cover for crew, catch, cargo, hull and machinery; license fees, levies and charges; harbour fees; and provisions. Similar cost elements related to onshore processing are added to the costs stemming from vessel operation to get the total cost. In this case too the annual costs under all the items above (except license fees, levies and charges) are added together to obtain the annual social costs of landing and processing a certain quantity of wetfish landings.

3.4 *The production and profit functions*

In both theoretical and applied fishery economics, it is common to use the following production function (see for instance, Reed, 1979 and Hannesson, 1993):

(5)

$$h_{i,t} = q_i x_t e_{i,t} \quad i = w, f$$

where h is the vessel and time dependent size of the harvest, x is the time dependent stock size or biomass, the parameter q denotes the vessel dependent catchability coefficient, and $e_{i,t}$ denotes the number of trawlers of type i taken out to fish in period t. The main assumption underlying h is that the ability to harvest fish at any point in time is proportional to the biomass available in the habitat. The simple logic here is that it is much easier (and by extension less costly) to harvest fish in a habitat full of fish than one virtually empty of fish. This is particularly so in the case of non-schooling species such as hake.

In the case where quotas are exogeneously determined as in this model, h is necessarily equal to the quota: due to the potential for making pure profits, one would expect the agents in the model to harvest up to the quota allocated. Hence, equation (5) above can be written as

(6)

$$h_{i,t} = q_i x_t e_{i,t} = \zeta_{i,t} \mathrm{Q}_t, \quad i = w, f \quad \text{and} \quad \sum_{\mathrm{i}} \zeta_{i,t} = 1$$