Ecological Economics 142 (2017) 257–267

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

An Agent-based Model of the South African Offshore Hake Trawl Industry: Part II Drivers and Trade-offs in Profit and Risk

Rachel Cooper [a,*], Astrid Jarre [b]

[a] Marine Research Institute, Department of Biological Sciences, University of Cape Town, Private Bag X3, Rondebosch, 7701 Cape Town, South Africa
[b] Marine Research Institute, Department of Biological Sciences, University of Cape Town, Private Bag X3, Rondebosch, 7701 Cape Town, South Africa

ARTICLE INFO

Article history:
Received 27 July 2016
Received in revised form 18 June 2017
Accepted 23 June 2017
Available online 7 July 2017

Keywords:
Fleet-size
Trawl fishery
CPUE
Fuel price
Profitability in fisheries
Mean-variance analysis
Risk

ABSTRACT

In South Africa's most valuable fishery, the offshore demersal hake trawl, participant companies differ in their rightsholdings, product streams, core business structure and their numbers and types of vessels. HakeSim, an agent-based model of this fishing industry, is used to explore these interactions, how companies could cope with increased fuel prices, and to provide insight into profit-risk trade-offs and vulnerabilities of companies. Apart from increasing catch per unit effort (CPUE), which is often detrimental to fish stocks, fuel price increases could be offset by increasing hake market value, achieved by processing fish to higher value end products with a lower catch cost per tonne. Industry's present fleet size and composition is demonstrated to result from profit-risk trade-offs: the flexibility to respond to mismatches between total allowable catch and CPUE, market demands for frozen and fresh product types, and environmental variability. Smaller companies have less risk-averse strategies and are more vulnerable to uncertainty in catches than larger companies, which may explain ongoing trends in consolidation in the industry. Increasing the proxy for environmental uncertainty increased risk to all companies without increasing profits. Incorporating more realistic environmental effects and feedbacks with industry in HakeSim could be an exciting future direction.

1. Introduction

In South Africa, the hake fishing industry is an important contributor to income in coastal communities, generating some 30,000 jobs (Rademeyer et al., 2008). It is also the country's most valuable fishery (Butterworth and Rademeyer, 2005; Petersen et al., 2010), generating an estimated 5 billion South African Rand (ZAR) per year at present. The costs, revenues and profits in this industry are much the same as those incurred by fisheries internationally, such as fuel and market price for fish (e.g. the target species *Merluccius capensis* and *M. paradoxus*). It is, however, a highly consolidated and vertically integrated industry with heterogeneous business models and a high level of complexity (Cooper et al., 2014). This makes the relative importance and complex interactions and trade-offs among different drivers like fuel price and environmental variability for the industry and its profits hard to estimate at a glance.

It is known that economic, ecological and social dimensions must be appropriately considered to ensure successful management for the sustainability of fisheries (Folke et al., 2007; Garcia and Charles, 2008; Pitcher and Lam, 2010). Effective policies for the sustainability of human (social and economic) and natural systems are underpinned by untangling the complexities of these systems, such as emergent properties and reciprocal effects (Liu et al., 2007). To be able to meaningfully incorporate ecological and human dimensions into management through appropriate objectives with measurable outcomes or indicators for South Africa's hake fishery, it is necessary to first have insight into the functioning of the industry and how its profits are affected by changes in some of its major drivers. Profitability is a significant incentive for commercial fishing companies (Sumaila et al., 2008).

A modelling approach can provide insight into this type of complex system and its structure, function and dynamics (Liu et al.,2007), particularly in a situation such as South Africa's where publically available economic data on the fisheries is scarce. Scenario testing provides further understanding of how changes in external drivers affect the industry's structure, function or dynamics. Achieving insight into the South African offshore demersal hake trawl fishery was the impetus behind the building of HakeSim, an agent-based model (ABM) of the fishery (Cooper, 2015; Cooper and Jarre, 2017). HakeSim captures the complex industry structure, complete with heterogeneous company, vessel and market agents, as well as important factors that affect the industry's profitability such as fuel price, total allowable catch, environmental variability (through a proxy), domestic and international market price and demand for hake.

* Corresponding author.
E-mail addresses: Rachel.Cooper@protonmail.com (R. Cooper), astrid.jarre@uct.ac.za (A. Jarre).

http://dx.doi.org/10.1016/j.ecolecon.2017.06.027
0921-8009/

Fuel price is one factor that majorly affects running costs and therefore profitability of the offshore hake trawl industry. It can account as much as 60% of running costs for fishing companies (Sumaila et al., 2008). It is well known as a core issue affecting fisheries economics and dynamics worldwide and, for example, has been identified as particularly significant for the profitability of wetfish trawlers that land fresh fish in neighbouring Namibia (BCLME, 2006; Gasalla et al., 2010; Sumaila et al., 2008). Even where it accounts a lower percentage (10 or 25%), such as in other trawl industries, it can hinder fisheries in the case of a price increase (Sumaila et al., 2008). Arnason (2007) point out that increased fuel prices from 2004 meant significant increases in cost and reductions in profit, which could push companies already not making a profit into exiting the fishery. Anecdotally, the South African industry complained of critical interactions between fuel price and catch per unit effort (CPUE) during high fuel price periods and that it was difficult to sustain profits at these times. Previous modelling scenario analysis with HakeSim demonstrated that prices above ZAR 18.783 per litre, prices that could occur with a large fuel price increase or removal of fuel subsidies, caused all modelled companies to make a loss and lower fuel prices than this could cause companies to make an unacceptably low return on investment to continue operations (Cooper and Jarre, 2017). Should such an increase occur in future, in light of a deteriorating currency (ZAR), a global fuel price rise or a decrease in fuel subsidy, it is possible that industry could offset losses by increasing revenue streams. It is unknown to what extent this is possible or how different companies might cope with these kinds of challenges. To be able to assess this it is useful to consider different types of costs and revenues for companies and the variation between these variables at an individual company or vessel level.

Additionally, there may be other variable costs to the industry such as labour or storage costs, and fixed costs such as repairs and maintenance or insurance (Whitmarsh et al., 2000). On the other hand, since it is an export-dominated fishery (Crosoer et al., 2006), market demand and international price (in Euros or US dollars) for hake, as well as the foreign exchange rate for the ZAR are important determinants of income to local companies. Indeed, exchange rate is known to be an important factor for fisheries and countries that export fish worldwide (Asche, 2014). The changes to and interactions among these and other variables that affect costs and revenue determine short-term gross profits. They also determine economic profits over the long term together with depreciation and opportunity costs (Whitmarsh et al., 2000). Understanding how profits of different types of companies might be affected is significant since changes to profit not only affect companies and their employees, but are also of social and environmental significance, for example on government decisions for public support or subsidies (Arnason, 2007).

It is not just the overall profit that is important to companies, but also variance in profit, which is a form of risk. Since companies in the South African offshore hake trawl industry differ in their rightsholdings, the composition and numbers of vessels that they own, the products that they sell and their core business structure (Cooper et al., 2014), they might make different trade-offs between profit and risk. They can also be quite differently affected by increased risk due to (environmental) variability in catches. This type of individual level variability and the collective, emergent properties at a fisheries system level that result from the interactions of these individual companies, vessels and markets are not captured in traditional economic models, but can be captured with an ABM.

Furthermore, the overall fleet size and composition of the entire hake trawl industry has changed significantly through time (Cooper et al., 2014), and this presumably reflects trade-offs between profit (i.e. vessel costs balanced against revenue under different catch and market conditions) and deviation in profits. Understanding how profit risk trade-offs affect fleet structure help to inform management and policies regarding what vessels companies can operate and how they operate them. For example, in Namibia government apportionment restrictions enforce a certain composition of wetfish to freezer trawlers (Kirchner and Leiman, 2014), whereas the South African government has allowed companies to allocate their catch between vessels as they see fit.

The objectives of the present paper are to use HakeSim to 1) examine trade-offs and interactions among industry drivers, such as fuel price and environmental variability, for example to understand whether losses due to high fuel price or low catches could somehow be offset and 2) examine the trade-offs in risk (variation in profit) and profit that companies experience for different company sizes and structures, and different fleet compositions and sizes in the South African context; it will provide insight into their different business strategies and how these might fare under different levels of uncertainty. As an ABM HakeSim incorporates individual variability and interactions and how these result in observable patterns (emergent properties) at the fisheries system level, as well as qualitative data, it will provide a novel way of examining these interactions and trade-offs in the absence of extensive quantitative economic data. It will also provide insights into why consolidation in the industry continues to happen despite governments attempts to divide up quota, as discussed in (Cooper et al., 2014), an important point in light of upcoming long term rights allocations.

2. Methods

To test a variety of scenarios for the offshore demersal hake trawl industry of South Africa, the model *HakeSim* was used, as described in Cooper and Jarre (2017). The core features of its design are summarised here for convenience. It is an ABM of the industry that captures the individual variability of and interactions among companies, fishing vessels and the domestic and international markets ('clients'), which are modelled as agents. There are three types of fishing vessel agents, four types of company agents that represent the four types of consolidated business entities described in Cooper et al. (2014), and eleven client agents (see submodels in Fig. 1). Client agents represent the South African domestic market for hake as well as the major export markets for hake that import on average 500 t or more of hake per annum from South Africa (Spain, Italy, Portugal, United Kingdom, Australia, France, Germany, the United States of America and the Netherlands) plus one agent that represents the collective South African hake imports of all countries that import on average less than 500 t per annum.

As shown in Fig. 1, fishing vessels are activated as appropriate by the companies that own them to catch and land hake as fresh or frozen fish. The company's objective is to catch all of its monthly quota using the minimum number of vessels and also to apportion catch between fresh and frozen vessels depending on international demand. As such, each company first determines whether there is an international market demand for fresh or frozen fish and then appropriately activates fresh, freezer or both types of vessels. Each company activates sufficient vessels from its own fleet to capture the monthly proportion of the company's quota (which is equal to the right multiplied by the total allowable catch averaged across months). Type and quantity of landings are therefore emergent. Type of landings (fresh versus frozen) are therefore determined by international market demand. The quantity of landings is determined by TAC, CPUE, an environmental variability proxy (which operates to a prescribed extent on variability of the CPUE) and the capacity of vessels available to each company. The model therefore assumes that TAC is reflective of hake population levels, which is not an unreasonable assumption in the South African context where TAC is calculated annually on the basis of an extensive stock assessment modelling and review process (Field et al., 2013). Unlike in many international contexts, the South African hake TAC is typically the amount recommended on the basis of the stock assessment models. Moreover, as TAC is the operational variable that limits catches by vessels, in the context of questions asked of industry profitability, drivers and profit-risk trade-offs, it was more relevant to use than population models, at least for this prototype version of the model.