Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER Journal of Economic Dynamics & Control 30 (2006) 2613–2636
JOURNAL OF Economic Dynamics & Control
www.elsevier.com/locate/jedc

A qualitative dynamical modelling approach to capital accumulation in unregulated fisheries

K. Eisenack[a,*], H. Welsch[b], J.P. Kropp[a]

[a]*Department for Integrated Systems Analysis, Potsdam Institute for Climate Impact Research, P.O. Box 601203, 14412 Potsdam, Germany*
[b]*Department of Economics, University of Oldenburg, P.O. Box 2503, 26111 Oldenburg, Germany*

Received 19 May 2005; accepted 15 August 2005
Available online 14 November 2005

Abstract

Capital accumulation has been a major issue in fisheries economics over the last two decades, whereby the interaction of the fish and capital stocks were of particular interest. Because bio-economic systems are intrinsically complex, previous efforts in this field have relied on a variety of simplifying assumptions. The model presented here relaxes some of these simplifications. Problems of tractability are surmounted by using the methodology of qualitative differential equations (QDE). The theory of QDEs takes into account that scientific knowledge about particular fisheries is usually limited, and facilitates an analysis of the global dynamics of systems with more than two ordinary differential equations. The model is able to trace the evolution of capital and fish stock in good agreement with observed patterns, and shows that over-capitalization is unavoidable in unregulated fisheries.

JEL classification: C63; D81; Q22

Keywords: Bio-economic model; Environmental management; Optimal control; Fishery management; Qualitative reasoning

*Corresponding author. Tel.: +49 331 2882625.
E-mail addresses: eisenack@pik-potsdam.de (K. Eisenack), welsch@uni-oldenburg.de (H. Welsch), kropp@pik-potsdam.de (J.P. Kropp).
URL: http://www.pik-potsdam.de/~eisenack/.

0165-1889/$ - see front matter
doi:10.1016/j.jedc.2005.08.004

1. Introduction

Following sustained interest from policy makers, recent years have seen a number of bio-economic models examining the effects of commercial fisheries on marine resources. Even though over-fishing has been a fact since historical times (Jackson et al., 2001), the problem has gained a new quality due to the industrialization of fisheries (FAO, 2004). In particular the latter has reduced fish biomass by 80% within 15 years of exploitation (Myers and Worm, 2003). In this context, the impact of capital accumulation has been a major issue in fisheries economics over the last two decades (Clark et al., 1979; McKelvey, 1985; Boyce, 1995; Jørgensen and Kort, 1997; Munro, 1999; Pauly et al., 2002). In these contributions, commercial fisheries are portrayed as a system in which a biological stock and a capital stock interact dynamically. As the capital stock is highly specialized and cannot readily be converted to other uses, investment decisions are characterized by irreversibility, which is assumed as a major cause of over-fishing.

The previous literature has treated capital accumulation in various settings. Clark et al. (1979) study the optimal management strategy for a renewable resource with irreversible investment, assuming that marginal investment costs are constant. The latter assumption is abandoned by Boyce (1995) on the grounds that constant investment costs imply an immediate jump in the capital stock, which is then followed by a period of decline in both the capital and fish stock. Contrary, observed patterns of capital accumulation are characterized by an initial phase of continuous growth of fleet size. Assuming increasing marginal investment costs leads to better agreement with observations, but makes the model more complicated. Considerations of tractability therefore lead Boyce (1995) to assume that harvest productivity is independent of the size of the biological stock.

In contrast to these optimal-exploitation models, approaches which study capital accumulation in more realistic settings are rare. An exception is McKelvey (1985, 1986) who examines an open-access fishery with irreversible investment under both perfect and imperfect competition. But the increased realism of these models comes at a cost in that marginal investment costs and harvesting productivity are kept constant in the analysis of out-of-equilibrium behaviour due to serious analytical difficulties. In general, the variety of modelling strategies pursued in the literature thus reflects the tension between realism and tractability, illustrating the need for new concepts in integrated modelling (cf. Knowler, 2002; Müller, 2003). In order to keep them accessible to analysis, most of the models mentioned above disregard at least one of these difficulties, e.g. those relating to investment costs, harvesting productivity, or industry structure. In many cases the difficulties restrict analysis to equilibria or comparative dynamics in the neighbourhood of an equilibrium.[1] But since fisheries systems tend to stay far away from equilibrium, e.g. when catches

[1]Even with one state and one control variable the analysis of the comparative dynamics can become difficult (Caputo, 1989, 2003). However, some papers investigate the dynamic properties of trajectories more thoroughly (e.g. Jørgensen and Kort, 1997; Scheffran, 2000).